Implications of Climate Change on Crop Production in Bangladesh and Possible Adaptation Techniques

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> ***This is a 'Working Draft' and is meant to raise discussion and seek comments. Please do not quote.***

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Executive Summary

The study suggests some suitable adaptation measures that have the potential to help farmers adapt with the climate change. These include identification of suitable cropping pattern, choice of seed, irrigation management, crop intensification and suitable transplanting. The current study has been conducted in the three most vulnerable regions in Bangladesh (Sirajgonj, Gaibandha and Shariatpur districts).

The current study shows the changing pattern of temperature and rainfall based on 33 years' (1976 to 2008) climate data in 18 metrological stations surrounding the selected three locations. It is observed that changes of those climatic parameters are significant during this period.

- **Temperature Change during 1976 to 2008**

From the study, it was found that monthly average maximum temperature increased at the rate of 0.01^{0}C, whereas monthly average minimum temperature increased at a rate of 0.04^{0}C per year at Gaibandha. Similarly, yearly average maximum and minimum temperature increased at the rate of 0.03^{0}C and 0.01^{0}C respectively for the same region. In Sirajgonj, monthly average maximum and minimum temperature for the period of May to December increased by 0.018^{0}C and 0.02^{0}C per year respectively and yearly average maximum and minimum temperature increased in each year by 0.02^{0}C and 0.01^{0}C, respectively. Both monthly average maximum and minimum temperature increased at the rate of 0.015^{0}C per year in Shariatpur, whereas yearly average maximum and minimum temperature increased at the rate of 0.02^{0}C and 0.014^{0}C respectively.

- **Rainfall Change during 1976 to 2008**

Likewise temperature, rainfall in pre-monsoon (March to May), monsoon (June to September) and post-monsoon (October to November) increased at the rate of 0.42 mm, 6.45 mm and 5.56 mm per year respectively whereas in winter season (December to February) rainfall decreased at the rate of 0.2 mm per year in Gaibandha. In Sirajgonj, rainfall increased 2.1 mm in each year and 3.04 mm in monsoon and post-monsoon respectively. However, it decreased at the rate of 0.5 mm and 1.5 mm per year during winter and pre-monsoon respectively for the same region. Similarly, rainfall changes by 5.47 mm and 2.90 mm during monsoon and post monsoon season, respectively are observed in Shariatpur, but in winter and pre-monsoon, the decreasing rates of rainfall per year are 0.4 mm and 1.75 mm are witnessed.

- **Implications of this study**

Geographically, Gaibandha and Sirajgonj are flood stricken area. Almost every year, these areas experience flood and consequently river bank erosion. Most of the farmers of those locations grow rice. During kharif season, they face difficulty to harvest their cultivated crops due to climate induced natural events. Considering the main climate induced changes, adaptation practices on cropping pattern, seed, irrigation management, crop intensification and selection of suitable date for rice transplantation have been suggested. These adaptation measures have been developed on the basis of local farmers' knowledge, field level data and information and field experiments.

Climate adaptive cropping pattern suggested in Gaibandha and Sirajgonj are wheat-mug dal (Pulse)-T.aman. Choice of seed like submerged tolerant rice varieties during kharif season-BRRI dhan51, BRRI dhan52 are also prescribed. The farmers are advocated to re-excavate ponds for supplemental irrigation and fish cultivation and integrated duck-fish-vegetables gardening for crop intensification. Transplantation of rice before 15 January is also encouraged because transplantation after the prescribed time might lead huge yield reduction.

Shairatpur witnesses salinity intrusion as a consequence of back water effect. Some climate adaptive practices suggested in this location include Boro rice-T.aman rice/Jute cropping pattern. Short duration and saline tolerant boro rice varieties-BRRI dhan47 and saline tolerant rice varieties during kharif season-BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54 are introduced to the local farmers. For irrigation management, excavation of mini ponds and surface water harvesting for supplemental irrigation and integrated duck-fish-vegetables gardening for crop intensification are suggested. It is also prescribed to transplant T.aman rice by or before 1 June to minimise yield drop.

The changing pattern of temperature and rainfall for the selected three regions were significantly high compared to the assumption of IPCC over the world in last 100 years. The changing patterns of those climatic parameters have a significant negative impact 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 increasing food security.

1. Introduction

Bangladesh is one of the most vulnerable countries to climate change because of geographic exposure, low income and greater reliance on climate sensitive sectors, particularly agriculture. People, exposed to the most severe climate-related hazards are often least able to cope with the associated impacts due to their limited adaptive capacity. This in turn poses multiple threats to economic growth, wider poverty reduction, and the achievement of the Millennium Development Goals (ADB *et al*., 2003; Stern *et al.*, 2006). Within this context, there is growing recognition of social protection as a response to the multiple risks and short and long-term shocks and stresses. Stern (2008) argues that social protection could become one of the priority sectors for adaptation in least developed countries like Bangladesh. However, limitation of resources prevails considering the linkages and value of social protection for adaptation in practice.

There is growing evidence that climate change is increasing the frequency and intensity of climate-related hazards and hence, the level and patterns of often inter-related risks are exacerbating the levels of vulnerability for poor and excluded people (Davies, 2009). Poverty and social impacts, though generally not well-understood, are likely to be profound and will have impact on human beings through a variety of direct (changes in climate variables) and indirect pathways (pests and diseases; degradation of natural resources; food price and employment risks; displacement; conflicts, negative spirals) (Heltberg *et al.*, 2008a).

Global climate has been changing due to adverse natural forces as well as anthropogenic activities, especially emissions of greenhouse gases and aerosols, and change in land use in recent decades. Observational evidences demonstrate that composition of global atmosphere is changing, e.g. increasing atmospheric concentrations of greenhouse gases, such as carbon-di-oxide (379 ppm recorded in 2005), methane (1774 ppb recorded in 2005) and nitrous oxide (319 ppb recorded in 2005) (IPPC, 2007). Earth's climate is also changing based on the evidences, e.g. recent recorded changes in temperature, precipitation, sea level, arctic ice temperature, mountain glacier and snow cover, and in some regions extreme events including heat waves, heavy precipitation events and droughts. 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.

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. Contextual analysis suggests that unless urgent actions are taken, climate change will undermine efforts to ensure the food security of the region. 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. In the circumstances under the RESOLVE programme, the study has been conducted on Sirajgonj, Gaibandha and Shariatpur districts due to their graving vulnerability to climate change.

The design of interventions of the current study was based on trend line analysis of temperature and rainfall data and impacts of their changing pattern on crop production in the future. In Bangladesh, climatic hot spots were identified by country level research through assessing the extent to which communities will be geographically exposed to specific change (using agro-ecological zoning mapping) and their capacity to adapt with the impacts (using poverty map and analysis). Since most of the people living in climatic hot spots are dependent on agriculture, it is therefore obvious to give top priority to adaptation in agriculture.

Climate change and agriculture possess an inverse relationship where climate impacts hamper agri-production. However, unsustainable agriculture contributes to greenhouse gas emissions. 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, eventually hampers agriculture production. Changes in soil moisture and temperature, evapo-transpiration, rainfall and possible increases in heat stress will affect the growth of some subsistence root crops and vegetables. Being a climate sensitive sector, agriculture in Bangladesh is totally dependent on seasonal weather variability.

Considering experiences on local level, the main objective of the current study is to find out suitable adaptation measures that have the potential to help farmers to adapt climate change. These include identification of suitable cropping pattern, choice of seed, irrigation water management, crop intensification and suitable transplanting. The first section of the study illustrates the changing pattern of climatic parameters mainly temperature (monthly and yearly average maximum and minimum temperature) and rainfall in the RESOLVE areas. The second portion focuses on the impacts of climatic variability (changing temperature and rainfall pattern) on crop production in the selected areas. The last section of the report provides prescription on possible adaptation techniques that have the potential to help farmers to adapt climate change and reduce yield loss in achieving food security.

2. Climate Change in RESOLVE areas during 1976-2008

To achieve the ultimate goal of making communities more resilient to adverse impact of climate change and to ensure food security, it is essential to estimate the changing pattern of climatic variability in the selected areas. It is also necessary to predict or assess the climate change impact and vulnerability may need to face in future for expected adaptation. The degree to which a future climate change risk is dangerous depends greatly on the likelihood and effectiveness of adaptations in that system. Studies that ignore or assume no adaptation are likely to overestimate residual or net impacts and vulnerabilities, whereas those that assume full and effective adaptation are likely to underestimate residual impacts and vulnerabilities (Reilly, 1999; Reilly and Schimmelpfennig, 1999; Risbey *et al*., 1999; Smit *et al.*, 2000). Hence, it is important to have an improved understanding of the process of adaptation and better information on the conditions under which adaptations of various types are expected to occur.

Historical trend line analysis has been conducted to find out the past scenarios and changing pattern of climatic phenomenon, mainly of temperature and rainfall in the three selected areas of RESLOVE during the period of 1976-2008 (33 years). It is essential to understand how much the pattern of temperature and rainfall had changed during this period. Consideration of such changing patterns would help to make adaptation practices more sustainable as well as comprehensive with considering peoples' perception in agriculture sector.

Crop yield varies year to year mainly due to the fluctuations in weather. The most important components of weather are temperature and rainfall distribution pattern during the life span of plant growth. Islam (1996) also finds a minor change in plant life and/or climatic environment also carried a large change in plant life and plant communities. Food security in South Asia is now threatened due to the increasing yield stagnation and growing demand of the continuing population. In addition, threats to sustainability including overexploitation of ground and surface waters, water logging and salinity, declining soil organic matter, water and atmospheric pollution and global climate change are hindering the achievement of food security (Hobbs and Gupta, 2003).

The IPPC (2001) projected climate change events during the 21st century with significant confidence which included higher maximum temperature and more hot days, higher minimum temperature and fewer cold days, increased heat index and more intense precipitation events.

Table 1: Plausible changes in area-averaged surface air temperature as a result of future increases in greenhouse gases (IPCC, 2001)

Regions	**2020s**			**2050s**			**2080s**		
	Temperature Change (°C)			**Temperature Change (°C)**			**Temperature Change (°C)**		
	Annual	Winter	Summer	Annual	Winter	Summer	Annual	Winter	Summer
Asia	1.58 (1.36)	1.71 (1.52)	1.45 (1.23)	3.14 (2.49)	3.43 (2.77)	2.87 (2.23)	4.61 (3.78)	5.07 (4.05)	4.23 (3.49)
South Asia	1.36 (1.06)	1.62 (1.19)	1.13 (0.97)	2.69 (1.92)	3.25 (2.08)	2.19 (1.81)	3.84 (2.98)	4.52 (3.25)	3.20 (2.67)
South-East Asia	1.05 (0.96)	1.12 (0.94)	1.01 (0.96)	2.15 (1.72)	2.28 (1.73)	2.01 (1.61)	3.03 (2.49)	3.23 (2.51)	2.82 (2.34)

Note: Numbers in parenthesis are area-averaged changes when direct effects of sulfate aerosols are included

Modeling studies by Huq *et al*. (1999) indicated that the average increase in temperature would be 1.3^{0}C and 2.6^{0}C for the projection years 2030 and 2075 respectively. Similar to IPCC projections, the rise in winter temperature in Bangladesh was predicted to be higher by Huq *et al.* (1999), probably due to significant increase in monsoon precipitation which could also cause severe flooding in the future. The projected changes were: 1.4^{0}C change in the winter and 0.7^{0}C in the monsoon months in 2030. For 2075, the variation would be 2.1^{0}C and 1.7^{0}C for winter and monsoon respectively. The increase of Temperature reported by World Bank (2000) are: by 2030, a 0.7^{0}C temperature rise in monsoon, and a 1.3^{0}C rise in winter temperature, and by 2050, 1.1^{0}C rise in monsoon, and 1.8^{0}C rise in winter. The projected increases in surface air temperature by Huq *et al.*, (1999) and World Bank (2000) were somewhat lower than those projected for south Asian regions by IPCC (2001).

A number of studies have been carried out on trends of change in climate parameters in the context of Bangladesh (Basak *et al.* 2009, Chowdhury and Debsarma, 1992; Warrick *et al.*, 1994; Karmakar and Nessa, 1997; Karmakar and Shrestha, 2000; World Bank, 2000; Mia, 2003; Debsarma, 2003; Karmakar, 2003). Warrick *et al.* (1994), Karmakar and Shrestha (2000) and Debsarma (2003) provided assessment of changes in temperature and precipitation over Bangladesh, while Chowdhury and Debsarma (1992) and Mia (2003) reported changes in temperature based on analysis of historical data of some selected weather stations in Bangladesh. Karmakar and Nessa (1997) and Basak *et al.* (2009) provided an assessment of climate change and variability in Bangladesh based on analysis of historical data of temperature and rainfall recorded at all 34 meteorological stations in Bangladesh. In particular assessments have been made of changes in maximum temperature, changes in minimum temperature, variations in number of hot days and cold days, and changes in precipitation pattern. The present study is conducted on the basis of monthly average maximum and minimum temperature, annual average maximum and minimum temperature and monthly average rainfall data of the RESOLVE areas and changing pattern of temperature and rainfall for the 33 years.

As specific weather stations are not available in the RESOLVE areas, 18 weather stations surrounding the project areas are selected which represent the whole areas' weather station in this study (Figure 1). Data on temperature and rainfall of 18 weather stations in Bangladesh are collected from the Bangladesh Meteorological Department (BMD). Among them, Bogra, Dinajpur and Rangpur weather stations were selected for Gaibandha (Block A); Bogra, Mymensingh, Ishurdi and Rajshahi for Sirajgonj (Block B) and Barisal, Bhola, Chandpur, Comilla, Dhaka, Faridpur, Feni, Jessore, Khulna, Madaripur, Patuakhali and Satkhira for Shariatpur (Block C). The data of temperature and rainfall for 33-year period from 1976 to 2008 have been used in the present study because data for the period of 1948-1975 are not considered reliable because at that time Bangladesh was going through a transitional period of political unrest and war of independence. Moreover, the data of Tangail station are available for only 18 years and these have not been considered for this study.

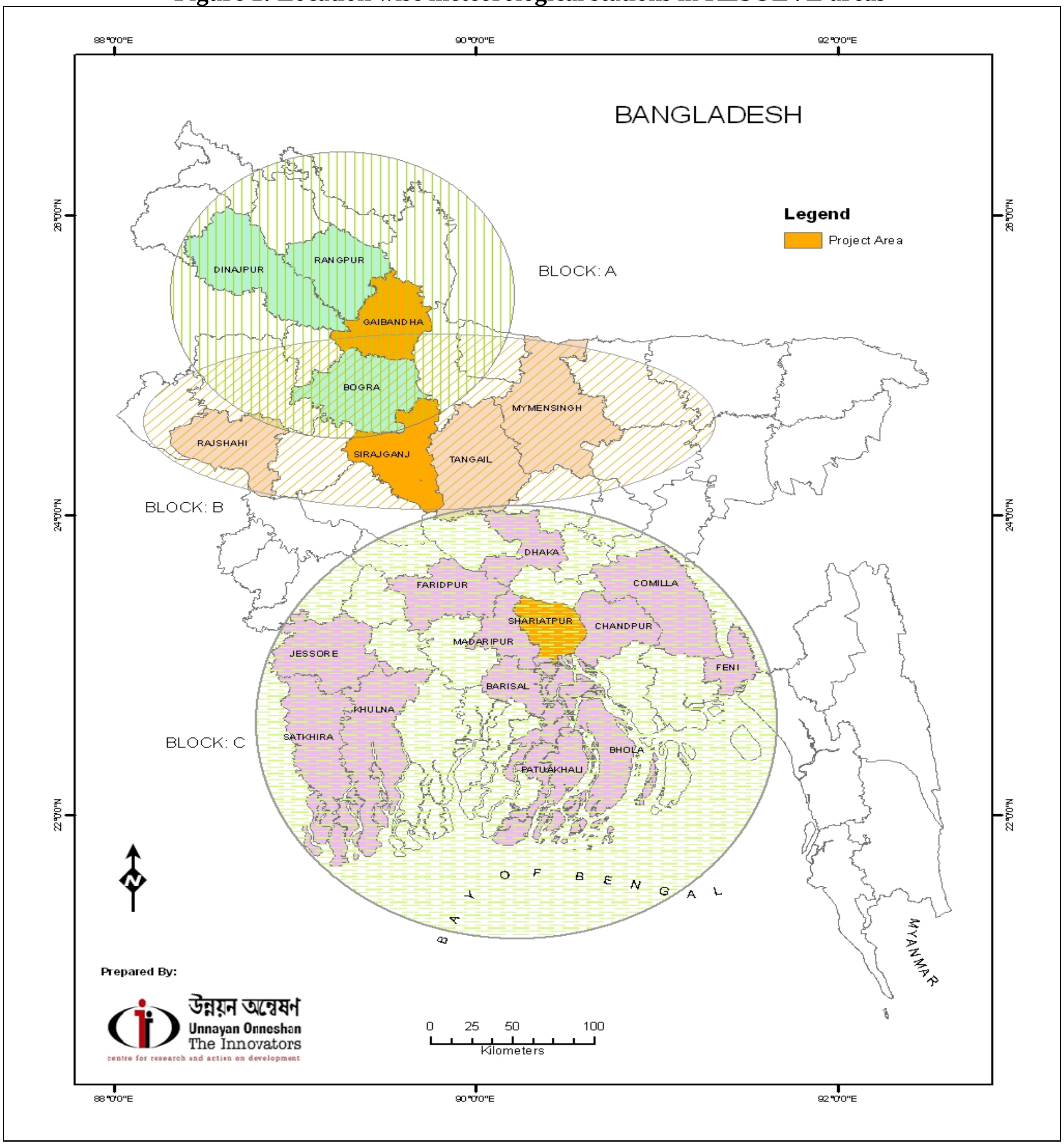
2.1 Changing pattern of Temperature and Rainfall in RESOLVE areas

For analysing the data of both temperature and rainfall, 18 weather stations are considered for RESOLVE areas. The name of the stations has already been mentioned above.

2.1.1 Change of Temperature pattern in RESOLVE areas during 1976-2008

The trend of variation of the monthly average maximum and minimum temperature is analysed during 1976-2008. Figure 2 and Table 2 (Annex A) show the changing pattern of monthly average maximum temperature during January to December. It shows that except for January and March (only for monthly average maximum temperature), both monthly average maximum and minimum temperature follow increasing trend for majority of the metrological stations. Increasing trend is particularly significant for the month of May to October and December; average increase in temperature for each of these months per year being about more than 0.02^{0}C for the 33 years. On an average, the total change of monthly average maximum and minimum temperature of each of the months has increased by near about 1^0C during this period. Likewise, monthly average maximum and minimum temperature, the trend of variation of yearly average maximum and minimum temperature also follow increasing trend during this period and it is more than 0.02^0C per year for yearly average maximum temperature and 0.01^0C per year for yearly average minimum temperature.

Figure 1: Location wise meteorological stations in RESOLVE areas



2.1.2 Change of Rainfall pattern in RESOLVE areas during 1976-2008

Most of the metrological stations show increasing trend of rainfall during monsoon (June to September) and post-monsoon seasons (October to November). However, significant number of stations show decreasing trend of total rainfall during winter (Figure 3). These results are consistent with the general climate change predictions that wet periods would become wetter and dry periods would become drier (IPCC, 2007). From the analysis, it is found that rainfall pattern for monsoon and post-monsoon season has increased at the rate of 4.75 mm and 3.38 mm per year whereas in winter (December to February) and pre-monsoon (March to May), it follows a decreasing trend. In winter, it decreases at a rate of 0.41 mm per year and for pre-monsoon, it is 1.48 mm per year for the period of 1976 to 2008 (Table- Annex B).

2.2 Changing pattern of Temperature and Rainfall in Gaibandha

Bogra, Dinajpur and Rangpur metrological stations are selected for Gaibandha to find out the changing pattern of temperature and rainfall for the period of 1976 to 2008.

2.2.1 Change of Temperature pattern in Gaibandha during 1976-2008

The analysis of monthly average maximum and minimum temperature shows that monthly average maximum temperature has 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. Therefore, changing pattern of monthly average maximum temperature is significantly higher than minimum temperature. Moreover, increasing trend is particularly significant for the month of May to December (Table Annex-A). On an average, the total change of monthly average maximum and minimum temperature for the particular months has increased about 1^0C during this period. Moreover, yearly average maximum and minimum temperature has increased at the rate of 0.03^0C and 0.01^0C, respectively.

2.2.2 Change of Rainfall pattern in Gaibandha during 1976-2008

Rainfall data for winter, pre-monsoon, monsoon and post-monsoon, between 1976 and 2008 in Gaibandha 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, which are significantly higher than that of the overall RESOLVE areas. On the contrary, in winter season, rainfall has decreased at the rate of 0.2 mm per year (Table Annex-B).

2.3 Changing pattern of Temperature and Rainfall in Sirajgonj

Bogra, Mymensingh, Ishurdi and Rajshahi metrological stations are selected for Sirajgonj to assess the changing pattern of temperature and rainfall for the period of 1976 to 2008.

2.3.1 Change of Temperature pattern in Sirajgonj during 1976-2008

Monthly average maximum and minimum temperature data for 33 years shows that both monthly average maximum and minimum temperature is following an upward trend. Moreover, rising trend is significant for the month of May to December (Table Annex-A). On an average, the total change of monthly average maximum and minimum temperature for the particular months has increased by 0.018^0C and 0.02^0C per year during this period. However, the yearly average maximum and minimum temperature has increased at the rate of 0.02^0C and 0.001^0C respectively for the period of 1976 to 2008.

2.3.2 Change of Rainfall pattern in Sirajgonj during 1976-2008

Rainfall data in Sirajgonj area shows that rainfall has increased during monsoon and post-monsoon whereas decreasing trend is witnessed in winter and pre-monsoon season (Table Annex-B). However, the rate of changes of rainfall is comparatively lower than that of the overall rainfall in the project areas. From this study, it is found that rainfall has increased by 2.1 mm and 3.04 mm in monsoon and post-monsoon respectively in each year. However, it has decreased at the rate of 0.5 mm and 1.5 mm per year during winter and pre-monsoon, respectively.

2.4 Changing pattern of Temperature and Rainfall in Shariatpur

Barisal, Bhola, Chandpur, Comilla, Dhaka, Faridpur, Feni, Jessore, Khulna, Madaripur, Patuakhali and Satkhira metrological stations are selected for Shariatpur to find out the changing pattern of temperature and rainfall for the period of 1976 to 2008.

2.4.1 Change of Temperature pattern in Shariatpur during 1976-2008

The analysis of monthly average maximum and minimum temperature shows that monthly average maximum temperature both increased at the rate of 0.015^0C per year. Moreover, increasing trend is particularly significant for the month of April to December except November (Table Annex-A). 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. On the contrary, yearly average maximum and minimum temperature has increased at the rate of 0.02^0C and 0.014^0C respectively.

2.4.2 Change of Rainfall pattern in Shariatpur during 1976-2008

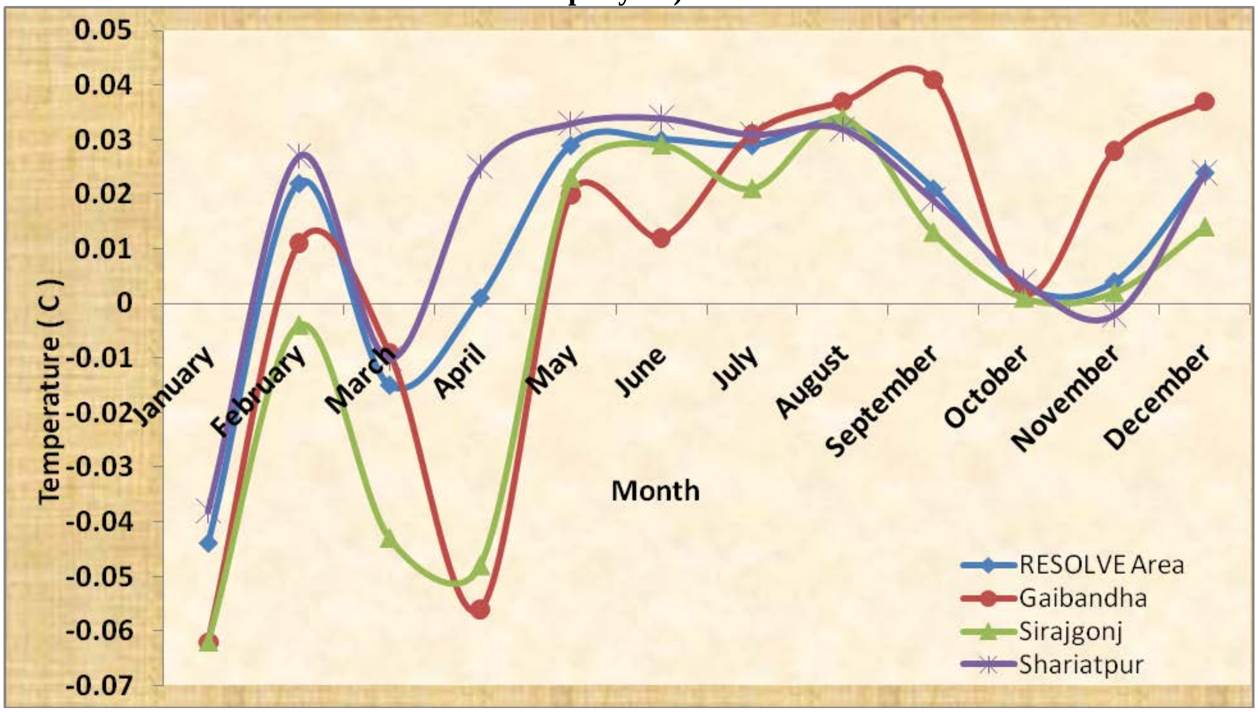
The rainfall during monsoon and post-monsoon season has increased whereas decreased in winter and pre-monsoon season in Shariatpur. The changing pattern of rainfall in each year is found 5.47 mm and 2.90 mm in monsoon and post-monsoon season respectively. However, in winter and pre-monsoon, the decreasing rates of rainfall per year are 0.4 mm and 1.75 mm.

Table 2: Changing pattern of Temperature and Rainfall in RESOLVE areas

	Temperature	Rainfall
RESOLVE Area	• Monthly average maximum and minimum temperature increased at the rate of 0.02^{0}C per year. • Yearly average maximum and minimum temperature increased in each year by 0.02^{0}C and 0.011^{0}C, respectively.	• Rainfall increased in monsoon and post-monsoon season at the rate of 4.75 mm and 3.38 mm per year respectively. • Rainfall in winter and pre-monsoon decreased in each year 0.4 mm and 1.5 mm, respectively.
Gaibandha	• Monthly average maximum temperature increased at the rate of 0.01^{0}C, whereas monthly average minimum temperature increased at a rate of 0.04^{0}C per year. • Yearly average maximum and minimum temperature increased at the rate of 0.03^{0}C and 0.01^{0}C, respectively.	• In pre-monsoon, monsoon and post-monsoon, rainfall increased at the rate of 0.42 mm, 6.45 mm and 5.56 mm per year, respectively. • In winter season, rainfall decreased at the rate of 0.2 mm per year.
Sirajgonj	• Monthly average maximum and minimum temperature for May to December increased by 0.018^{0}C and 0.02^{0}C per year, respectively. • The yearly average maximum and minimum temperature increased in each year by 0.02^{0}C and 0.001^{0}C, respectively.	• In each year, rainfall increased 2.1 mm and 3.04 mm in monsoon and post-monsoon, respectively. • It decreased at the rate of 0.5 mm and 1.5 mm per year during winter and pre-monsoon, respectively.
Shariatpur	• Both monthly average maximum and minimum temperature increased at the rate of 0.015^{0}C per year. • The yearly average maximum and minimum temperature increased at the rate of 0.02^{0}C and 0.014^{0}C, respectively.	• The changing pattern of rainfall in each year is 5.47 mm and 2.90 mm positively in monsoon and post monsoon season, respectively. • In winter and pre monsoon, the decreasing rates of rainfall per year are 0.4 mm and 1.75 mm.

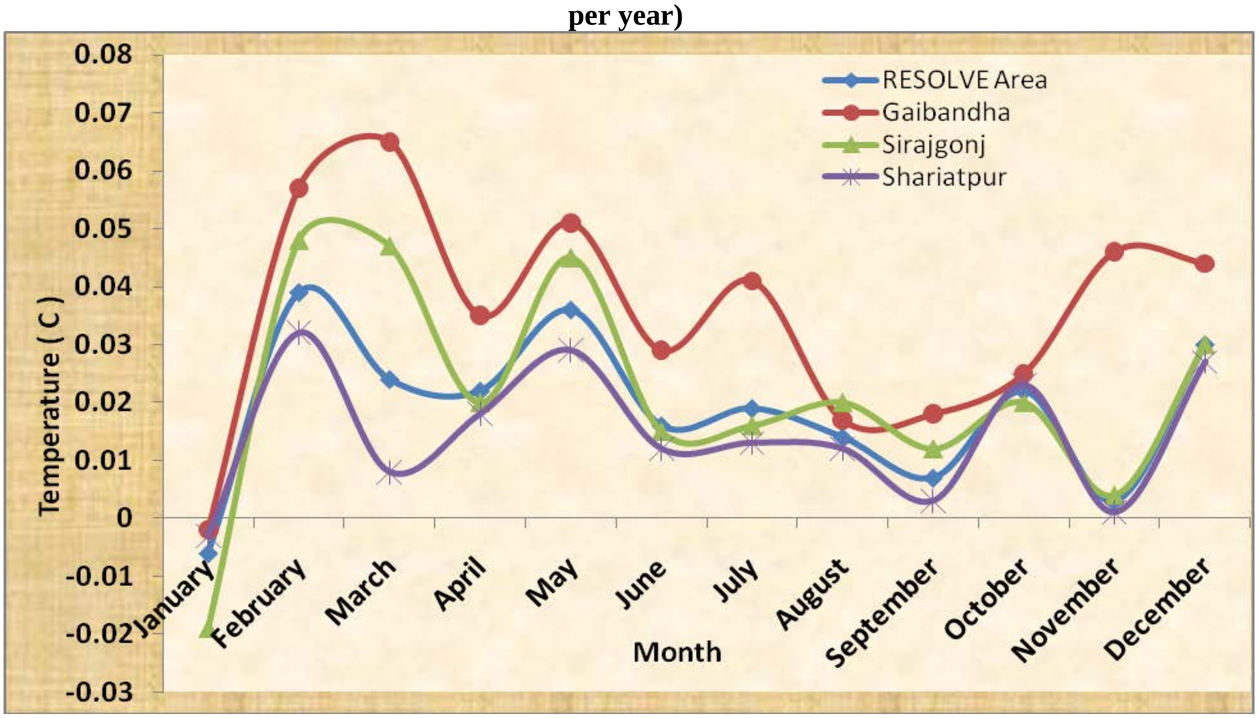
Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Figure 2: Changes in monthly average maximum temperature during 1976-2008 (degree centigrade per year)



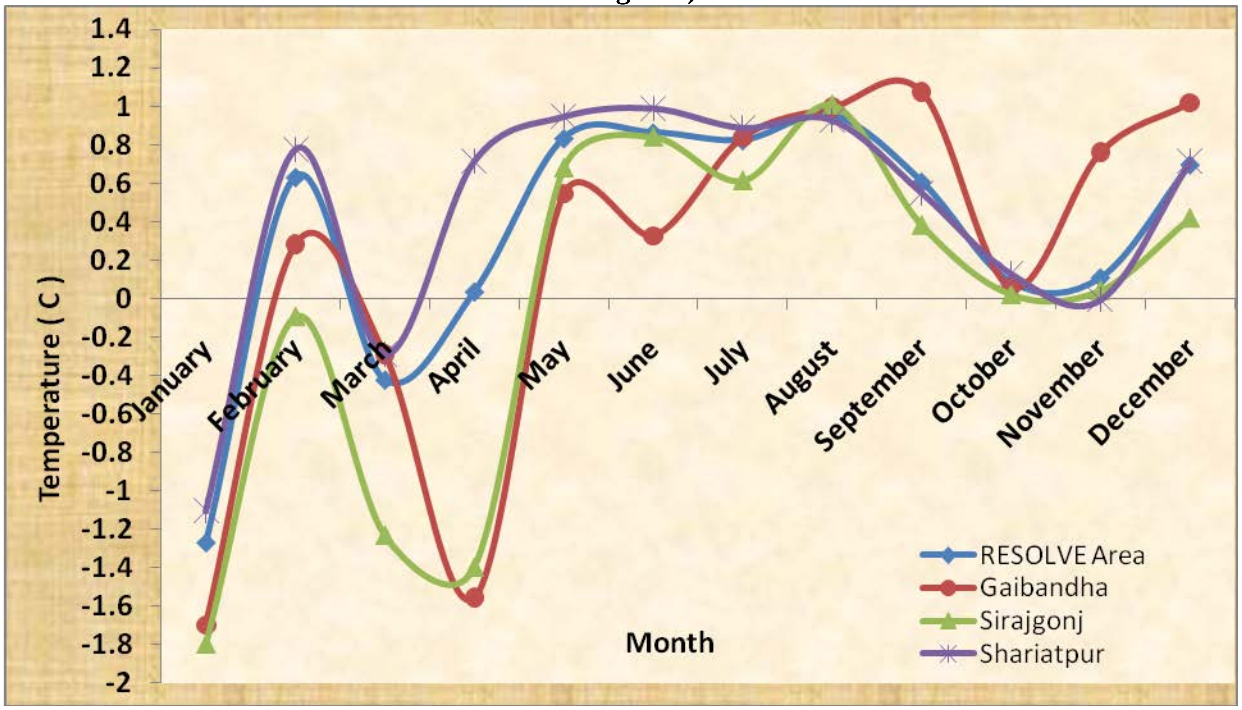
Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Figure 3: Changes in monthly average minimum temperature during 1976-2008 (degree centigrade per year)



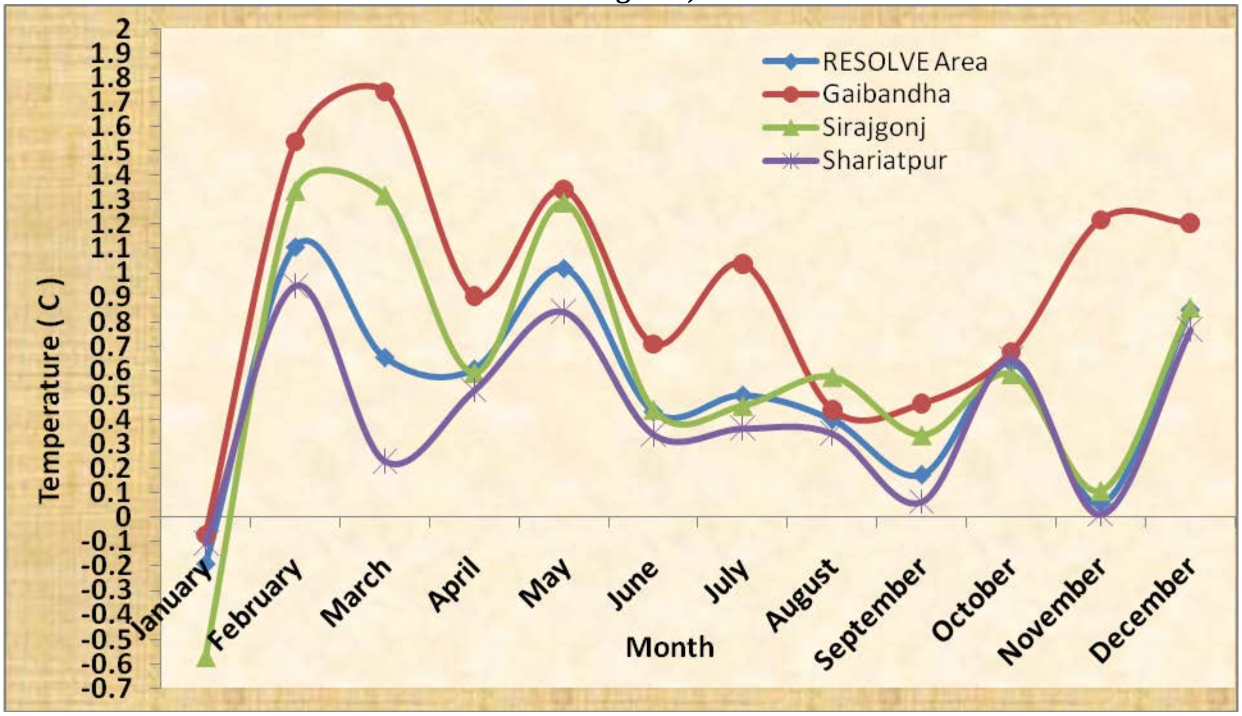
Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Figure 4: Total changes in monthly average maximum temperature during 1976-2008 (degree centigrade)



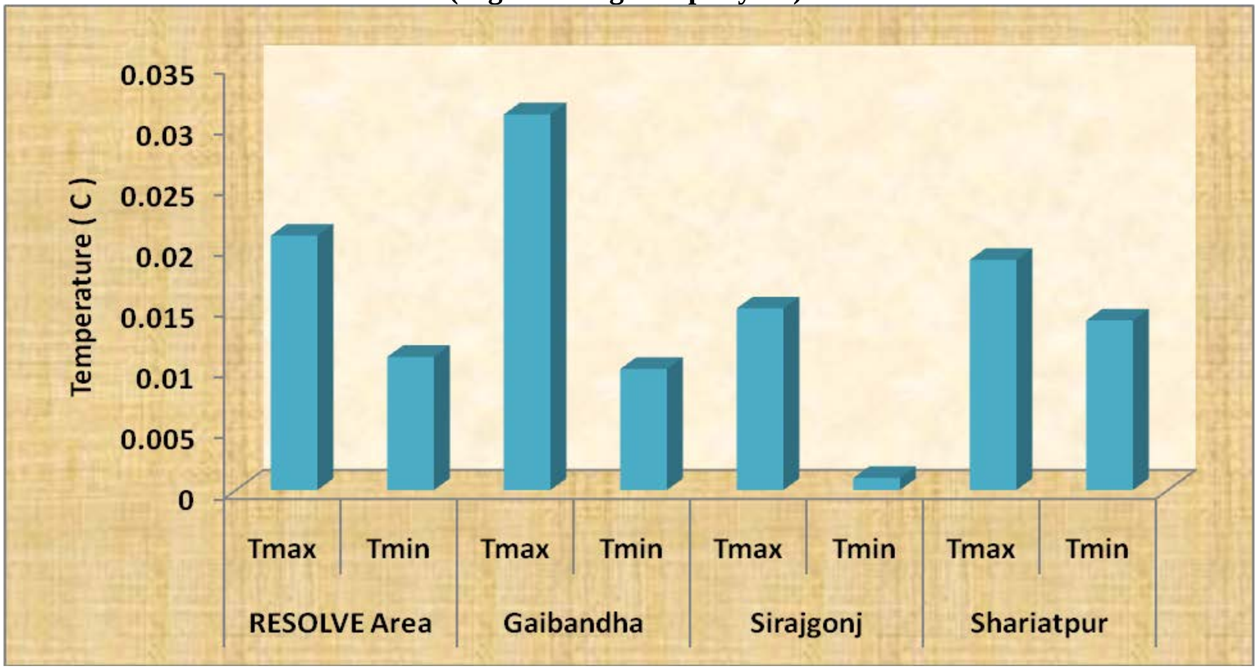
Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Figure 5: Total changes in monthly average minimum temperature during 1976-2008 (degree centigrade)



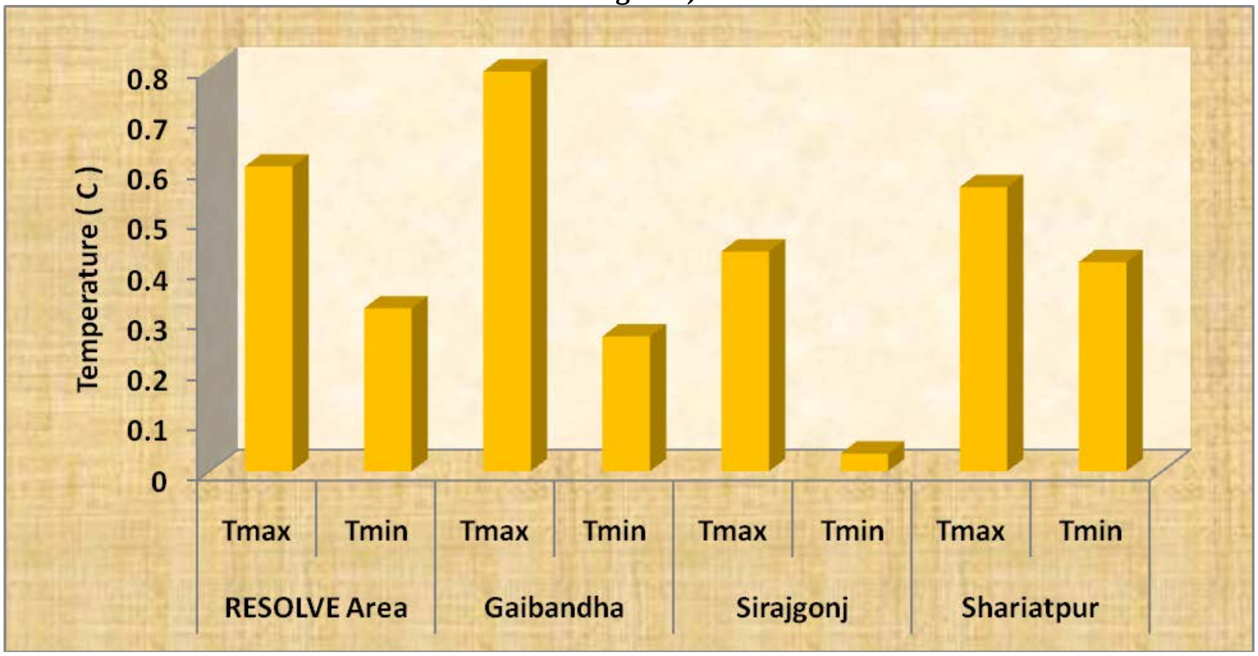
Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Figure 6: Changes in annual average maximum and minimum temperature during 1976-2008 (degree centigrade per year)



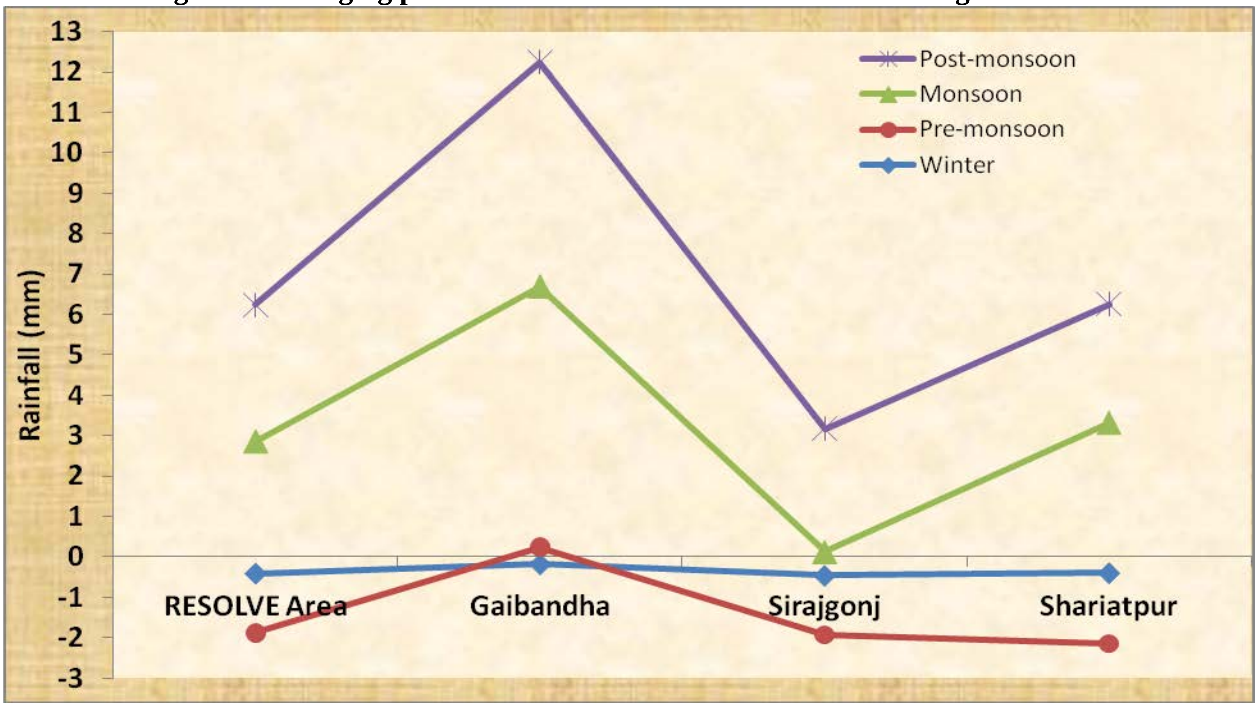
Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Figure 7: Total changes in monthly average minimum temperature during 1976-2008 (degree centigrade)



Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Figure 8: Changing pattern of rainfall in RESOLVE areas during 1976-2008



Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

3. Impacts of Climate change on Agriculture sector in Bangladesh

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.

There is an inverse relationship between climate change and agriculture production. 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, eventually hampers agriculture production. Changes in soil moisture and temperature, evapo-transpiration, rainfall and possible increases in heat stress will affect the growth of some subsistence root crops and vegetables. Being a climate sensitive sector, agriculture in Bangladesh is totally dependent on seasonal weather variability.

During the growing season, the mean temperature, and the temperature sum, range, distribution pattern, and diurnal changes, or a combination of these may be highly correlated with grain yields (Basak *et al.*, 2009b). 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 for the development of the rice plant at different growth phases (vegetative, reproductive and ripening) are shown in Table 3. These critical temperatures differ according to variety, duration of the critical temperature, diurnal changes and physiological status of the plant (Yoshida, 1981). Extreme temperatures, whether low and high, cause injury to the rice plant. 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).

Table 3: Critical temperature for the development of rice plant at different growth stages

Growth stages	Critical temperature (^{0}C)		
	Low	**High**	**Optimum**
Germination	16-19	45	18-40
Seedling emergence	12	35	25-30
Rooting	16	35	25-28
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Initiation of panicle primordia	15	-	-
Panicle differentiation	15-20	30	-
Anthesis	22	35-36	30-33
Ripening	12-18	>30	20-19

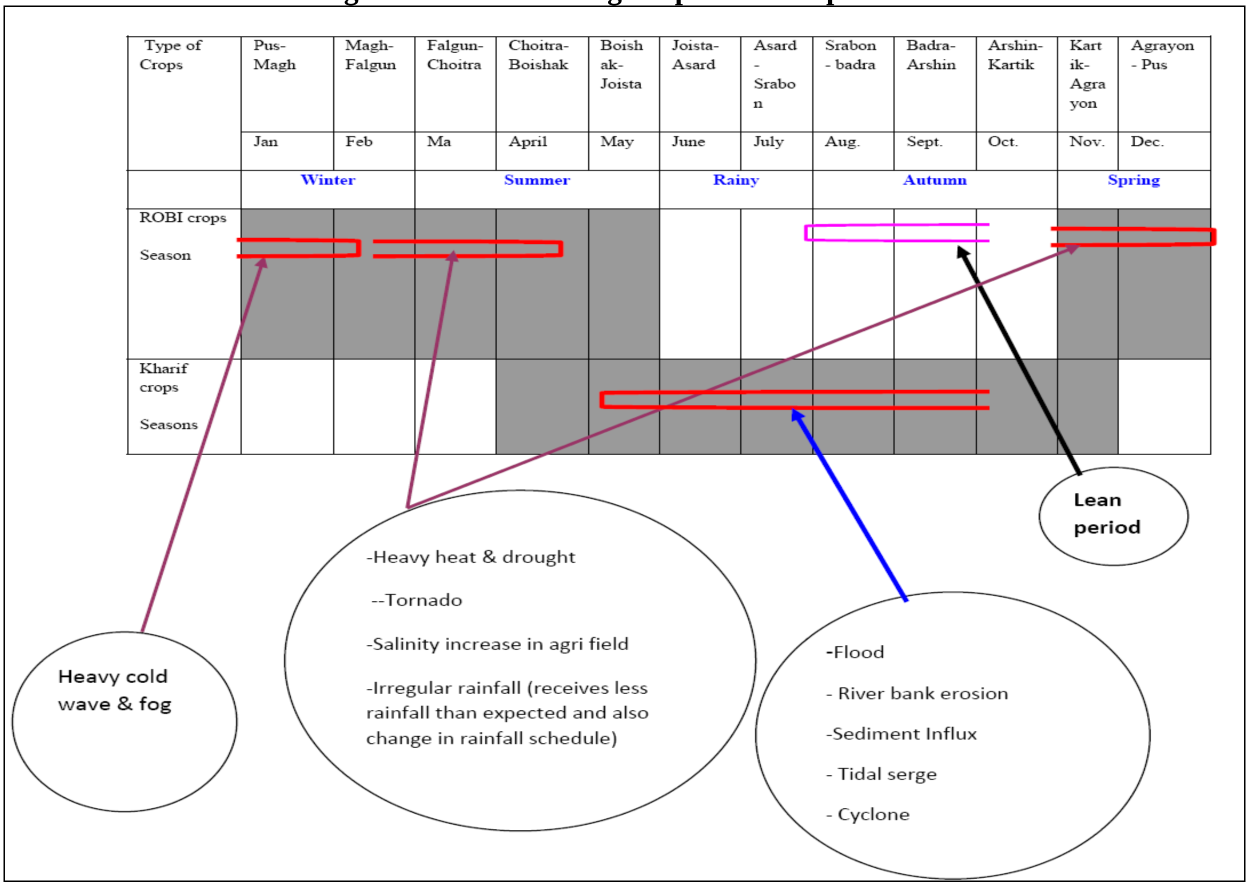
(Source: Yoshida, 1978)

A number of simulation studies have been carried out to assess impacts of climate change and variability on rice productivity in Bangladesh (e.g., Basak *et al.*, 2009; Mahmood *et al.*, 2003; Mahmood, 1998; Karim *et al.*, 1996) and some of these studies have predicted lower rice yield under different climate change scenarios. Basak (2009a) and Basak *et al.* (2010) predicted significant reduction in yield of some varieties of boro rice due to climate change. 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^o c), carried by Basak (2009c) showed that rice yield would be reduced by 10.41 percent and 22.87 percent due to increased temperature at the level of 2^0C and 4^0C respectively. Karim *et al.*, argued that a significant yield reduction may have occurred for rice and wheat (35% and 31%, respectively) due to changing climatic conditions in future. Therefore, there is a great possibility to hamper both rice and wheat production (main food grain in Bangladesh) which may directly affect the food security and also make a social security problem for developing countries like Bangladesh.

3.1 Impacts of Climate change on Agriculture sector in RESOLVE areas

Depending on rainfall pattern and temperature, agriculture season in Bangladesh is divided into two parts such as Kharif and Robi. The Kharif season is characterized by high temperature, rainfall and humidity. Usually, Kharif crops are grown during the season that starts from April and extends up to November when the moisture of the soil from rainfall is enough to support rain-fed crops. From seasonal point of view, Kharif crops are grown in the spring or summer season and harvested in early winter. On the other hand, Robi season is characterized by dry sunny weather and warm at the beginning and end but cold in December-February. From seasonal point of view, Robi crops are grown in winter and harvested at early Rainy season. It is therefore clearly evident that both Robi and Khraif crop require certain types of seasonal arrangement to sustain productivity. Any changes in seasonal weather events will eventually hamper agriculture production and there by food security.

Figure 9: Climate change impacts on crop season



(Source: Field study of Tapan Kanti Dey, SDS, 2010)

Temperature regime greatly influences not only the growth duration but also the growth pattern of plant. During the growing season, the mean temperature, and the temperature sum, range, distribution pattern, and diurnal changes, or a combination of these, may be highly correlated with grain yields (Moomaw and Vergara, 1965). Lower temperature during growing period is one of the main causes of cold injury which severely affects the yield. Another cause of cold injury is cold irrigation water. Kaneda and Beachell (1974) pointed the common types of symptoms caused by low temperature. These are given below:

1. Poor germination
2. Slow growth and discoloration of seedlings
3. Stunted vegetative growth characterized by reduced height and tillering
4. Delayed heading
5. Incomplete panicle exsertion
6. Prolonged flowering period because of irregular heading
7. Degeneration of spikelets
8. Irregular maturity
9. Sterility
10. Formation of abnormal grains

From the analysis of temperature data, it is found that both of the monthly average maximum and minimum temperature decreased at a significant rate in all RESOLVE areas in January during 1976-2008 and the rate of change is comparatively higher in Sirajgonj which might have impact on crop production in future. Moreover, changing pattern of those two temperature parameters for other two regions are also high compare to many locations in Bangladesh. Furthermore, it has also been observed from the 33 years data that the monthly average maximum and minimum temperature highly fluctuated during the period of January to April which might play a negative role on robi season when maximum cereals are grown. A considerable amount of production may be lost due to this climatic variability. In the field study in 1990, it was shown that very high grain sterility (40-90%) due to unusual fall of temperature in March results in crop failure in several regions of Bangladesh (Haque *et al.*, 1992).

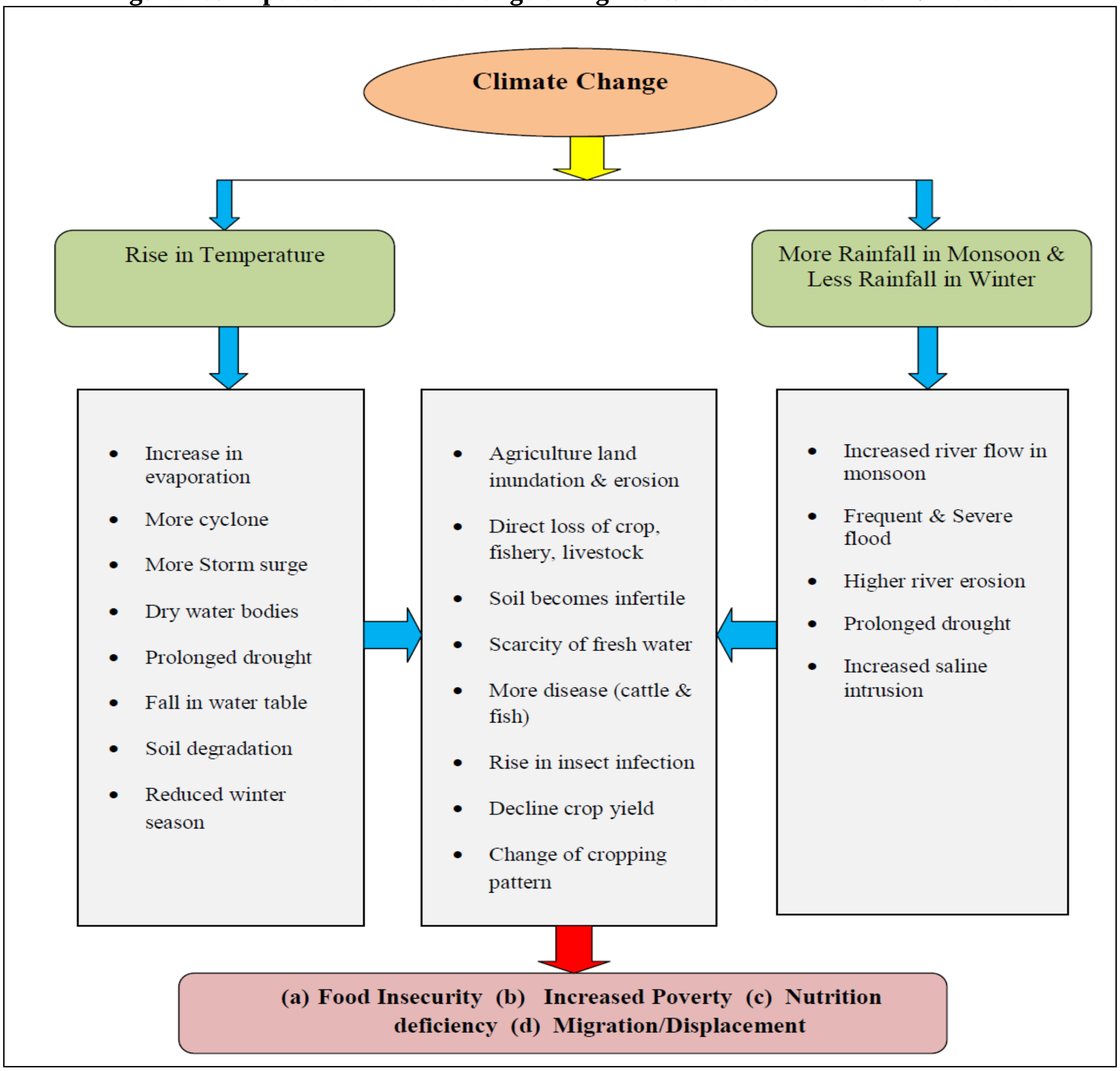
However, on an average, both monthly average maximum and minimum temperature increased in each year about 0.02^0C during May to October in all RESOLVE areas. The increasing rate of temperature might have a significant negative impact on Kharif crops and a part of Robi crops in future. Islam (1995) studied 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 revealed that higher mean temperature at vegetative stage affected grain yield too. According to Satake and Yoshida (1978), spikelet sterility from high temperature is induced largely on the day of flowering. Within the flowering day, high percentage just before anthesis was second most detrimental and high temperature after anthesis had little effect on spikelet fertility.

The study shows that yearly average maximum and minimum temperature increased in all selected regions under RESOLVE areas. The increasing rate of temperature would also have an effect on moisture available for crop growth, whether or not levels of rainfall 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 also likely to increase in severity in areas where precipitation increases. Under warmer and more humid conditions, cereals would be more prone to diseases such as Septoria (Beresford *et al.*, 1989).

Similarly, temperature, rainfall pattern also changed over the years in RESOLVE areas. From the study, it is observed that a considerable amount of rainfall increased during monsoon and post-monsoon season, whereas, it decreased during pre-monsoon and winter. The changing pattern might have a significant negative impact on crop production for the selected areas in upcoming year. Few studies relating to changing rainfall pattern and water requirement of crops showed that variability of rainfall affects crops at different times. If the variability is associated with the onset of the rain, stand establishment and the growth duration of crops are affected. 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 for planting an irrigation water supply system (Talukder *et al.*, 1994). Thus, rainfall deficit information for different areas and periods can greatly help to determine optimal water release from sources (ground or surface) for RESOLVE areas.

Figure 10: Impacts of Climate change on Agriculture sector in RESOLVE areas



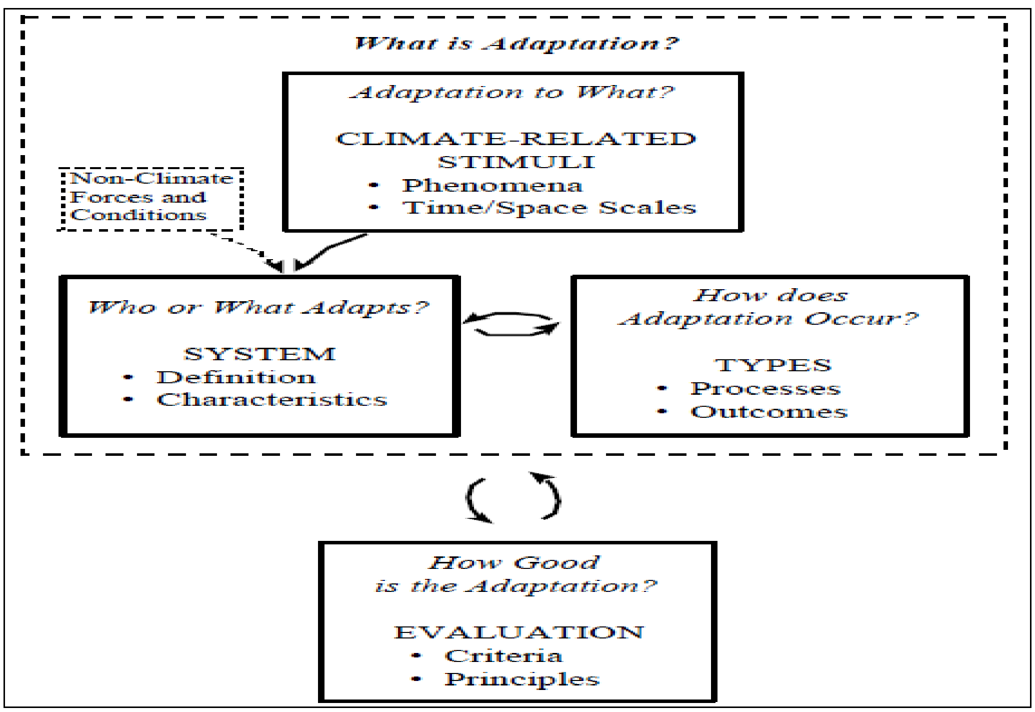
(Source: Field survey at RESOLVE areas, 2011)

4. Adaptation process

According to the IPCC Third Assessment Report, adaptation "has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages." Furthermore, it is argued that human and natural systems will, to some extent, adapt autonomously and that planned adaptation can supplement autonomous adaptation. However, "options and incentives are greater for adaptation of human systems than for adaptation to protect natural systems" (IPCC 2001: 6-8).

Smit *et al.* (2000) pointed out that several definitions of adaptation are found in the climate change literature. The following are some of the examples found: adaptation to climate is the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides (Burton 1992, quoted in Smit *et al.* 2000). Adaptation involves adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer-term climate change (Smit 1993, quoted in Smit *et al.* 2000). The term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change (Stakhiv 1993, quoted in Smit *et al.* 2000); adaptation to climate change includes all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system (Smith *et al.* 1996, quoted in Smit *et al.* 2000); and adaptability refers to the degree to which adjustments are possible in practices, processes or structures of systems to projected or actual changes of climate.

Figure 11: Adaptation to climate change and variability



(Source: Smit *et al*., 2000).

Therefore, 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).

4.1 Adaptation practices in Agriculture at RESOLVE areas

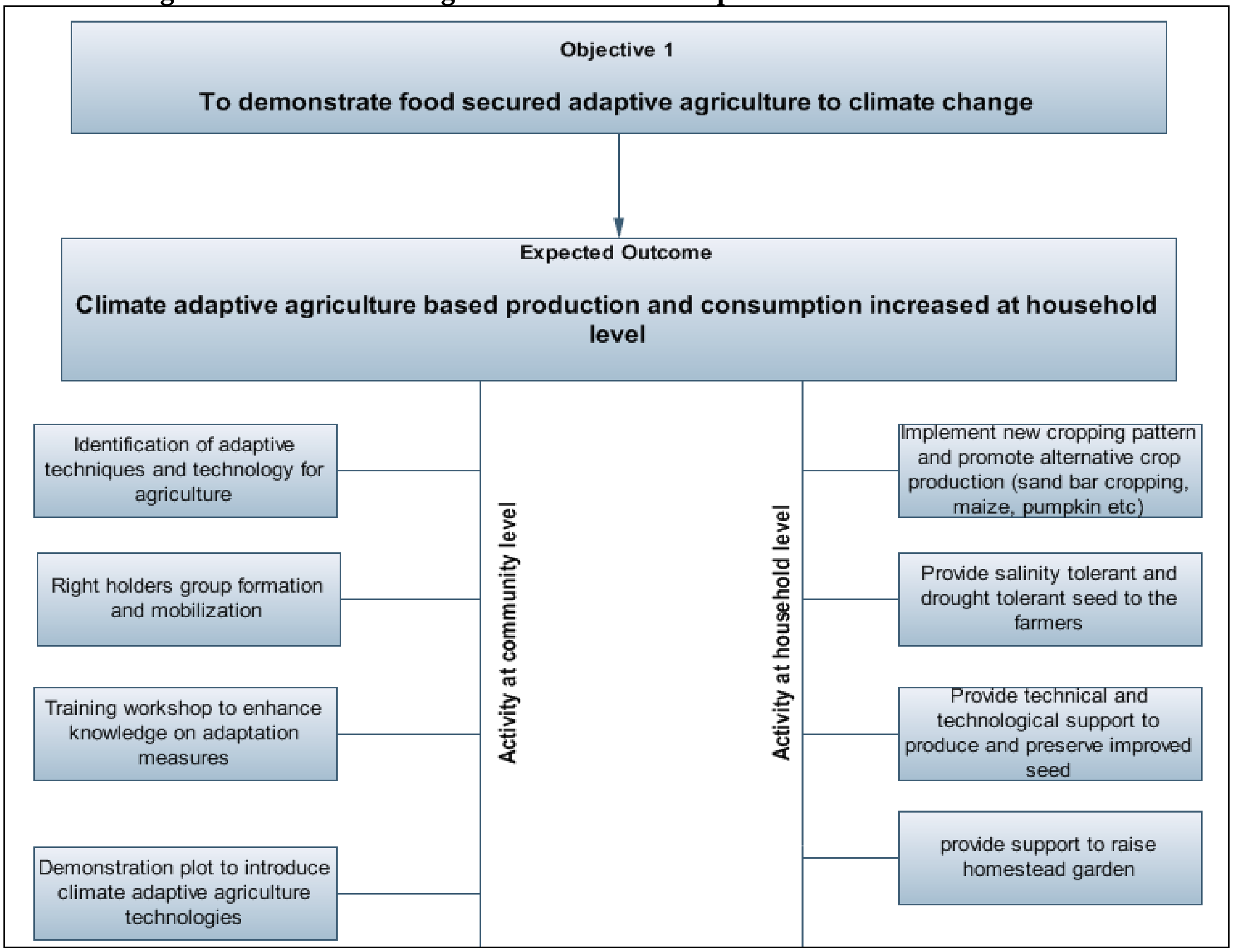
Adaptation is adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts (Burton *et al.*, 2002). This term refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climatic change and variability. Adaptation is important in the climate change issue in two ways. One is related to the assessment of impacts and vulnerabilities and the other is related to the development and evaluation of response options.

Incorporating or integrating adaptation to climate change into planning processes is a necessary strategy for sustainable development over the long term (Burton *et al.*, 2002). Climate change impacts do not happen in isolation. Impacts in one sector can adversely or positively affect another. Sectors can be affected directly and/or indirectly by climate change and indeed sometimes a change in one sector can offset the effects of climate change in another sector. Therefore, assessing the impacts of and vulnerability to climate change and subsequently working out adaptation require good quality information. This information includes climate data, such as temperature, rainfall and the frequency of extreme events, and non-climatic data such as the current situation on the ground for different sectors including water resources, agriculture and food security.

Ensuring food security in RESOLVE areas under a changing climate has suggested a multi-pronged adaptation approach which supports households to increase food production, improve their economic access to food, and enhance community capacities to cope with climate change risks. To address the climate change impacts on the agriculture and livelihood of the targeted areas, RESOLVE has selected five components and food secured adaptive agriculture is one of them.

Various climatic events are impacting on cropping seasons in different magnitude resulting yield reduction, for instance, Kharif season is mostly affected by floods at Gaibandha; whereas moisture stress, drought and irregular rainfall are major threat for Robi season, therefore, specific adaption practices must be essential on location wise with considering changing climatic conditions on the basis of people perception, as well as scientific based sustainable way. Different climatic variables and their induced natural events are given below at location wise.

Figure 12: Schematic diagram of intervention options addressed in RESOLVE



(Source: RESOLVE Proposal, 2010)

4.1.1 Adaptation practices in Agriculture in Gaibandha and Sirajgonj

Geographically, Gaibandha (agro-ecological zones namely AEZ 2 (whole) and AEZ 7 (partly)) is a flood stricken area. Almost every year, this area experiences flood and consequently river erosion. It is estimated that about 1600 families are being displaced each year due to flood and river bank erosion. However, climate change has added value to the already prevailing natural disasters. The frequency and intensity of flood have increased in many folds in recent years due to climate change. Moreover, flash flood, as a consequence of heavy rain in upstream, devastates lives and livelihood bases without any notice recurrently. On the other hand, Sirajgonj is located around the mighty river Jamuna and chalonbeel (wetland) ecosystem. The area is generally flat and land elevation is not very high. The flat terrain of the area is prone to extended monsoon flooding and river bank erosion mainly during the rainy season. Bangladesh Climate Change Strategy and Action Plan (BCCSAP) has mentioned these areas as critical environmental region and these regions will be more prone to enhanced flooding and river erosion due to adverse effect of climate change such as heavy rainfall.

Being a flood plain, agriculture is the major economic sector for the both selected regions. However, climate change induced disasters such as flood, river bank erosion, drought, cold wave, dense fog, heat wave are contributing to reduce agriculture production and in some cases destroying whole production and thereby hampering the overall food security of the area.

Flood damages crops, vegetables and other different livelihood options like poultry and livestock. 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 falling debt and poverty. Drought is another major climatic disaster that hampered/damaged different livelihood options like agriculture, on farm and off farm laborers (rickshaw/van pulling, earth work), poultry and livestock, fishing/aquaculture, small business, etc. In winter, cold wave and dense fog negatively affect agriculture, fisheries, livestock, and at different levels. It decreases production of winter crops and vegetables due to the increase of fungal diseases.

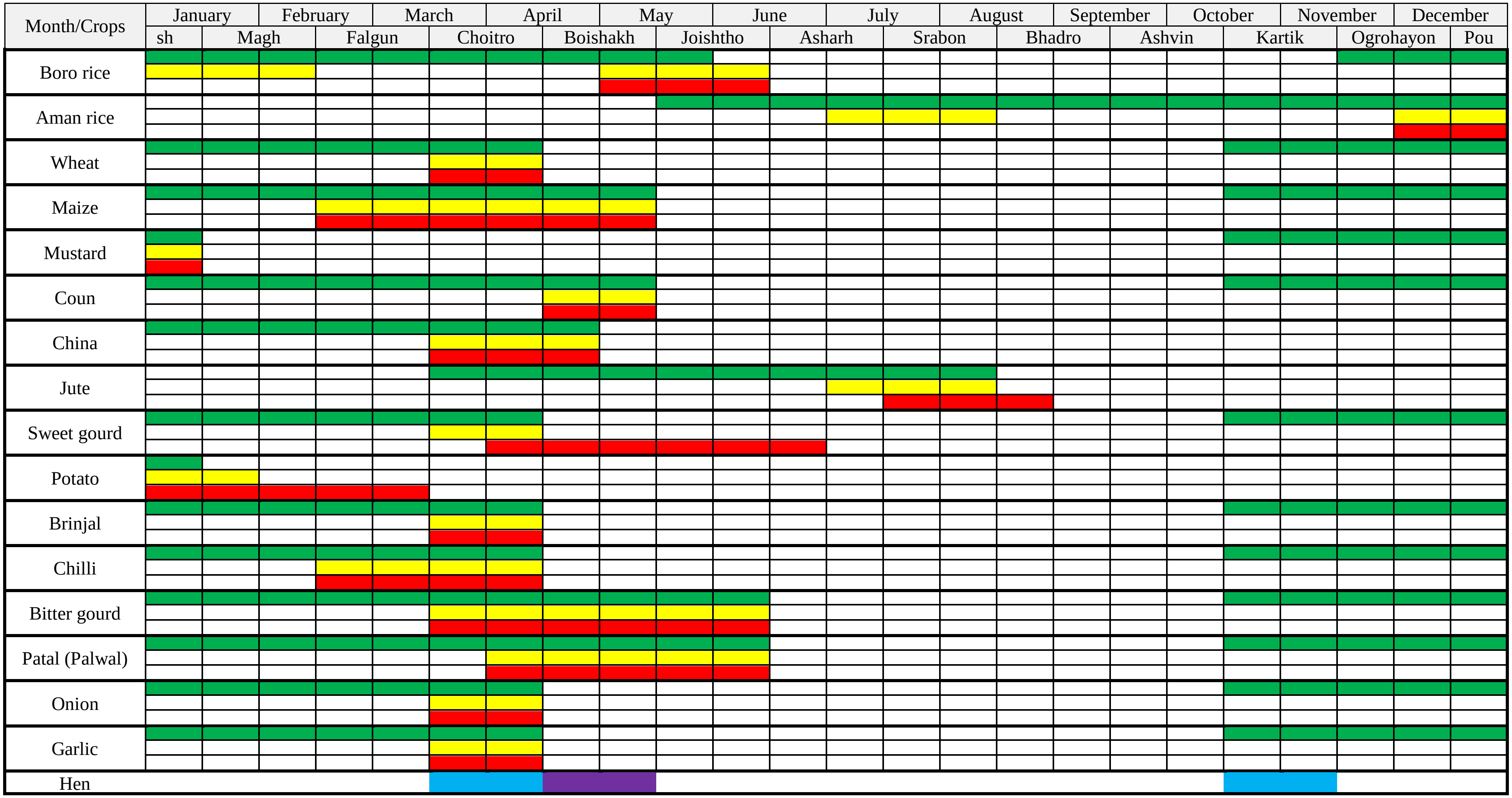
Maximum farmers of these locations follow rice cropping pattern and cropping intensity is near about two. However, during kharif season, farmers face difficulty to harvest their cultivated crops due to climate induced natural events. From the field survey, it was found that maximum farmers have a little knowledge about selection appropriate cropping pattern and technology, selection of seed, irrigation water management, selection of transplanting date and crop intensification. Therefore, after acquiring knowledge from field levels and discussing with different experts of different organizations, climate adaptive cropping patterns were developed.

Table 4: Location wise natural events due to climatic variability

Main Climatic parameters	Influence of main Natural events in Gaibandha	Influence of main Natural events in Sirajgonj
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) (****** Severe natural events; * moderate natural events)

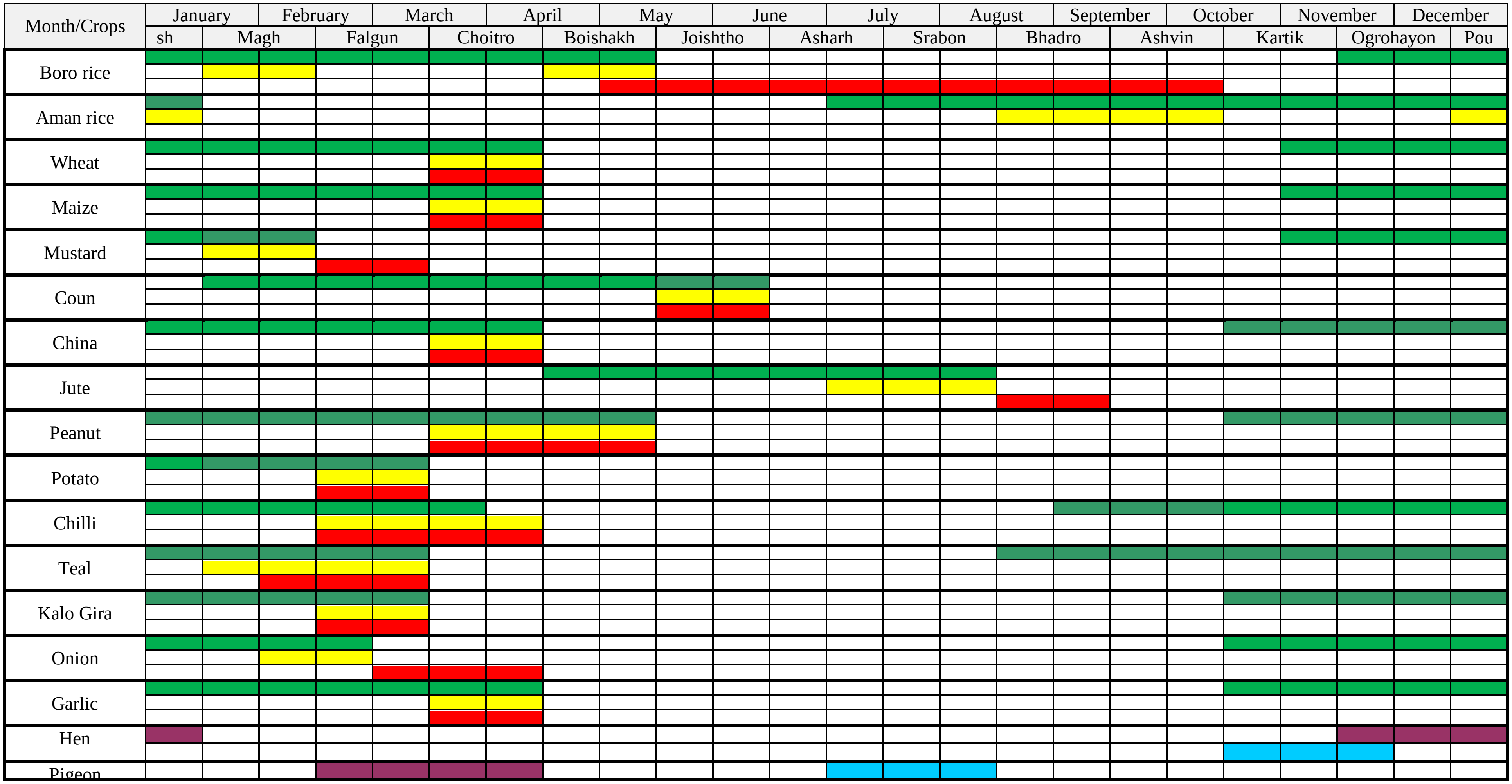
Figure 13: Local Crop Calendar for Gaibandha District (Union: Sreepur, Thana: Sundargonj, District: Gaibandha, Date: - 12-05-2011)



(Developed by Author, supported by Md. Rokonuzzaman Zillulla, Md. Mominul Islam; Md. Shahedul Islam and Mosst. Sabina Yesmin (GUK), discussed with local farmers, Isahuq Ali; Abdur Sattar; Shanju Mia; Nurul Nobi; Abdur Rashid; Rowshna Begum; Salma Begum; Mashud Begum; Abu Bokkor Siddque; Anjura Begum; Delowar Hossain, Kopil Uddin and Shoda Begum, 2011)

Growing period High Labour Demand Selling Period Diseases affecting period Most productive period

Figure 14: Local Crop Calendar for Sirjgonj District (Union: Kajipur, Thana: Sirjgonj, District: Sirjgonj, Date: - 16-05-2011)



(Developed by Author supported, by Md. Wahedul Haque, Md. Helal Uddin, Md. Abul Kalam Ajad (GKS) discussed with local farmers: Md. Jihad Ali, Md. Abdul Based, Most. Marina Khatun, Md. Rafiqual Islam, Most. Khuki Begum, Md. Jamal Hossain, Most. Rashed Khatun, Md. Al Amin, Md. Koboj Ali and Md Mojibor Hossain, 2011)

Growing period High Labour Demand Selling Period Diseases affecting period Most productive period

Figure 15: Suggested Crop Calendar for Gaibandha and Sirjgonj District at Field Level

<table>
<tr><th rowspan="2">Month/Crops</th><th colspan="2">January</th><th colspan="2">February</th><th colspan="2">March</th><th colspan="2">April</th><th colspan="2">May</th><th colspan="2">June</th><th colspan="2">July</th><th colspan="2">August</th><th colspan="2">September</th><th colspan="2">October</th><th colspan="2">November</th><th colspan="2">December</th></tr>
<tr><th>Sh</th><th colspan="2">Magh</th><th colspan="2">Falgun</th><th colspan="2">Choitro</th><th colspan="2">Boishakh</th><th colspan="2">Joishtho</th><th colspan="2">Asharh</th><th colspan="2">Srabon</th><th colspan="2">Bhadro</th><th colspan="2">Ashvin</th><th colspan="2">Kartik</th><th colspan="2">Ogrohayon</th><th>Pou</th></tr>
<tr><td>Boro rice-T.aman</td><td colspan="8">BRRI dhan 28</td><td colspan="12">BRRI dhan 51 and BRRI dhan 52 (Submerged Tolerant)</td><td colspan="4">BRRI dhan 28</td></tr>
<tr><td>Wheat-Mug dal-T.Aman</td><td colspan="5">Wheat (Hashi developed by BARI)</td><td colspan="6">Mug dal (BARI Mug 6)</td><td colspan="8">T. Aman (BRRI dhan 39 and BRRI dhan 33)</td><td colspan="5">Wheat (Hashi developed by BARI)</td></tr>
<tr><td>Chilli-T.aman</td><td colspan="8">Chilli</td><td colspan="11">BRRI dhan 51 and BRRI dhan 52 (Submerged Tolerant)</td><td colspan="5">Chilli</td></tr>
<tr><td>Maize-T.aman</td><td colspan="8">Maize</td><td colspan="11">BRRI dhan 51 and BRRI dhan 52 (Submerged Tolerant)</td><td colspan="5">Maize</td></tr>
<tr><td>Mustard-Mug dal-Jute</td><td colspan="3">Mustard</td><td colspan="5">Mug dal (BARI Mug 6)</td><td colspan="11">Jute</td><td colspan="5">Mustard</td></tr>
<tr><td>Mustard-Mug dal-T.aman</td><td colspan="3">Mustard</td><td colspan="5">Mug dal (BARI Mug 6)</td><td colspan="11">BRRI dhan 51 and BRRI dhan 52 (Submerged Tolerant)</td><td colspan="5">Mustard</td></tr>
<tr><td>Sweet gourd-Jute/T.aman</td><td colspan="8">Sweet gourd</td><td colspan="11">BRRI dhan 51 and BRRI dhan 52 (Submerged Tolerant)/Jute</td><td colspan="5">Sweet gourd</td></tr>
<tr><td>Potato-Mug dal-Taman/Jute</td><td colspan="3">Potato</td><td colspan="5">Mug dal (BARI Mug 6)</td><td colspan="11">BRRI dhan 51 and BRRI dhan 52 (Submerged Tolerant)/Jute</td><td colspan="5">Potato (Diamond/Cardinal variety)</td></tr>
</table>

(Source: Developed by Author with detail discussion with BRRI, BARI and BJRI scientists and following climate adaptive techniques which is developed by BRRI Rich Farming division, 2011)

Table 5: Location wise adaptation options (Gaibandha and Sirajgonj)

Management/Practices	Adaptation options
Cropping pattern	• Boro rice-T.aman rice • 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 dhan28 • Short duration and cold tolerant boro rice varieties-BRRI dhan36 • Submerged tolerant rice varieties during kharif season-BRRI dhan 51, BRRI dhan52 • Short duration rice varieties during kharif season-BRRI dhan39, BRRI dhan33 • Drought tolerant rice varieties during kharif season-BRRI dhan42, BRRI dhan43 • 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 (Basak, *et al.* 2009) • 1 June for T.aman rice transplantation (Mahmood, *et al.* 2003)

(Source: Developed by Author after detail discussion with BRRI, BARI and BJRI scientists and following climate adaptive techniques which were prepared by BRRI Rich Farming division, 2011)

4.1.2 Adaptation practices in Agriculture in Shairatpur

Shairatpur district is located at the estuary of the Brahmaputra and Padma. Geographically, the Padma, the Meghna, the Krittinasha and the Ariyalkha surround Shariatpur district. Having a close proximity to couple of rivers and to the dominance of monsoon climate, the area is subject to multiple climate change impacts such as flood, river bank erosion, and salinity intrusion as a consequence of back water effect, tidal surge and cyclone. Poorest communities are the most vulnerable and bear the burden of climate change mostly.

River dominated area makes Shariatpur as one of the suitable places for artisanal fishing, besides agriculture as people's main occupation. However, climate change has changed the scenario. Climate induced sea level rise is resulting back water to the rivers and consequently salinity hits the rivers and agricultural land in Shariatpur. Such salinity intrusion is not only hampering agriculture production but also affecting distribution and availability of native fish species. Usually, the farmers in the district produce majority of their food grain in Robi season. Unfortunately, this season is mostly affected by salinity intrusion, cold wave, fresh water scarcity. On the other hand, Kharif season is dominated by rain-fed agriculture.

Table 6: Location wise natural events due to climatic variability

Main Climatic parameters	Influence to main Natural events at Shariatpur
Temperature Rainfall	• Scarcity of fresh water** • Saline water intrusion** • Drought* • Prolonged heat** • Short winter season** • Cold spell** • Dense fog*

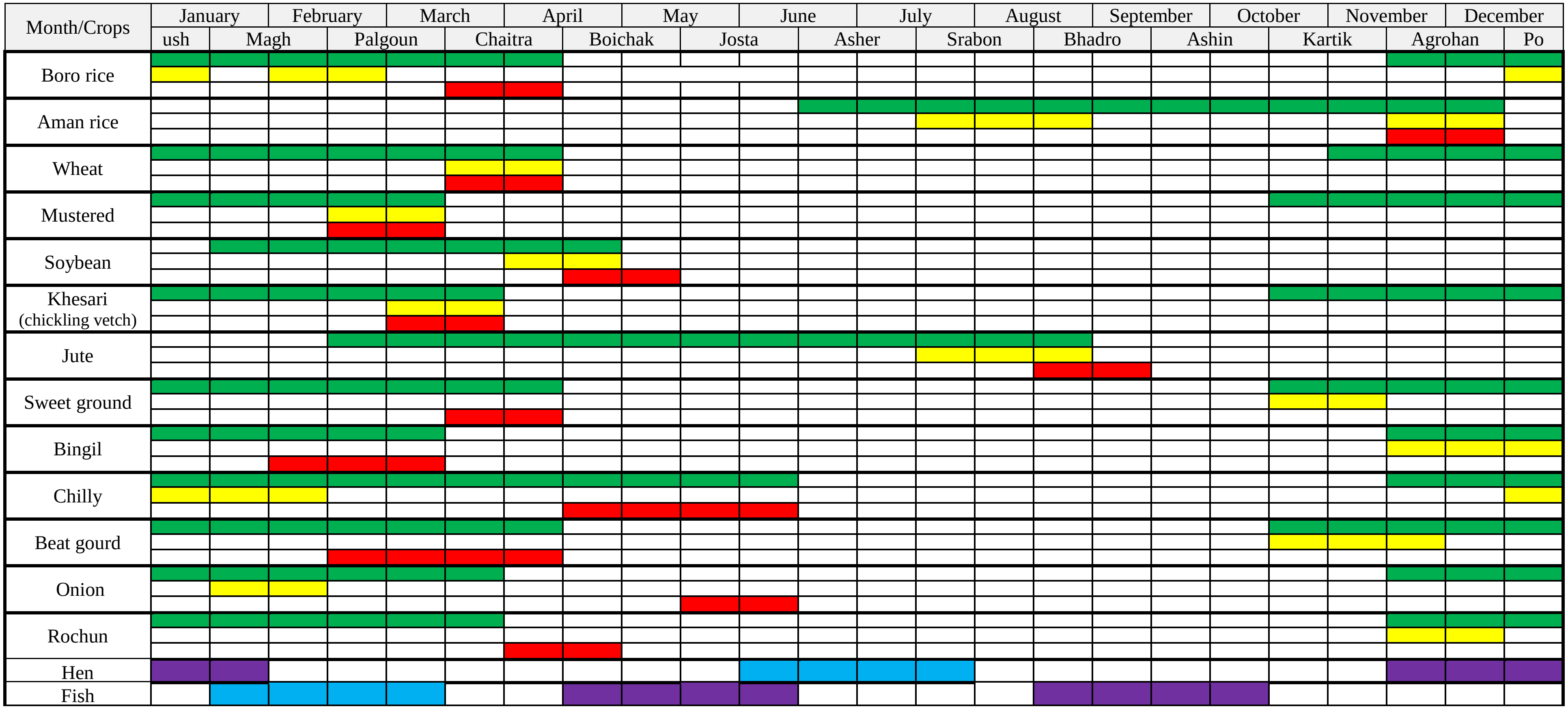
(Source: Field survey, 2011) (****** Severe natural events; * moderate natural events)

Table 7: 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 Author with detail discussion with BRRI, BARI, BJRI and BSRI scientists and following climate adaptive techniques which prepared by BRRI Rich Farming division, 2011)

Figure 16: Local Crop Calendar for Shariatpur District (Union: Nolmuri, Thana: Goshair Hat, District: Shariatpur, Date:- 15-09-2011)



(Developed by Author, supported by Nurjahan Begum, Md. Mizanur Rahman, Md. Kobir Hossain, Bobita Mondal (SDS), discussed with local farmers, Nur Islam Bapari, Babul Bapari, Md. Azad Matubbor, Kuddus Howlader, Shohid Molla, Alamin Sordar, Jane Alam Bapari, Ripon Bapari, Mostofa Howlader, Goni Sordar, Bellar Maji, Kanchon Bapari, Bachhu Bapari, Jamal Chokidar, 2011)

Growing period; High Labour Demand; Selling Period; Diseases affecting period; Most productive period

Table 17: Suggested Crop Calendar for Shariatpur District at Field Level

<table>
<tr><th rowspan="2">Month/Crops</th><th colspan="2">January</th><th colspan="2">February</th><th colspan="2">March</th><th colspan="2">April</th><th colspan="2">May</th><th colspan="2">June</th><th colspan="2">July</th><th colspan="2">August</th><th colspan="2">September</th><th colspan="2">October</th><th colspan="2">November</th><th colspan="2">December</th></tr>
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<tr><td>Boro rice-T.aman</td><td colspan="8">BRRI dhan 47 (Salinity Tolerant-12-14 ds/m)</td><td colspan="12">BRRI dhan 40 and BRRI dhan 41 (Salinity Tolerant-8 ds/m)</td><td colspan="4">BRRI dhan 47</td></tr>
<tr><td>Wheat-Mug dal-T.Aman</td><td colspan="5">Wheat (Hashi developed by BARI)</td><td colspan="6">Mug dal (BARI Mug 6)</td><td colspan="8">BRRI dhan 40 (Salinity Tolerant-8 ds/m)</td><td colspan="5">Wheat (Hashi developed by BARI)</td></tr>
<tr><td>Chilli-T.aman</td><td colspan="8">BRRI dhan 47 (Salinity Tolerant-12-14 ds/m)</td><td colspan="11">Jute (CVL-1 and HC-95) (Salinity Tolerant-8 ds/m)</td><td colspan="5">BRRI dhan 47</td></tr>
<tr><td>Maize-T.aman</td><td colspan="8">Maize</td><td colspan="11">BRRI dhan 40 and BRRI dhan 41 (Salinity Tolerant-8 ds/m)/ Jute (CVL-1 and HC-95) (Salinity Tolerant-8 ds/m)</td><td colspan="5">Maize</td></tr>
<tr><td>Mustard-Mug dal-Jute</td><td colspan="3">Mustard</td><td colspan="5">Mug dal (BARI Mug)</td><td colspan="11">BRRI dhan 40 and BRRI dhan 41 (Salinity Tolerant-8 ds/m)/ Jute (CVL-1 and HC-95) (Salinity Tolerant-8 ds/m)</td><td colspan="5">Mustard</td></tr>
<tr><td>Mustard-Mug dal-T.aman</td><td colspan="24">Sugarcane (ISWARDI-40)</td></tr>
</table>

(Source: Developed by Author with detail discussion with BRRI, BARI, BJRI and BSRI scientists and following climate adaptive techniques which is developed by BRRI Rich Farming division, 2011)

Table 8: Location wise adaptation options (Shariatpur)

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 dhan28 • Short duration and saline tolerant boro rice varieties-BRRI dhan47 • Saline tolerant rice varieties during kharif season-BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54 • Short duration rice varieties during kharif season-BRRI dhan39, BRRI dhan33 • Drought tolerant rice varieties during kharif season-BRRI dhan42, BRRI dhan43 • 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 (Basak, *et al.* 2009) • 1 June for T.aman rice transplantation (Mahmood, *et al.* 2003)

(Source: Developed by Author with detail discussion with BRRI, BARI and BJRI scientists and following climate adaptive techniques which is developed by BRRI Rich Farming division, 2011)

5. Conclusion

In Bangladesh, different climate change impacts such as recurring floods, river bank erosion, drought in dry season, salinity intuition 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. Contextual analysis suggests that unless urgent actions are taken, climate change will undermine efforts to ensure food security of the region.

The study on "Implications of Climate Change on Crop Production in Bangladesh and Possible Adaptation Techniques" is conducted in the three most vulnerable regions in Bangladesh (Sirajgonj, Gaibandha and Shariatpur districts) due to their graving vulnerability to climate change under RESOLVE programme. From the field study, it is observed that maximum farmers of those locations follow rice cropping pattern. However, during kharif season, they face difficulty in harvesting their cultivated crops due to climate induced natural events. Considering to the main climate induced natural events, adaptation practices on cropping pattern, choice of seed, irrigation management, crop intensification and selection of suitable date for rice transplantation have been suggested to help farmers to adapt with the effects of climate change. Moreover, the study has also shown that the changing pattern of temperature and rainfall in 33 years' (1976 to 2008) climate data in all 18 metrological stations surrounding for the selected three locations and the change of those climatic parameters were significant during this period. Furthermore, changing pattern of temperature and rainfall in Gaibandha are high compared to other two regions.

From this study, it is also found that the changing pattern of temperature and rainfall for the selected three regions are significantly higher compared to IPCC assumption 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 increasing food security.

The results found from the study are preliminary findings under the Five Year Action Programme (RESOLVE). Therefore, it is difficult to confirm a crop as adaptive under climate change situations using only one season of crop related data. At least three years of experimentation is required to conclude, whether a crop is adaptive under climate change situations in the selected three regions or not. The finding for selected crop varieties, irrigation management, cropping pattern, crop intensification and selection of suitable date for rice transplantation for both robi and kharif season are need to be confirmed by more trails. Moreover, the findings should be disseminated to the farmers of the regions. Necessary inputs and technology should be provided to the farmers with a purpose to start farming practices in their respective fields with the recommended varieties and technology.

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Annex A

Table A1: Changes in monthly average maximum and minimum temperature during 1976-2008 (degree centigrade per year)

	RESOLVE Area		Gaibandha		Sirajgonj		Shariatpur	
	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
January	- 0.044	-0.006	-0.062	-0.002	-0.062	-0.019	-0.038	-0.003
February	0.022	0.039	0.011	0.057	-0.004	0.048	0.027	0.032
March	-0.015	0.024	-0.009	0.065	-0.043	0.047	-0.010	0.008
April	0.001	0.022	-0.056	0.035	-0.048	0.020	0.025	0.018
May	0.029	0.036	0.020	0.051	0.023	0.045	0.033	0.029
June	0.030	0.016	0.012	0.029	0.029	0.015	0.034	0.012
July	0.029	0.019	0.031	0.041	0.021	0.016	0.031	0.013
August	0.033	0.014	0.037	0.017	0.034	0.020	0.032	0.012
September	0.021	0.007	0.041	0.018	0.013	0.012	0.019	0.003
October	0.003	0.022	0.002	0.025	0.001	0.020	0.004	0.023
November	0.004	0.003	0.028	0.046	0.002	0.004	-0.002	0.001
December	0.024	0.030	0.037	0.044	0.014	0.030	0.024	0.027

Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Table A2: Total changes in monthly average maximum temperature during 1976-2008 (degree centigrade)

	RESOLVE Area		Gaibandha		Sirajgonj		Shariatpur	
	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
January	-1.273	-0.192	-1.699	-0.072	-1.799	-0.572	-1.105	-0.107
February	0.631	1.108	0.282	1.537	-0.095	1.337	0.777	0.948
March	-0.425	0.655	-0.289	1.741	-1.233	1.318	-0.290	0.231
April	0.034	0.607	-1.557	0.906	-1.399	0.592	0.715	0.520
May	0.833	1.020	0.544	1.341	0.679	1.289	0.947	0.842
June	0.862	0.432	0.326	0.710	0.840	0.441	0.990	0.340
July	0.823	0.500	0.839	1.037	0.613	0.457	0.889	0.364
August	0.952	0.400	0.994	0.440	1.007	0.575	0.929	0.343
September	0.606	0.174	1.076	0.465	0.381	0.336	0.550	0.064
October	0.083	0.632	0.058	0.677	0.020	0.586	0.128	0.648
November	0.108	0.056	0.762	1.218	0.042	0.109	-0.006	0.012
December	0.697	0.850	1.019	1.203	0.418	0.859	0.714	0.768

Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Table A3: Changes in annual average maximum and minimum temperature during 1976-2008 (degree centigrade per year)

	RESOLVE Area		Gaibandha		Sirajgonj		Shariatpur	
	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
Annual	0.021	0.011	0.031	0.010	0.015	0.001	0.019	0.014

Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Table A4: Total changes in monthly average minimum temperature during 1976-2008 (degree centigrade)

	RESOLVE Area		Gaibandha		Sirajgonj		Shariatpur	
	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
Annual	0.606	0.324	0.795	0.268	0.437	0.035	0.565	0.416

Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Annex B

Table B1: Changing pattern of rainfall in RESOLVE areas during 1976-2008

	RESOLVE Area	Gaibandha	Sirajgonj	Shariatpur
Winter	-0.407	-0.179	-0.460	-0.397
Pre-monsoon	-1.475	0.421	-1.467	-1.752
Monsoon	4.746	6.448	2.056	5.471
Post-monsoon	3.378	5.555	3.038	2.940

Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Table B2: Total changing pattern of rainfall in RESOLVE areas during 1976-2008

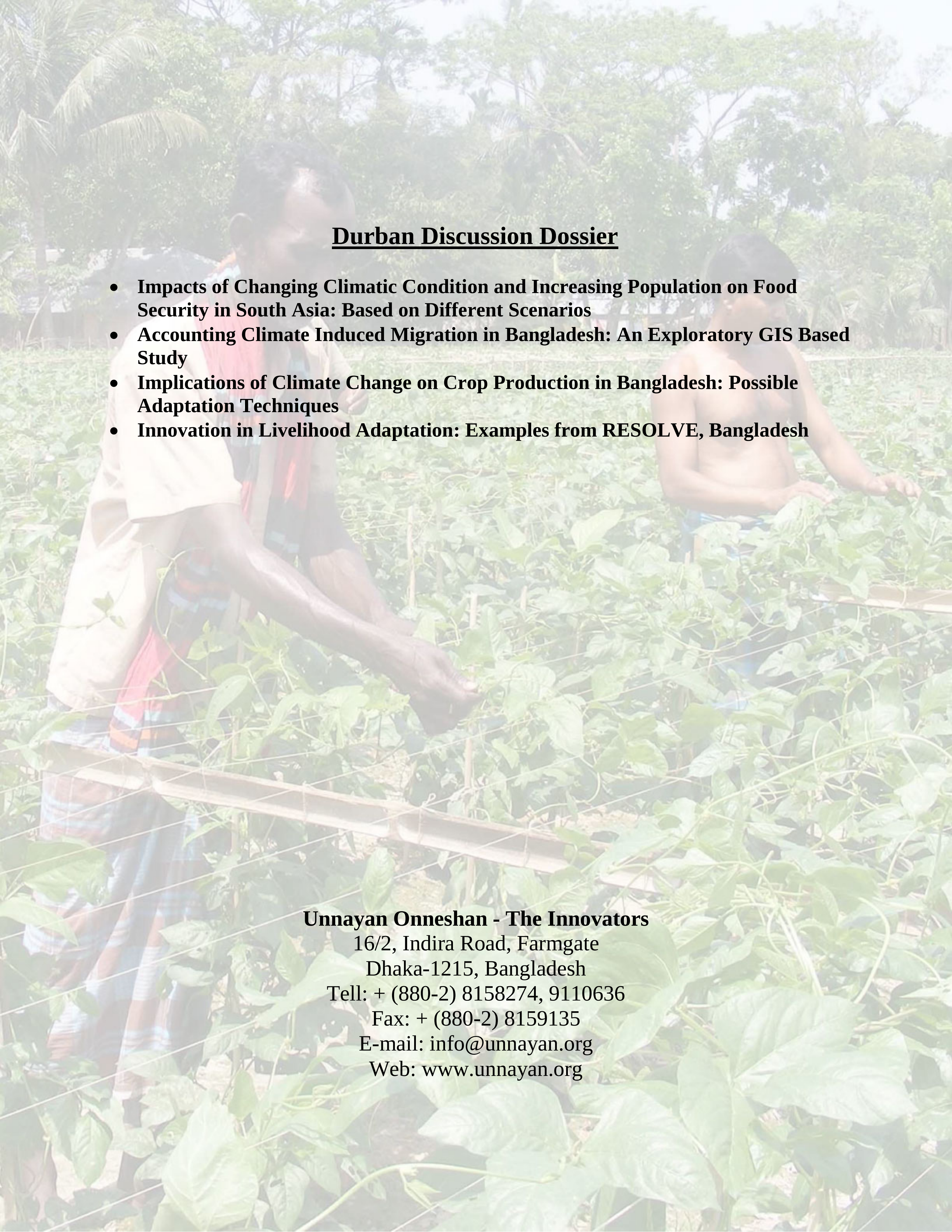
	RESOLVE Area	Gaibandha	Sirajgonj	Shariatpur
Winter	-11.767	-3.485	-13.80	-11.698
Pre-monsoon	-42.016	16.885	-43.289	-50.515
Monsoon	136.854	178.638	59.274	160.371
Post-monsoon	97.452	154.207	91.133	85.475

Source: Author's calculation based on Bangladesh Meteorological Department (BMD)

Table B3: Changing pattern of rainfall in RESOLVE areas at 18 meteorological stations

	RESOLVE Area		Gaibandha		Sirajgonj		Shariatpur	
	No. of Station showing increasing trend	No. of Station showing decreasing trend	No. of Station showing increasing trend	No. of Station showing decreasing trend	No. of Station showing increasing trend	No. of Station showing decreasing trend	No. of Station showing increasing trend	No. of Station showing decreasing trend
Winter	6	12	2	1	1	3	4	8
Pre-monsoon	6	12	2	1	1	3	4	8
Monsoon	15	3	3	0	3	1	10	2
Post-monsoon	18	0	3	0	4	0	12	0

Source: Author's calculation based on Bangladesh Meteorological Department (BMD)



Durban Discussion Dossier

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- **Innovation in Livelihood Adaptation: Examples from RESOLVE, Bangladesh**

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