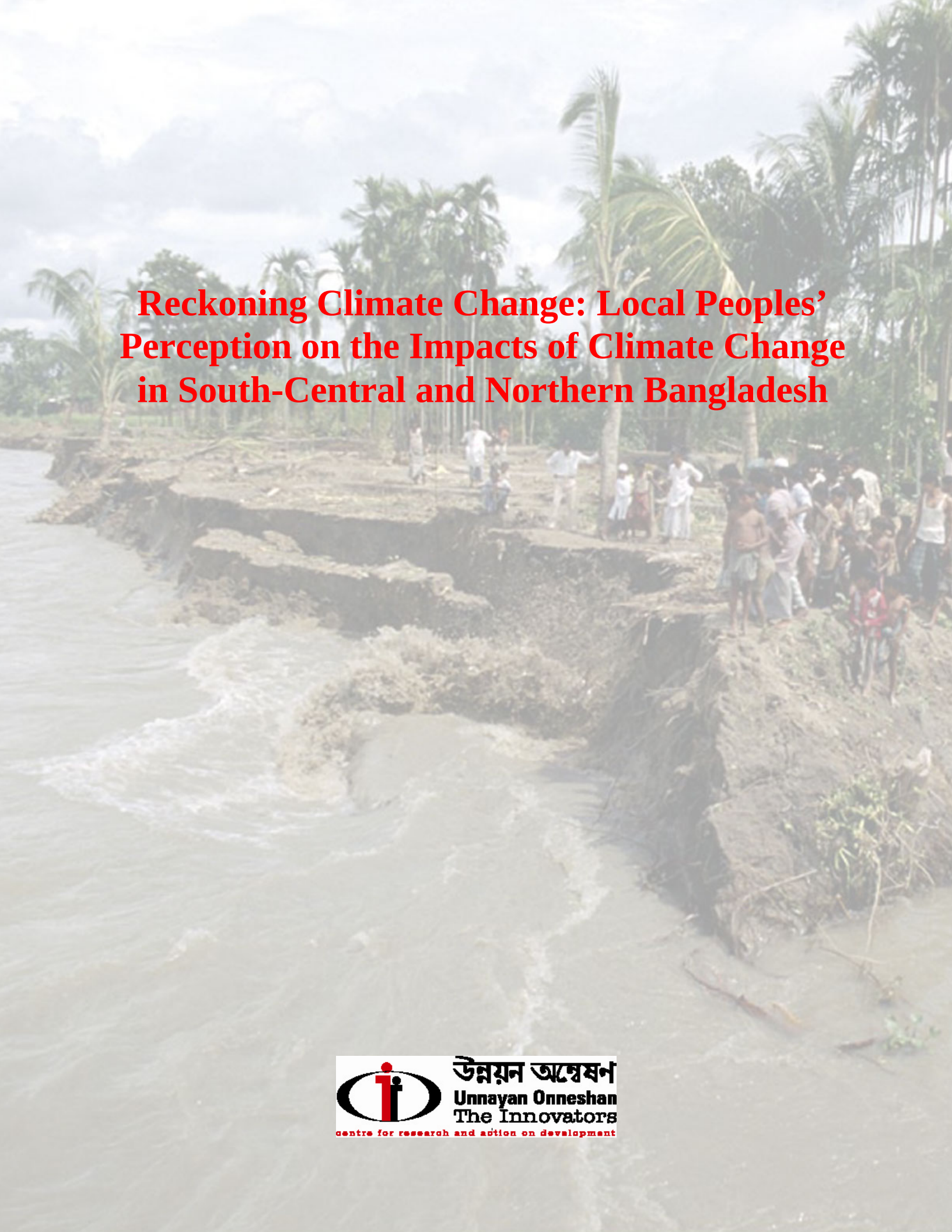

Reckoning Climate Change: Local Peoples' Perception on the Impacts of Climate Change in South-Central and Northern Bangladesh

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Unnayan Onneshan
The Innovators
centre for research and action on development

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Authors
Lubna Seal
Mohammed Abdul Baten

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For orders and request please contact:
Unnayan Onneshan - The Innovators
16/2, Indira Road, Farmgate
Dhaka-1215, Bangladesh
Tell: + (880-2) 8158274, 9110636
Fax: + (880-2) 8159135
E-mail: info@unnayan.org
Web: www.unnayan.org

Executive Summary

Rising temperature is likely to change precipitation pattern, the rate of evapo-transpiration that ultimately influences the distribution and availability of water. Agriculture, highly dependent on weather event, is particularly vulnerable to the change of these two factors. The agriculture in Bangladesh experiences multifaceted problem both in dry and wet season due to changes in water distribution and availability. Even though climate change affects different geographic locations, but charland is particularly vulnerable due to their geo-formation and lack of infrastructure to protect impacts of climate change.

Charland is formed of unstable sandy soil, characterized by continuous accretion and erosion process. Life and livelihood in charland is entirely dependent on weather; such exclusive dependency on natural environment makes the charland people most vulnerable to the impacts of climate change in northern and south-central region. In order to address the challenges posed by climate change and to find sustainable solution in agriculture and livelihood of charland in northern and south-central Bangladesh, the study intends to focus on the people's perception of the Gaibandha, Sirajgonj and Shariatpur to evaluate local knowledge for exploring the magnitude and impacts of different hazards namely flood, riverbank erosion, salinity intrusion, water scarcity in agriculture production. A predesigned semi structured questionnaire containing questions regarding agriculture, livelihood and climate change impacts was assessed to collect and analyze data. The empirical data was accompanied by existing literature for analyzing and constructing rigorous evidence on the issue.

Flood, more particularly river flood, is the most dominant hazard in the study areas. The study reveals that agricultural production of Sundargonj upazila of Gaibandha district appears to be the most flood victim. Moreover, the respondents identify riverbank erosion as the most commanding peril for agriculture in Kazipur upazila of Sirajgonj district. The impact of water scarcity existing in the three study areas, though still not at a critical level, results into a low flow condition of surface water due to higher rate of evaporation and withdrawal of water by upstream neighboring country. Under the circumstances, farmers become more dependent on ground water resources for irrigation propose. Therefore, it increases production cost due to the increased cost of water extraction. In addition, agriculture of Gosairhat upazila of Shariatpur, an interior coast, started experiencing salinity in dry season, though still not at the threatening level, will be detrimental in future due to sea level rise unless effective measures are taken based on thorough scientific assessment.

The collective impacts of climatic hazards on agricultural production results into reduced crop production, changed crop calendar, and crop variety and consequently exert pressure on livelihood and income of the people. The poorer especially the small and subsistence farmers, and daily agro wage labours are hit the hardest in most of the cases as they directly involve in food production activity and have a low withstand capacity in the altered situation when food production is hampered.

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1. INTRODUCTION

Bangladesh has unique physiographic characteristics that are distinctive by two salient features: a broader deltaic plain, prone to frequent flooding and a hilly region relatively small, comprises of swiftly flowing rivers. Around 80 percent of the total land is low-lying and composed by alluvial plain is known as Gangetic plain. Except the Chittagong Hill Tracts in the far southeast and Sylhet division in the northeast region, the topography is flat in the most of the cases and the average elevation is below 10 meters from the sea level. The elevation decreases to the sea level in the coastal south. The geographical location makes Bangladesh one of the most vulnerable countries to the consequences of climate change. Low elevation, abundant rivers, and marine climate make Bangladesh prone to climatic hazards like flood, sea level rise, tropical cyclone and storm surge etc. that undermines the development activities of the country. Recurring disaster is jeopardizing present gains and putting future developments at risk. The sectors that are extremely vulnerable at present and potentially at the risk of graving threat in future are, among others, agriculture, livestock and forest resources, human settlement, human health and biodiversity.

Agriculture and climate change possess an inverse relationship. Being the largest source of methane and considerable contributor of carbon-di-oxide, agriculture is held responsible for causing climate change. Conversely, climate change induced natural hazards mostly affect the agriculture sector. Moreover, weather dependency makes agriculture sector the most vulnerable in both production and distribution. Any changes in temperature and precipitation hamper certain crop productivity through disrupting the normal growing cycle.

Bangladesh is predominantly an agrarian country. Different scientific reports and popular perceptions signify Bangladesh's position as one of the worst victims of climate change due to its least capacity to withstand climatic shocks and sheer dependence on weather sensitive agriculture. Agriculture is practiced all over Bangladesh except few hilly areas. However, northern and central region is producing major share of country's total agro-production. Numerous rivers that cross this area endow the agriculture lands with fertile sediment carried from upstream deposited through regular seasonal floods. However, people of char land entirely depend on weather-sensitive agriculture, as they have no other means of livelihood. In this sense, flood is beneficial for agro-production. However, climate change has changed the scenario. Frequency and intensity of floods has increased many times. Moreover, temperature increase, erratic rainfall, water scarcity, salinity intrusion are other extreme weather events that affect these segment of the country at varying degrees. Climatic hazard induced agriculture production damage is aggravating and threatening food security.

1.1 Objective

To address the challenges posed by climate change and to find a sustainable solution in agriculture and livelihood of northern and south-central Bangladesh, Unnayan Onneshan (UO) along with three other national development organizations SDS[1], GUK[2], GKS[3] has started an action research project titled "Regenerative Agriculture and Sustainable Livelihoods for Vulnerable Ecosystems" (RESOLVE) in Sirajgonj, Gaibandha and Shariatpur districts with the financial assistance from Oxfam Novib. The current study is a part of RESOLVE programme, which intends to explore the magnitude and impacts of different natural hazards namely flood, riverbank erosion, salinity intrusion, water scarcity in livelihood system, more particularly agriculture in project districts. The study relies on local people's perception and understanding on climate change impacts in agriculture.

2. MATERIALS AND METHODS

A mixture of qualitative and quantitative techniques was used to collect and analyze data. Total 900 households were being selected by stratified sample technique from Gaibandha, Sirajgonj and Shariatpur districts (300 from each area) and were interviewed through a predesigned semi structured questionnaire containing questions regarding livelihood, agriculture, climate change impacts etc. The empirical data was accompanied by existing literature for analyzing and constructing rigorous evidence on the issue. Affected people's understanding on climate change and perception on the impacts have been assessed from the interview. While searching literature on impacts of climate change in northern and south-central areas, particularly study areas, a dearth of literature compelled to rely on ground data, rather than scientifically tested evidence. On the contrary, this limitation creates a window of opportunity of considering this study as important contribution for RESOLVE as well as country's climate change research profile.

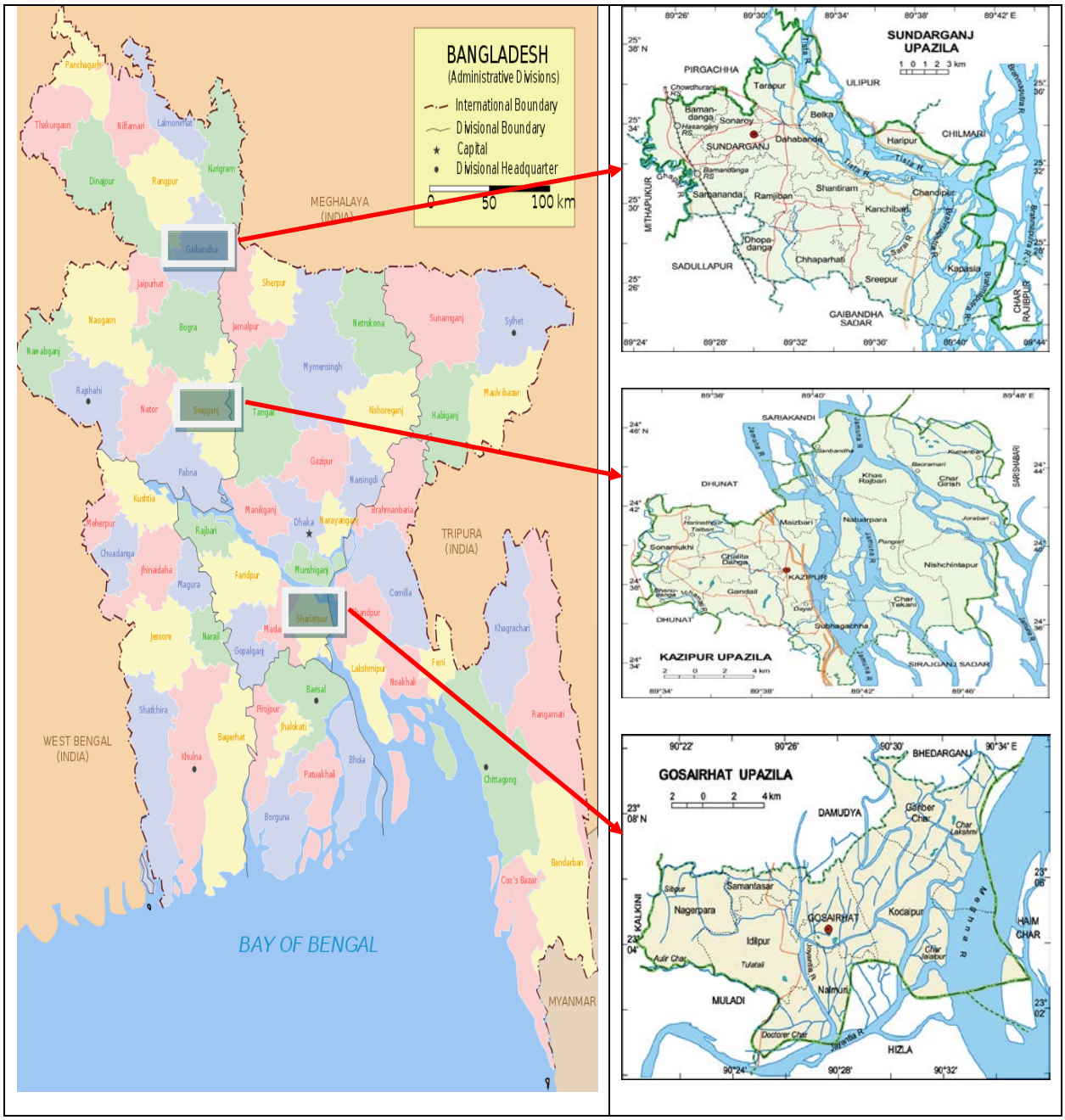
2.1 Study area

The study focuses some villages from different upazilas of Sirajgonj, Gaibandha and Shariatpur district, where agriculture is the main occupation. They are located in the flood plain formed with siltation carried by three mighty rivers Ganga, Brahmaputra and Meghna. Some parts of Gaibandha are located on Active Tista Floodplain (AEZ-2) and the area comprises of an uneven prototype of grey stratified, sand and silts. Eastern part of Gaibandha and Sirajgonj are situated on the Active Brahmaputra-Jamuna (AEZ-7) floodplain. The region encompasses the belt of unstable alluvial land along the Brahmaputra-Jamuna River and the land is continually being formed and eroded by shifting river channels. Some Eastern part of Shariatpur is located in the Low Ganges river floodplain (AEZ-12). The area includes the eastern half of the Ganges river flood plain, which is low-lying. The region has a typical meander flood plain landscape of broad ridges and basins. Most of the part of Shariatpur is formed in the Old Meghna

[1] SDS: Shariatpur Development Society
[2] GUK: Gana Unnayan Kendra
[3] GKS: Gono Kalyan Sangstha

estuarine floodplain (AEZ-19). The region occupies a large area, mainly low-lying between south of Surma-Kusiyara floodplain and north edge of the Young Meghna estuarine floodplain. The region comprises of smooth, almost level, floodplain ridges and shallow basin (BBS, 2004). These regions are specifically vulnerable to the impacts of climate change for their geographic location.

Figure 1: Map of the Study Area



Source: Adopted from Wikipedia (2007) and Banglapedia (2006)

2.2 Shariatpur

The study covers 300 households from different villages (Attached Char) of Gosairhat upazilla under Shariatpur District. The villages are Pach Kathi, Char Bhuiya and Kul Churi Patarchar and the main rivers are the Meghna and Jayantia. The average land elevation of the area is a little higher than the main sea level of Bay of Bengal. The district is dominated by monsoon climate. Having a close proximity to a couple of rivers and 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. Poorest communities are the most vulnerable and bear the burden of the impacts of climate change mostly.

2.3 Sirajgonj

The study covers 300 households from different Villages (Island char) of Kazipur Upazilla under Sirajgonj District. Kazipur Upazila, with an area of 368.63 sq km, is bounded by Dhunat, Sariakandi and Sarishabari upazila. The Jamuna River on the north, Sirajgonj Sadar upazila on the south, Sarishabari upazila and the Jamuna river on the east, Dhunat upazila on the west. The upazila is the most riverbank erosion prone area in the country. Many old inhabitation including Mallickpara, Dhulaura, Maijbari, Manik Patal, Kazipur, Meghai, Tarakandi, Tengalahata are gradually getting extinct by riverbank erosions. Jamuna-Brahmaputra Flood Protection Dam known as WAPDA Dam, built in the 1960 on the west side of the Jamuna could not help much to resist river erosion nor to control flood. Of course, it helped much in irrigation.

2.4 Gaibandha

The study covers 300 households from different villages (Attached Char) of Sundargonj Upazilla under Gaibandha district. Pirgacha, Ulipur and Chilmari upazila on the north, Gaibandha Sadar and Sadullapur upazila on the south, Chilmari and Char Rijibpur upazila on the east, Pirgacha, Mithapukur and sadullapur upazila on the west, bound Sundarganj Upazila, with an area of 426.52 sq km. Main rivers are the Tista, Bhramaputra and Ghaghat. Noted depressions are Kalsar Beel, Kumlia Beel, Nalbari Beel and Haldi Doba Beel.

2.5 Physical Vulnerability of the study areas to natural hazards

Gaibandha, Sirajgonj and Shariatpur experience river floods and rainfall floods almost every year. These areas, especially the study areas of Gaibandha and Sirajgonj, are probably the most flood prone areas in the country as they are located at the active Brahmaputra-Jamuna flood plain. The people face riverbank erosion and floodwater inundation during monsoon, which damage their homestead, livestock, agriculture crop, livelihood, drinking water availability, sanitation, health and above all total life system. Increased evapo-transpiration depletes the moisture from top soil, diminish organic matter from top soil and decline ground water level. The areas, Gaibandha and Sirajgonj, also suffer from heat wave during summer. From the last decade, a new natural hazard added to their suffering and that is cold wave. In addition to flood and riverbank erosion, Shariatpur also experiences salinity intrusion due to backwater effect during dry season.

The employment opportunity is very limited in char areas. The principal occupation is farming. Some households are engaged in raising cattle and harvesting fish. However,

land is the important resource but cannot be utilized fully in the char land because they lack of technical support, training, supply of materials and accessibility to the market. (HKI, 2003)

As rice is the staple food of the country, the most of the food grain lands in study areas are occupied for rice production. The production of rice is highly dependent on the arrival, withdrawal and magnitude of monsoon precipitation. Mirza (2001) recommends that both seedbed preparation and plantation of Aman rice, during kharif-II, depend on the timely onset of monsoon, normal rainfall and non-existence of high floods. He further adds that Broadcast rice can tolerate the rise of floodwater up to 5 cm/day, where as high-yielding Aman rice varieties are unable to keep the pace of growth with increasing depth of floodwater. On the other hand, the production of Boro rice hampers due to water scarcity in cultivation period and floodwater before or during harvesting period. Changes in seasonal pattern and resultant rainfall cycle disrupt agriculture production and make this area as one of the most vulnerable areas to climate change in Bangladesh.

3. CONCEPTUAL FRAMEWORK

Climate change is a hydro-meteorological event. Long-term change in weather distribution, mainly temperature and precipitation, is termed as climate change. Since the birth, global climate is continuously changing; therefore, many scientists argue that climate change is a natural phenomenon. However, the process has accelerated after industrial revolution since early nineteenth century, particularly indiscriminate emission of 'Green House Gases' from combustion of fossil fuel, trapping temperature and causing global warming. Intergovernmental Panel on Climate Change (IPCC) addressed such anthropogenic activities responsible for global warming and strongly argued that climate change is man made through couple of studies and simulations, results of those studies have been accentuated in their different reports.

Water resource is in the prevalent concern to the climate change at present as well as different scenarios; and the agricultural production is hindered by excessive water during the wet season and diminutive during the dry season (khan *et.al*, 2010). The availability and distribution of water resources is highly influenced by climate change. Rising temperature is likely to change the precipitation pattern, the rate of evapo-transpiration and the expansion of sea surface water as well. All these change affect agriculture in varying degrees and forms. The changed values of different climate parameters like temperature, precipitation and evaporation are bringing a massive change in the agricultural sector of Bangladesh. The study area is subject to water related hazards mainly arising from changed combination of precipitation and temperature.

In wet season, the climatic variability grounds the following type of water related hazard in the study areas:

I. Level of river water is likely to change during monsoon resulting inundation with high magnitude and intensity.

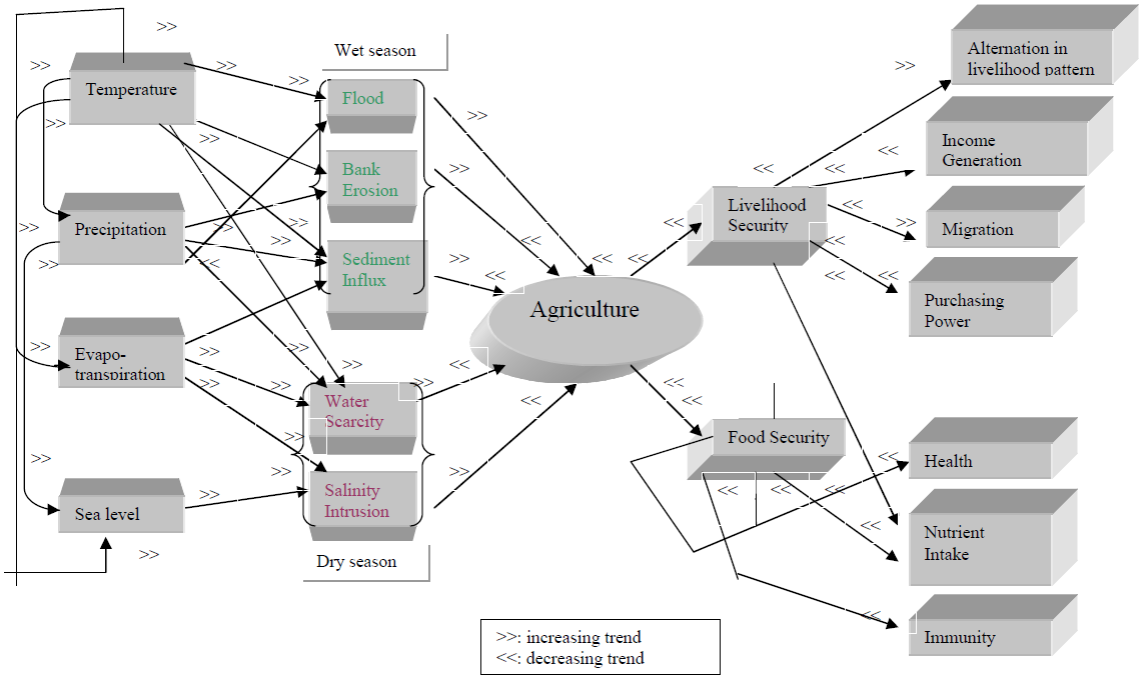
II. Accumulation of sediment in cultivable land during or after the withdrawal of flood.

III. River bank erosion is a predominating natural hazard in the study areas, especially in Sirajgonj and Gaibandha. Although no empirical data have been found so far to support the relation between the climate change and riverbank erosion, but its impact on agriculture is detrimental. However, flood may accelerate the occurrence to some extent. Therefore, flood with higher intensity and magnitude in the climate change scenario may exacerbate the occurrence.

Unlike the wet season, water related hazard during the dry season might occur in the forms of:

I. Depletion of ground water level and soil moisture from the top soil
II. Reduction of organic matter from the top soil
III. Inland salinity ingression by Low flow of fresh water and sea level rise.

Figure 2: Schematic diagram of climate change impacts on agriculture and livelihood system of study area



3.1 Causes of Flood

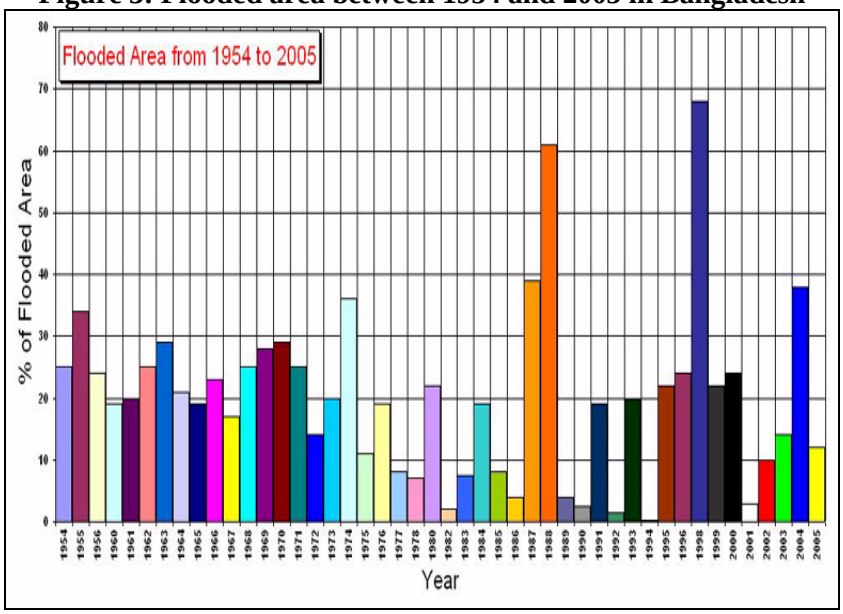
Bangladesh is formed at a deltaic confluence of the Ganges, Brahmaputra and the Meghna (GBM) Basin. The flood of the central and north-west part of the country is highly influenced by the GBM river system. Even though about 92.5 percent of the total Bengal Basin area is outside the country, the flow in Bangladesh depends on how much flow is generated in the upstream catchments of GBM Basin ((Mirza, 2001, CCC, 2009). To find out causes of flood, Mirza (2001) identified drainage congestion as the most important factor and argues that huge cross boarder monsoon runoff is added to Bangladesh's own runoff; therefore, the country is required to drain a combined runoff

through its own network of rivers. The amount of collective runoff often surpasses the capacity of its drainage system and makes Bangladesh one of the most flood prone countries in the world.

IPCC (2007)) argues that the reduction of snow cover and the mass loss of glaciers will likely to continue throughout the Twenty-first century. This will cause reduction of water availability, hydropower potential and also change the flow of seasonal water in the region situated in the downstream of major mountain ranges (Hindu-Kush, Himalaya, Andes), which is the present residence of one-sixth of the world population. The report further states that a large reservoir, which is formed by the storage of precipitation in the form of snow and glaciers, regulates water distribution to the downstream countries annually. Climate change is likely to disrupt the flow.

Global warming is likely to influence the characteristics of floods in many ways. Climate change is increasing monsoon precipitation and resulting increased peak discharges of the major rivers that may intensify the flooding problem in the areas. Mirza (2001) predicts that timing of flood incidence may change as there is a strong possibility of advanced and delayed onset or withdrawal of monsoon, and monsoon precipitation is likely to increase the duration of flood through changing in size, rate, intensity, and coverage. He also claims that the climate induced changing scenario will probably alter land usage pattern as well as crop calendar and crop variety dramatically by changing the nature of flood.

Figure 3: Flooded area between 1954 and 2005 in Bangladesh



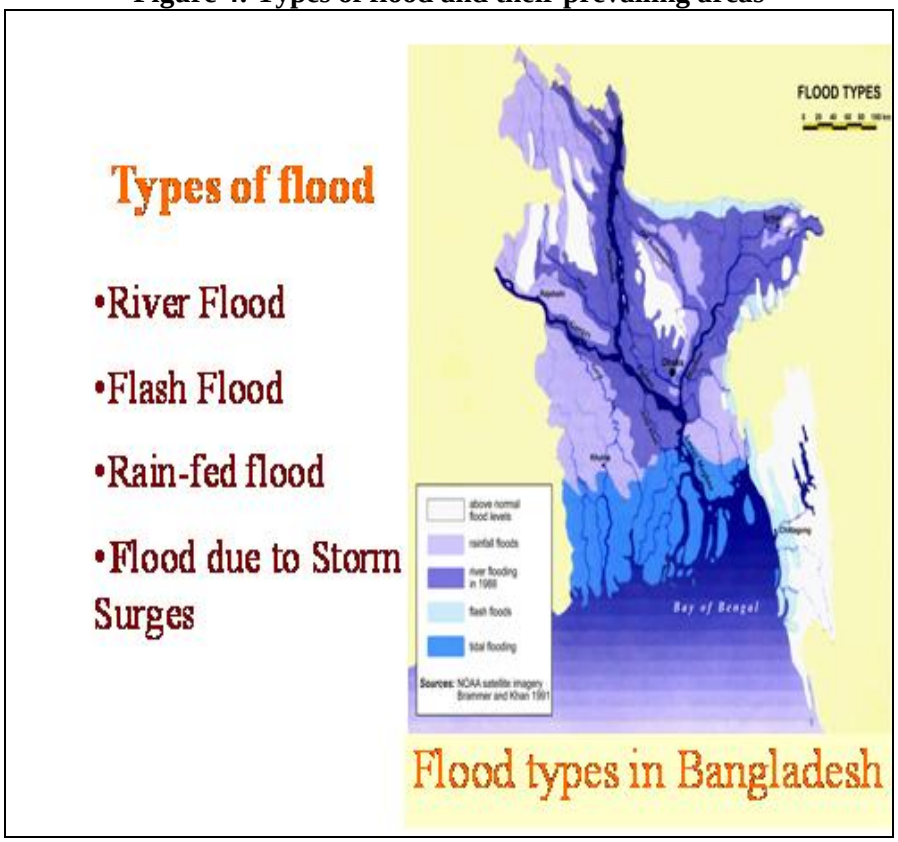
Source: Climate Change Cell, 2009

The table illustrates that flood area coverage increases to a large extent and it was the highest in 1998 followed by 1988, 1987 and 2004. Reflecting upon the table above, anyone can argue that flood is a common phenomenon from pre-historic time in Bangladesh, even before scientific evidence of climate change. Therefore, many scientists are skeptical to blame climate change for flooding. However, if we critically

analyze the causes of flood, it will be clearly visible that the magnitude and frequency of floods have increased in the last two decades with the onset of climate change. IPCC (2007) signifies the evidence by arguing that glacier stored in Himalayas are melting faster than before due to global warming, which is increasing runoff beyond drainage capacity of Hindu-Kush Himalayan rivers and contributing to increased occurrences of inundation.

Generally four types of flood occur in Bangladesh and they are i) Flash flood, ii) River flood, iii) Rain fed flood, and iv) Flood caused by cyclonic storm surges (figure 4). The project areas are particularly prone to river flooding as the study areas of Sirajgonj and Gaibandha are formed at the active Brahmaputra-Jamuna flood plain. Khan *et al.* (2010) identified Sirajgonj as the hotspot for river floods. Historically, these areas produce relatively high amount of crops than other parts of the country because every year river flood makes the land more fertile by caring organic matter enriched silt. However, climate change has altered the scenario. River flood has become a recurring phenomenon with a higher intensity in recent times, resultant from increased snowmelt in the Himalayas and torrential rainfall during the monsoon (Brammer, 2004).

Figure 4: Types of flood and their prevailing areas



Source: Climate Change Cell, 2009

Despite loss and damage of flood to lives and properties, flood is considered as a blessing for agriculture, for their fertile sediment deposition characteristics. Trend shows that Bangladesh received bumper production after every major flood. However, barren sand

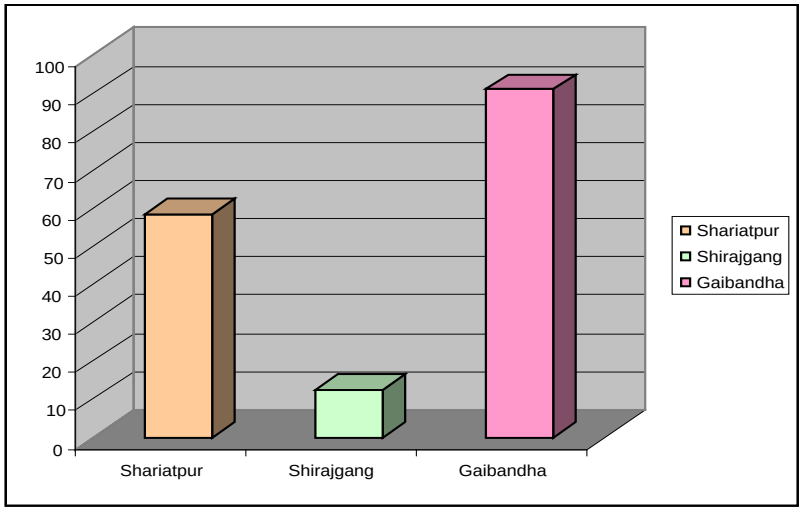
deposition in the productive agriculture land instead of fertile sediment through river water inundation is incurring huge loss to the farmers in recent times. They have to clear thick layers of sand for commencing future production from preventing the land to become permanently unproductive. Thus, the total production cost increases and puts the poor farmers into deeper vulnerability as a result. Increased deforestation in the upstream and withdrawal of water are responsible for barren sand influx, as hydrologists perceive.

3.2 Impacts of Flood

The impact of flood fluctuates depending on its intensity, magnitude and geographical location. In case of sector-wise impacts, the effect may vary depending on formation and physical settings. For instance, even though the impacts of flood in rural Bangladesh is evident, however, sectors like agriculture, human health, rural infrastructure are likely to be affected the most. Higher runoff, erratic rainfall, low drainage capacity creates devastating flood and affect agricultural production massively. The respondent in all the three study areas argue that whether flood is a blessing or curse depends on the depth and duration of flood. If the standing crops place well above the water level and this sort of inundation does not last more than the expected tenure, then it could be a blessing to them. In contrast, when the inundation continues more than the expected tenure and when the water depth is more than the optimal level, then flood turns out to be a curse. However, the respondents of each area argue that flood is no more a blessing for them for the last couple of years rather they find it as the major obstacle for agricultural production in their locality. More than 58 percent of the total respondents in Shariatpur agree that flood is the dominating hazard that in one hand creates problem in cultivation of Kharif crop and on the other hand damage standing Robi crop before or during the harvesting period. Flood is a prevalent natural hazard in Sirajgonj from time immemorial. Khan *et al*. (2010) identify Sirajgonj as the hot spot for river flood and Kazipur Upazilla (RESOLVE project area) as the most river flood prone upazilla not only in the district but also in the whole country. It signifies how severely the project area is exposed to flood. In the char land under the study areas of Khas Rajbari in Kazipur upazila, the homesteads have been found in the higher available land or they elevate their homesteads further on built-up plinth to protect them from annual inundation. Therefore, they can secure their land from normal flood; however, this practice cannot protect their homestead from moderate to severe flood. The char dwellers are more vulnerable than the mainland dwellers, more specifically the island char dwellers that are even more vulnerable than the attached char dwellers in terms of inundation of crop, homestead and cultivable land. Moreover, they experience a negative economic outcome as they sale their cattle in a premature stage and at a lower price prior to monsoon. According to the respondents, every year flood causes a huge damage to the infrastructure especially sanitation and spread diarrhea and other water borne diseases. However, the respondent argues that riverbank erosion is more dominant a natural hazard that poses a massive damage in agriculture sector. The respondent claims that they practice their traditional knowledge to address hazards induced from flood. They design their crop calendar based on local knowledge in such a way that they can avoid the impact of flood to some extent. Therefore, an insignificant percentage (0.7 percent) of the total respondents claims that changes in crop calendar take place. However, the reduction of crop production is detrimental according to 80 percent of the total respondents in Sirajgonj due to riverbank

erosion, which washes away standing crops and inundates the cultivable land and no local knowledge is sufficient enough to withstand against a hazard like riverbank erosion.

Figure 5: Percent of respondent blaming flood as obstacle for agriculture in the study areas



Source: Unnayan Onneshan field survey, 2011

Gaibandha can be considered as the worst flood affected area among the three project areas according to the opinions of the interviewees. The respondents consider flood as the most significant obstacle for agricultural production. Of the total respondents, 91 percent reports that flood causes land inundation, sand deposition, results a major hindrance in the agricultural production and late withdrawal of floodwater create a severe hindrance in the agricultural production, particularly obstructs the starting of cropping in due time.

3.3 Causes of River Bank Erosion

Erosion of riverbank is a natural phenomenon because it changes its course in alluvial plains. It is normally a slow onset and localized process but tend to gets severe and frequent during flood.

Upper riparian country has speeded up deforestation as a means of its increased dependency on the natural forest resources to keep pace with the increasing demand of food, shelter and fuel for a rapidly growing population. Deforestation in the upstream increases erosion and consequently deposition of sediment in the downstream riverbed carried through current. Since monsoon precipitation has increased due to climate change, soil erosion from deforested area increased along with landslides. The eroded soil ultimately is deposited in the riverbeds of downstream regions like Bangladesh. It changes the level of riverbed and thus results into decreased river gradient. Decreased river gradient accelerates the process of sediment deposition at riverbeds as it makes the slope of the flow less steeper. A raised riverbed cannot hold the expanded volume of precipitation and gets wider on both side and consequently riverbank erosion increases.

The flood plain and the Char land, less compact land formation, are very exposed to the riverbank erosion as these parts of the country that are formed with soft silt soil. Ahamed

(2006) reports that wave action and river current creates new underground channel, shifts channel direction and ultimately flops the riverbank.

3.4 Impact of River Bank Erosion

Riverbank erosion is omnivorous in affect. It swallows land, settlements, crops, everything within a blink of eye. Riverbank erosion differs from other disasters when damage structure is concerned. Flood, cyclone or other disasters have huge damage potentiality, but still there is some retention. Moreover, by appropriate preparedness the extent of loss and damage can be reduced in case of those disasters. But bank erosion only leaves awful memories of lost lives and properties. In no time, rich landowners become landless beggars.

Sirajgonj is predominantly an erosion prone area. The area is particularly under the constant threat from the mighty river Jamuna. The river is found widening along the both banks in Sirajgonj and causing people displaced from their own settlement at a high rate. By analysing erosion and accretion data of Jamuna from 1973 to 2009, CEGIS (unpublished) found that during this time the highest land loss has occurred in Sirajgonj due to bank erosion. During the period, the highest erosion occurred in Sirajgonj district with 22,400 ha eroded area, whereas the accreted area is only 2,410 ha. Overall eroded area is 90,830 ha; in contrast accreted area is only 10,140 ha (Table 2). The estimated land loss is the highest in Sirajgonj, which signifies that active Brahmaputra-Jamuna flood plain is rigorously exposed to riverbank erosion.

Table 1: Bank Erosion along the Jamuna River during the Period 1973-2009

District	Eroded area (ha)	Accreted area (ha)	Total loss of land
Kurigram	18,510	40	18,470
Gaibandha	9,220	920	8300
Jamalpur	11,810	4,880	6930
Bogra	10,500	1,880	8620
Sirajgonj	22,400	2,410	19990
Tangail	10,920		10,920
Pabna	1,770		1,770
Manikgonj	5,700	10	5690
Total	90,830	10,140	80,690

Source: Adopted from CEGIS (unpublished)

The riverbank erosion in Kazipur upazila under Sirajgonj district is very detrimental. Around 72 percent of the total respondent agrees that it is the major obstacle for their agricultural production. There understanding is also constant with statistics, where it is found that between 1961 and 1981, total 4784 ha of land eroded due to bank erosion (Elahi, 1989).

Table 2: Total eroded area in Kazipur Upazila from 1961-1981

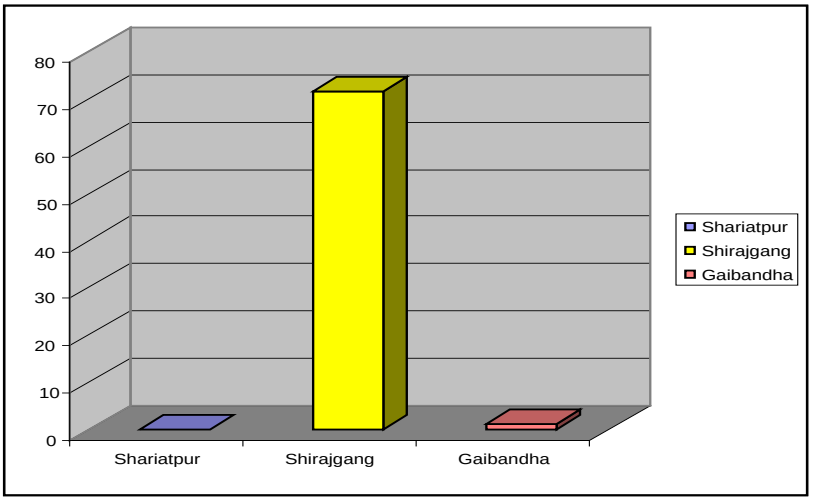
Area eroded (ha)	Area accreted (ha)	Net eroded area (ha)
6978	2194	4784

Source: Adopted from Elahi, 1989

The study areas of Sirajgonj are the char lands, located at some villages in Khas Rajbari Union under Kazipur Upazila. The char lands are highly erosion prone. The intensity of erosion differs in different char lands based upon the dynamics of river as well as other characteristics like variation in water level, velocity of flow, supply of sediment etc. (Sarker, et. al., 2003). Bank erosion is the most severe natural hazard for the char dwellers. However, the chars emerged from the Jamuna river are more prone to bank erosion than any other chars. The river, dynamic in nature with one of the largest braided river in the world, has direct impact on the agriculture and livelihood of char dwellers. Sarker, et.al., (2003) predicts that the char emerges from the Ganges, Padma and Lower Meghna rivers are more stable than the chars in the Jamuna river, whereas, the chars in upper Meghna is the most stable among all of them. He further argues that 40 percent of the total char lands in Jamuna preserves, where as the dwellers of 60 percent land are to migrate once or more than once within six years. The chars in Khas Rajbari under Kazipur upazila is at the gravest threat from the bank erosion of the Jamuna River in the recent years.

As a whole, Gaibandha is under high risk of riverbank erosion, but Sundarganj is experiencing less damage from bank erosion in recent years. The local people also identify riverbank erosion as less frequent threat to their agriculture production system (figure 6).

Figure 6: Percent of respondent blaming riverbank erosion as obstacle for agriculture in the study areas



Source: Unnayan Onneshan field survey, 2011

Depending upon past trends CEGIS conducted a study on riverbank erosion to draw future scenarios and reports that river erosion is closely interlinked with peak discharge. It finds a direct relationship between peak discharge and bank erosion in Brahmaputra River depending on historical data from 1973 to 1999 and claims that increase in discharge accelerates erosion. Using CCRNIESB-2 model, they predict the erosion level for the year 2050 report that a 10 percent increase in discharge may cause 20 percent increase in bank erosion on an average, when the existing situation of river bank along the Brahmaputra-Jamuna remain unchanged.

Shariatpur also experiences riverbank erosion, but not as severe as Sirajgonj (figure 6). In Sirajgonj, huge cultivable land goes under river every year. Even though a considerable area has been accreted over the years, but the new accreted land takes a certain period, in most cases 10 or more years, to attain full productivity, where as the lost land in maximum cases was cultivable agricultural land. Therefore, reduction of cultivable lands ultimately reduces agricultural production and force people to change their livelihood pattern as well.

3.5 Causes of Water Scarcity

Himalayan glaciers that nourish Ganges and Brahmaputra by ensuring water supply around the year now face deglaciation at a higher rate as a response to global warming. Probably this phenomenon will create a huge crisis in fresh water supply in the near future. The consequences of deglaciation are likely to result a huge precipitation during monsoon as they are melted by the increased temperature impacted by global warming and creates huge drainage congestion in the downstream region. However, increasing rate of glacier melting will lead to a reduction in their total mass and ultimately they will produce less precipitation during winter resulting water scarcity. It has been found that Gangotri glacier, the origin of the river Ganges, is retreating at a rate of 23 meters/year (Hasnain, et al. 2004 cited *in* Shilpakar, et al., 2009).

The media report of BIPSS (2008) states that around 80 rivers are near to die whereas 100 others have already changed their normal distinctiveness because of the withdrawal of water by upstream neighbouring country using dams and barrages during winter.

Water resource has been identified as the most susceptible sector exposed to climate variability in Bangladesh (Khan, et. al., 2010). The country is predominantly vulnerable to water related hazards and the reception of too much water during wet season and of inadequate amount during dry season hampers normal functionality of lives, agriculture, and other important sectors.

Water scarcity is a natural hazard take place during pre monsoon and post monsoon. The problem gets overstated when the rate of evapo-transiration from both top soil and surface of fresh water bodies increases. It has been predicted that evapo-transpiration will increase to a certain extent during pre-monsoon and post monsoon seasons under climate change scenario (CCC, 2006).

The agricultural sector in Bangladesh, irrigation to be specific, shares the largest percentage of fresh water followed by domestic demand. In Bangladesh, irrigated rice production has been practiced from the last three decades. The total irrigated area was 5685.41 thousand hectares (BRRI, 2003) and Boro rice is the principle irrigated crop in Bangladesh which occupy 68 percent of total irrigated area (BRRI, 2003).

Irrigation process hampers during low flow condition, particularly in Rabi crops that grows in winter season. Farmers depend on ground water under such a condition, however, the level of ground water declines because of over exploitation for both agricultural and non-agricultural purposes. (Karim, *et al*., 1999).

Both temperature and precipitation regulate the availability of water resources. A warmer winter and a hotter summer with a prominent increase in both maximum and minimum temperature has been observed over the last couple of decades. Extreme temperature along with heat wave quiet often increases the rate of evapo-transpiration from both surface water and top soil during summer, where as a substantial reduction at the moisture level in atmosphere results an increased rate of evapo-transpiration to intake moisture from surface water and top soil.

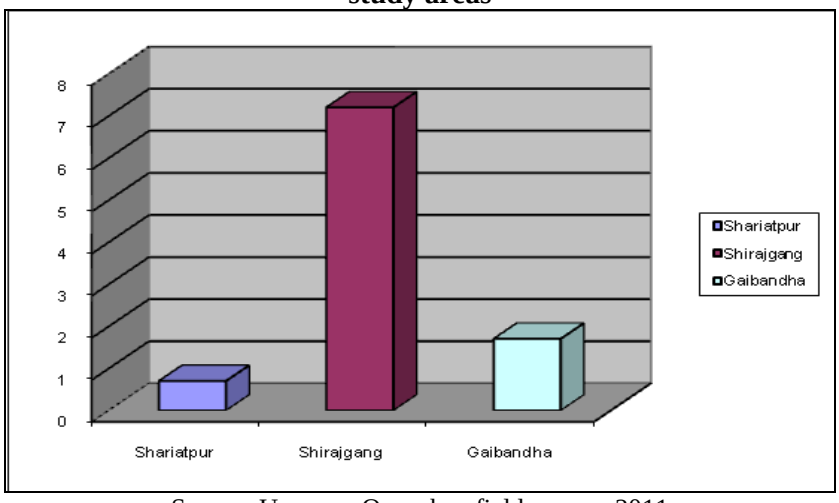
On the other hand, Ahmed and Alam (1999) predict that winter rainfall is likely to decrease in future. In addition, the rate of decomposition of organic matter from top soil is likely to increase with the increase of surface temperature. The content of organic matter in the study areas is low, ranging from low (1-1.7%) to medium (> 1.7-3.5%). (Karim, *et al*.,1999). When the organic matter declines below the critical point, water scarcity problem would even be aggravated because the water holding capacity of soil will deteriorate in absence of sufficient organic matter.

3.6 Impacts of water Scarcity

The study areas either are located in the island char or attached char. Moreover, they are situated near the mighty rivers of Jamuna and Meghna. Therefore, there is an abundance of water in the wet season. In dry season, a low flow condition prevails but does not tend to water stress along the bank proximate villages. However, the villages in interior char land may depends on ground water for both drinking and irrigation purpose.

Water scarcity creates pressure over crop production during pre monsoon and post monsoon period according to the opinion of interview in Sirajgonj. More than seven percent respondents of Sirajgonj argue that water scarcity is an increasing warning for their crop production (figure 7). According to them water stress arises when they do not provide irrigation during dry season because of financial constraints or during the seedling period when there is a late arrival of monsoon.

Figure 7: Percent of respondent blaming water scarcity as obstacle for agriculture in the study areas

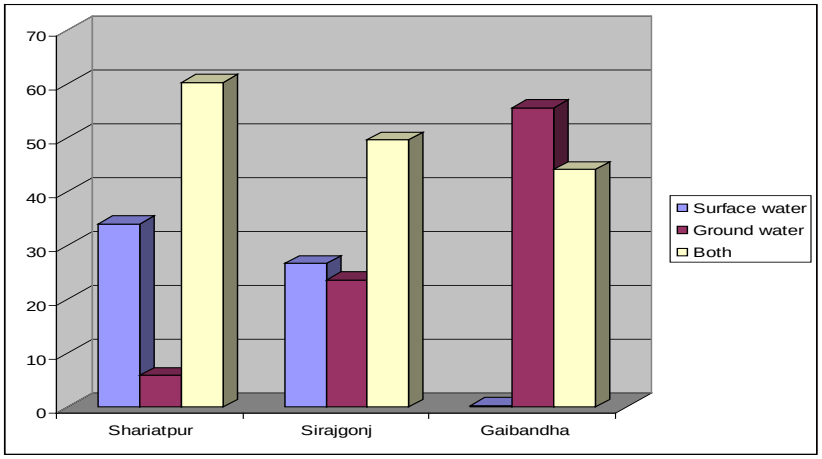


Source: Unnayan Onneshan field survey, 2011

The respondent of Gaibandha argues that High temperature increases the rate of evapo-transpiration from top soil and decreases moister availability at the root zone of crops. Empirical data shows that the 56 percent of total households extract ground water for irrigation in Gaibandha. Dependency on ground water shapes their response on water scarcity. The extraction of ground water is likely to increase crop production cost and therefore, put extra financial burden to the small landholders and poor farmers.

Among the project areas, dependence of surface water is the highest in Shariatpur (Figure 8). They use drinking water from shallow tube well; however, the presence of salinity in both surface and underground water makes it incompatible for drinking purpose. Therefore, they need to carry drinking water from the distant deep tube wells. Moreover, during dry season they irrigate using surface water from the nearby water bodies that are actually tidewater from the Meghna River with the presence of salinity. Therefore, according to them, during dry season they experience fresh water scarcity for both drinking and irrigation purpose.

Figure 8: Percent of respondent regarding the dependency of different source of water in the study areas



Source: Unnayan Onneshan field survey, 2011

Crop production is dependent on sufficient and timely rainfall. The study finds that T-Aman is affected by untimely and insufficient rainfall at reproductive stage during the month of October in the project areas, where soil's organic matter content is usually low and thereby water-holding capacity is low. On the other hand, Rabi crops such as HYV Boro, potato, wheat, pulse etc. are particularly suffering from water stress due to growing pattern in dry season and reduced rainfall due to climate change.

3.7 Causes of Salinity Intrusion

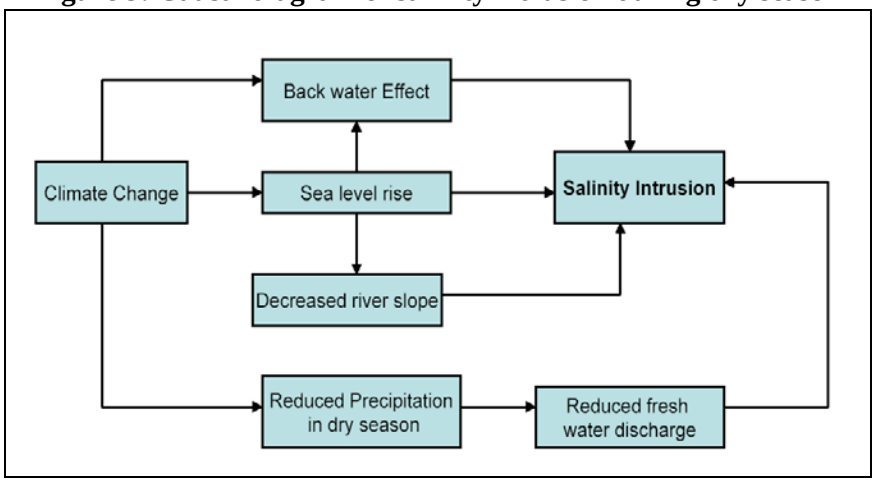
Salinity intrusion might be the worst damaging event for coastal Bangladesh, resulting from Sea Level Rise (SLR). Different climate change scenarios warn that Bangladesh will experience Sea Level Rise of 10 cm by 2020, 25 cm by 2050 and 1m by 2100, which will overrun 2-17.5 percent of its total land by sea water (WB, 2000), and thereby incur significant amount of crop yield lose every year including loss of other properties. Even though affect of salinity intrusion in lives and properties are evident but the focus remains in coastal regions still. However, salinity has started to affect along the Meghna estuary.

Unlike coastal region, in the Meghna estuary salinity is a slow onset and causing mainly due to Back Water Effect (BWE).

BWE is an estuarial phenomenon, particularly in the Meghna river estuary as 90 percent of the total river water discharges into the Bay of Bengal through it. The effect may occur when the river outflow get retarded at the mouth of the river by the rise of sea level at the estuary of the river (Ali, 1999). Khan, *et. al.* (2010) argue that the higher sea levels reduce the river gradient. It may cause salt intrusion in the south central part of the country in one hand and it worsens the flood condition of this part of the country and contributes to continue the accumulation of floodwater into the area with increasing length and depth on the other hand.

Karim and Mimura (2008) report that BWE became prominent after constructing water polders along with sluice gates during 1960. The polders were built to control the flow of river, to prevent low-lying agricultural lands from tidal inundation, and to protect saline water intrusion. They further states that the silt started depositing at the bed of the river causing rise of the level of river bed after the polders' construction and ultimately the empoldered areas got permanently water logged, since the sluice gate blocked the outpoint. According to them, water logged area has extended into the main agricultural land of the Ganges tidal plain with the coverage of 1500 Km². They predict that saline water ingression into inland will be continuing and aggravating with cumulative effect of SLR and unnecessary dams.

Figure 9: Causal diagram of salinity intrusion during dry season



The flow chart illustrates the potential causes of salinity intrusion, especially in the estuarial region in Bangladesh.

It has been predicted that the sea level rise will continue throughout, and Bangladesh will be one of the worst victims of SLR (IPCC, 2007). By analyzing historical data, SAARC Meteorological Research Centre (SRMC) finds evidence of sea level rise in different parts of Bangladesh (table 4). Sea level rise reduces slope of discharging water at the mouth of the river, especially in the estuaries. Ali (1999) predicts that the river slope is likely to decrease due to sea level rise. He reports that the slope of the Meghna River to its mouth is 1.136 cm/km in 100 km inland close to Chandpur district. Using a high

scenario of one meter sea level rise, he predicts that the river slope will decrease by 0.136 cm/km and result salinity intrusion in inland.

SAARC Meteorological Research council made a trend of sea level rise in the tidal station based on 22 historical data.

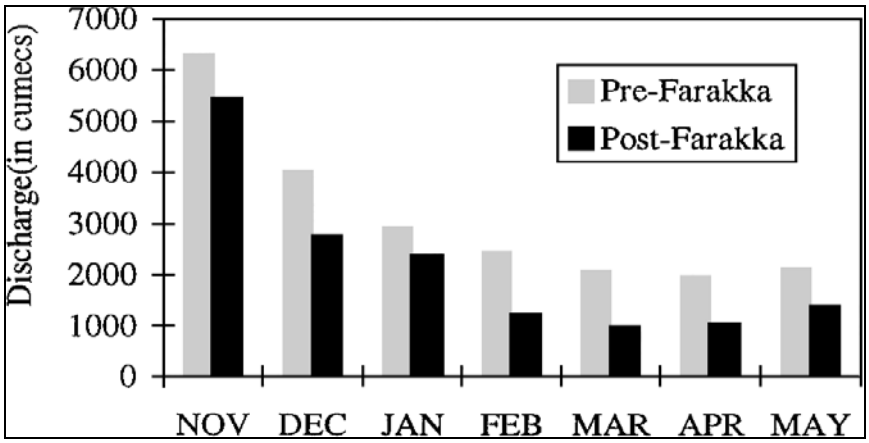
Table 3: Trend of tide in the three coastal stations

Tidal Station	Region	Latitude (N)	Longitude (E)	Datum (m)	Trend (mm/year)
Hiron Point	Western	21°48´	89°28´	3.784	4.0
Char Changa	Central	22°08´	91°06´	4.996	6.0
Cox's Bazar	Eastern	21°26´	91°59´	4.836	7.8

Source: SMRC; cited *in* Rahman and Alam, 2003

Mirza (1998) reports that a significant decline of water flow in the Ganges River in dry season has been observed during post Farakka period. This causes a low flow condition in the river Padma ultimately reduces the mean monthly discharge to the lower Meghna. This kind of human induced phenomenon exacerbates ingression of salinity in the interior region of the country especially in the Meghna estuarial region.

Figure 10: Mean monthly discharge of the Ganges River in dry season (November-May) during post Farakka period at Hardinge Bridge in Bangladesh.

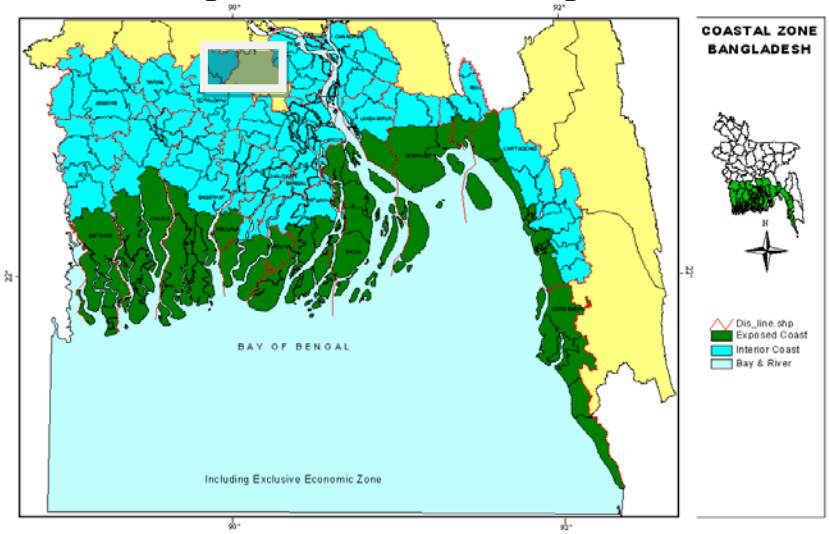


Source: Mirza, 1998

Fresh water reduction, resultant from the less precipitation, during dry season also accelerates inland salinity intrusion. Rahman and Bhattacharia (2006) argue that during dry season, when there is less precipitation, the peak discharge reduces and causes salinity towards inland and it intrudes up to 150 km inland; 290 km up in the southeast (lower Meghna) and the southwest (Passur River) part of the country. They further show that inland salinity starts during November and reaches maximum level during March-April.

Shariatpur district, an interior coast, is already experiencing salinity intrusion (Fig 11). SRDI (2001) finds trace of salinity in surface water of Shariatpur less than 1 ppm (table 5).

Figure 11: Coastal zone of Bangladesh



Source: Islam, 2004

However, the current salinity rate would be higher as salinity intrusion is closely interlinked with sea level rise and sea level is gradually rising throughout the last few decades. No systematic research so far has been carried out to measure the level of present inland salinity in Shariatpur district. Under such reality, Unnayan Onneshan has started a research to know the current salinity level of surface water and soil of Shariatpur and its impact on agriculture.

Table 4: Salinity levels in ppm in 19 coastal districts in Bangladesh

District	Surface water	Soil
Bagerhat	5->10	4->15
Barguna	1-5	4->15
Barisal	0	0-4
Bhola	1-10	4->15
Chandpur	<1	0
Chittagong	0-<1	0-8
Cox's Bazar	<1	>15
Feni	0-10	0-15
Gopalganj	<1	0-15
Jessore	<1	4-8
Jhalokati	<1	4-8
Khulna	5->10	8->15
Lakshmipur	<1	4-8
Narail	0	<4-8
Noakhali	<1-10	0->15
Patuakhali	1-10	8->15
Pirojpur	0-10	0-15
Satkhira	5-<10	4-<15
Shariatpur	<1	0

Source: SRDI, 2001 cited *in* Rahman and Bhattacharya, 2006

3.8 Impacts of Salinity intrusion

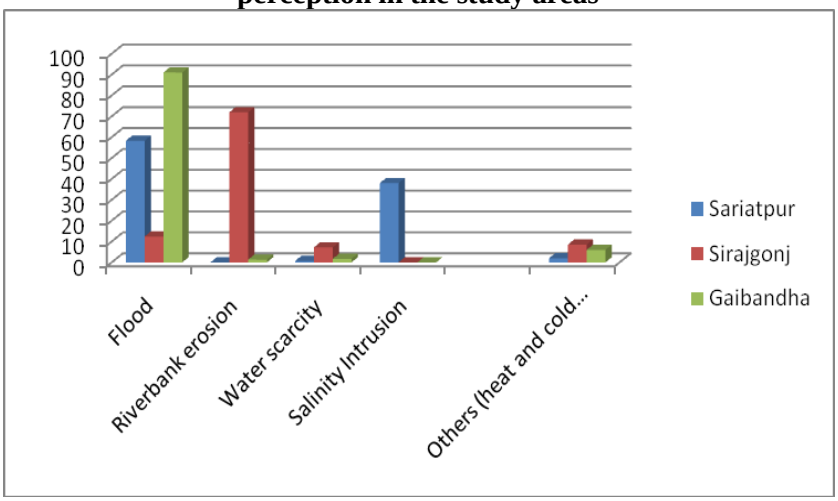
Among the three study areas, Shariatpur is prone to salinity intrusion. A significant percentage of respondents agree that salinity intrusion poses a new challenge to the agriculture in the locality. Salinity intrusion is a slow onset and takes couple of years to be apparent, however, the impact is already visible in the study areas of Shariatpur.

Approximately 38 percent of the total respondent agrees that the decline of crop production in dry season is detrimental. According to them, the percent of yield fall almost half compared to the yield of four to five years back. A sharp decline in the production of boro rice has been observed for the last couple of years. As for example: the yield of boro rice is around 0.25 MT from 40 decimal of land in recent years, whereas it was 0.6 MT in five years back from the same land area according to the opinion of one house hold head who depends on agriculture for livelihood. The respondent argues that the height of the plant is also reduced to a considerable extent. The average height of boro rice plant was around 2.5 feet in the previous years. However, from the last four to five years the height reduced to 1.5 feet in an average. The size of the yield of ladies finger has also reduced remarkably. According to the respondent, the maximum average of ladies finger was seven (7) inches in three years back, while in recent years, the maximum average size has reduced to four (4) inches and minimum average has become two (2) inches. They argue that the size of chili got reduced as well and from last four to five years, it turns from two inches as maximum average and one inch as minimum average. The cumulative impact in agriculture by salinity intrusion in dry season is massive. Unless effective measures are taken based on thorough scientific assessment of salinity level, the area would experience enormous loss in properties in near future.

4. LOCAL PEOPLES' PERCEPTION ON CLIMATE CHANGE IMPACTS

Local people as well as existing literature identifies flood, a consequence of drainage congestion, as the most dominating natural hazard in RESOLVE project area; however, agricultural production of Gaibandha appears as the most flood victim from opinion of the interviewee. Moreover, the respondents of Sirajgonj identify riverbank erosion as the most commanding peril for agriculture and most erosion, according to them, take place during the course of strong flood flows. Though, bank erosion can also occur in dry season and not only confined in monsoon (Brammer, 2004), however, Flood induced bank erosion is more frequent in the study areas of Sirajgonj. The impact of water scarcity, though still not significant, has high potentiality to impose a momentous impact in future. Salinity intrusion in Shariatpur, an interior coast, has already started putting impact on agriculture.

Figure 12: Overall climate impact on agricultural production based on the people's perception in the study areas



Source: Authors' calculation from Unnayan Onneshan field survey, 2011

Sediment influx has appeared as one of the problems of Sirajgonj and Gaibandha. Historically, agriculture of Sirajgonj and Gaibandha is endowed with flood induced sedimentation and farmers used to receive higher production after any flood. However, the trend has changed significantly in recent years. Rather than boosting agriculture production, sedimentation loaded with barren sand is occupying productive land and the whole land turn into barren as a result unless the sand is manually removed. People living in chars of Sirajgonj and Gaibandha consider this sediment influx in their productive land as curse of their mischief, therefore very few of them identifies this is as a problem for their agriculture.

Bangladesh enjoys a tropical monsoon climate. However, extreme heat and cold wave is often observed during summer and winter, particularly in the north and northwestern part of the country. The average temperature of summer is showing an upward trend, with increased number of heat waves due to climate change. Generally, winter in Bangladesh is mild and the days are short with dry and fresh weather. However, severe cold wave along with dense fog has been observed in Bangladesh, particularly in central and northern part, over couple of years. The coldest season of the country is January with 10 degree Celsius as an average minimum temperature. Such fluctuation of temperature disrupts physiological cycle of crops and reduce yield. Each stage of crop production has its own threshold and critical level of temperature. Any deviation from the range may cause a severe damage at any stage of crop production (table 6). Sirajgonj and Gaibandha are particularly delicate to the hazard like temperature fluctuation, since these two areas are observing high temperature during summer and very low temperature during winter. Local people notices temperature fluctuation as detrimental to their agriculture production. They argue that their traditional knowledge on temperature and crop season cannot result into good practice in recent years. Over the last few years, heat waves hit harvesting stage and cold wave hampers seedling stage of *Rabi* crops resulting considerable yield loss. They do not know how to get rid of such problems or why nature is behaving abnormally.

Table 5: Critical temperature at different stage of crop production

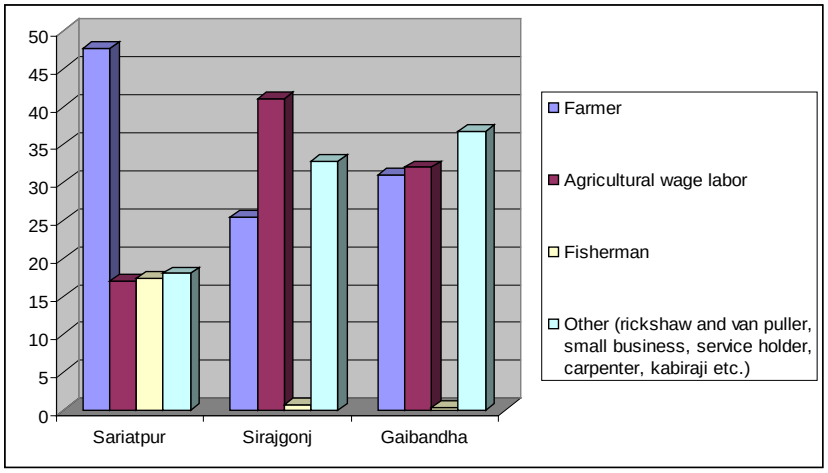
Growth stages	Critical temperature (Degree Celsius)		
	Low	High	Optimum
Germination	16-19	45	18-40
Seedling emergence	12	35	25-30
Rooting	16	35	25-28
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Initiation of panicle primordial	15	-	-
Panicle differentiation	15-20	30	-
Anthesis	22	35-36	30-33
Ripening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

Source: Yoshida, 1978

4.1 Impacts of climate change on livelihood and food security

Climate change is contributing to reduce crop production, erode cultivable land, restrict accessibility to common property resources like forestry and fisheries because of their depletion; which force the small holder and subsistence farmers not only to alternate their livelihood pattern but also decline income considerably. In most of the cases, the poorer are the extreme sufferer, especially those who directly involve in food production activity and those having low withstand capacity in the alternative scenario when food production is hampered.

Figure 13: Existing livelihood pattern among the households based on opinion of the respondent of the study areas



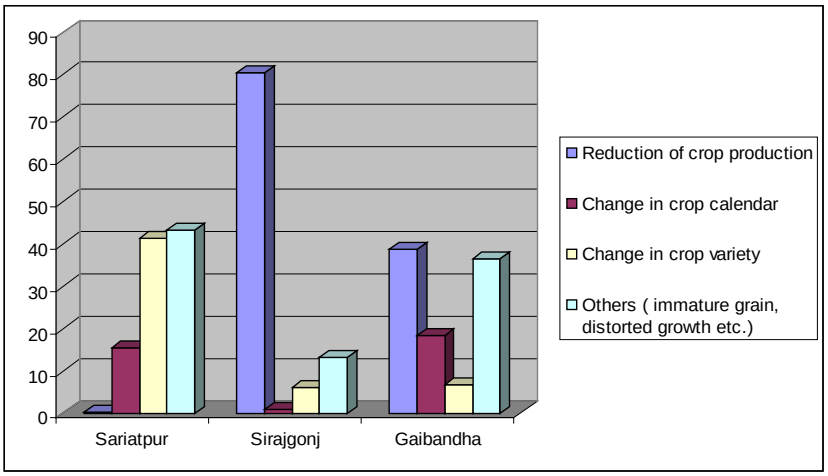
Source: Authors' calculation from Unnayan Onneshan field survey, 2011

The study shows that 47.7 percent population of Shariatpur directly depends on agriculture for their livelihood and more than 17 percent is engaged in agriculture as wage labour. Therefore, alteration of agro-production due to climate change will disrupt the livelihood of majority of the people, and consequently the food security will be worsened. Similar scenario prevails in Gaibandha, where 31 percent households are directly involved with agriculture and another 32 percent maintains their livelihood by engaging themselves as wage labourer in agriculture sector. In case of Sirajgonj, share of agriculture occupants is 25.5 percent whereas 41 percent people are day labourers in

agriculture sector. In RESOLVE areas flood, bank erosion, water scarcity and temperature fluctuation as consequences of climate change, are damaging standing crops, changing the crop calendar and resulting into food insecurity. The collective impacts of climatic hazards on agriculture make a drastic decline in their livelihood pattern and force them to alter their livelihood pattern.

A failure in crop production and changes in crop calendar including crop variety reduce employment opportunities in agriculture sector. Unemployed small landholders and day labourers will have a low access to food and suffer from seasonal hunger. Local people of RESOLVE areas claim that an ample reduction of crop production already took place in recent years due to various natural hazards. In Sirajgonj, 80 percent people states that the main problem they face in agriculture is reduction of crop production, which is incurred from riverbank erosion. On the other hand, 39 percent people of Gaibandha identify reduction of crop yield as their main problem in agriculture sector. They also notice immature gain, distorted growth as some other major problems that hamper agro-production. However, 41 percent people of Shariatpur are forced to change their crop variety due to climate change (Figure 14).

Figure 14: The impact of climate change on food security based on the opinion of the respondent in the study areas.



Source: Authors' calculation from Unnayan Onneshan field survey, 2011

Reduction of livelihood options and food insecurity cause a poor nutrient intake of the local people, which will lead to a poor health and lessened immunity. In case of permanent inundation of cultivable land or loss of lands and settlement by bank erosion, people are forced to migrate from their origin. Often they migrate to urban areas, seeking for livelihood option, and thus create pressure on urban utilities and undermine the national development process.

4.2 Concluding Remarks

The fragile char land ecosystem is already prone to several hazards due to poor geomorphologic and poor socio-economic condition. The livelihood options are very limited in the char lands and agriculture is the principle occupation for most of the households. Therefore, the life and livelihood of char land people are extremely

vulnerable to climate variables. Flood and bank erosion are the prevalent hazards in the char lands from time immemorial. However, the people used to shape their life and livelihood in such a way through the local knowledge that they could reduce the impact of those hazards to a large extent when climate variability did not come into effect. Hazards like frequent and intensified flood with higher magnitude and flood induced bank erosion are becoming more and more unpredictable with an addition of water stress or salinity intrusion. They all are putting new challenges to the life, livelihood of char land people, and their perceptions.

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