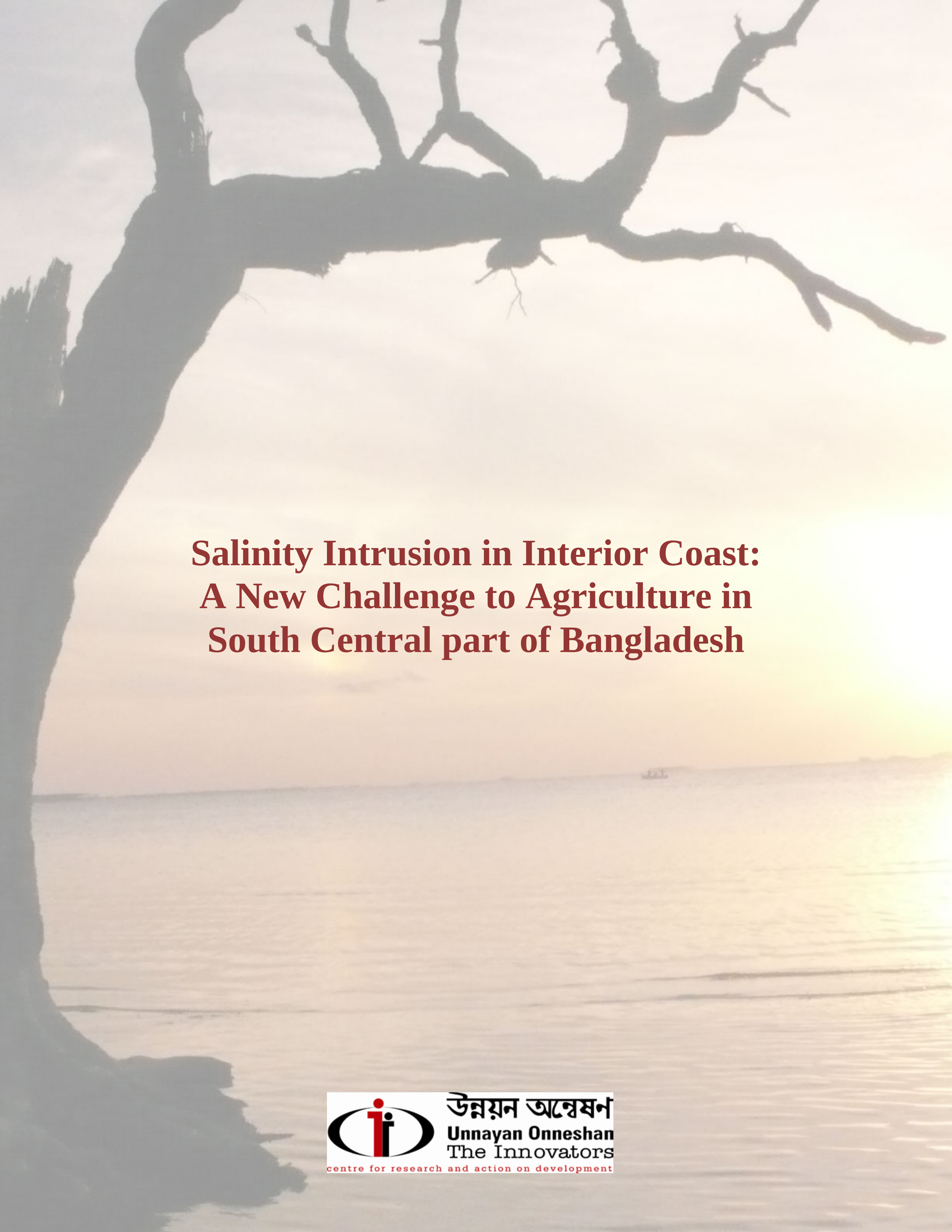

Salinity Intrusion in Interior Coast: A New Challenge to Agriculture in South Central part of Bangladesh

উন্নয়ন অন্বেষণ
Unnayan Onneshan
The Innovators
centre for research and action on development

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Author
Lubna Seal
Mohammed Abdul Baten

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 Please do not quote.

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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

Salinity intrusion is an increasing problem in the coastal areas around the world. Climate Change and its associated hazards like sea level rise, cyclone and storm surge have been increasing the salinity problem in many folds. The coastal zone of Bangladesh is already under the constant threat of salinity. Any increase in sea level may intrude much longer distance in inland as the topography of the coastal zone in Bangladesh is relatively low-lying.

The coastal zone, more appropriately, exposed coast has come into focus in a number of policy and academic studies for land desertification and loss in agricultural production due to salinity. Although the salinity extends from the exposed to the interior coast with increased land coverage and puts its negative impact in the crop production over the years, the impact of salinity in the interior coast in terms of loss in crop production has been overlooked so far. Under this circumstance, the study is intended to explore the level of salinity in surface water in Gosairhat upazila, an interior coast, and the causes behind the salinity intrusion. This study also intends to quantify the impact of salinity in agriculture and gives possible solutions to address the problem.

In the study area, the concentration of salinity shows an increasing trend over the years. Existing salinity concentration of surface water has been estimated 1.3 dS/m which is 0.4 dS/m higher than the earlier estimation by ICZMP (2003). Considering salinity increase over the years, the study predicted that the salinity level might be close to 2.3 dS/m at the end of 2030.

The current study used IPCC and World Bank scenarios to predict future salinity increase and likely effect on the lives and livelihood of the study area in particular and interior coast of Bangladesh in general. Within IPCC scenarios, A2 and A1FI warn for a bleak future where the study area is likely to experience drastic decline in rice and wheat production by 2099 against the base year 2010. Around 42% of the total land area of Gosairhat upazila will be under the coverage of tidal inundation during 2099 under A2 scenario, whereas, the penetrated area will be approximately 79% under A1FI scenario. Considering per day intake of rice and wheat as 416.01gm and 26.09gm respectively (HIES, 2010), it is estimated that approximately 102526 people may face food insecurity due to rice shortage and 37859 people may face food insecurity due to wheat shortage respectively under A2 scenario at the end of the century. Similarly, 195308 and 72098 people will face food insecurity under A1FI scenario for the decline in the production of rice and wheat respectively at the end of the century. However, using the World Bank scenario for Bangladesh, it has been estimated that the land penetration is likely to be 42% by 2050 at Gosiarhat Upazila in Bangladesh.

Present salinity concentration has already put a threat to the crop production and a significant yield loss has already been observed in the dry season. In the changing scenario of sea level rise, it has been predicted that the increasing concentration of salinity will create more pressure to the farmer by reducing yield on one hand and threatening livelihood, income generation and food security on the other hand. Therefore, to reduce the future loss and to prevent the present loss, the study recommended some adaptive techniques to manage salinity. Among them, fulfilling leaching requirements and selecting salinity tolerant crop varieties are important ones.

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1. INTRODUCTION

Salinity intrusion is a growing problem in the coastal areas around the globe. The problem becomes exacerbated especially in the dry season when rainfall is inadequate and incapable of lowering the concentration of salinity on surface water and leaching out salt from soil. Climate change associated hazards like sea level rise, cyclone and storm surge have been contributing to the problem in many folds. IPCC AR4(2007) predicted that the sea level rise is likely to persist for centuries, resulting from the process and feedback of climate, even though the concentration of GHG are to become steady. German watch (2004) reported that the rise in the sea level is not indistinguishable in every geographical location. The rise may be expected a little more in some regions than to others depending on some factors and these are not limited to some climate independent factors like land subsidence and climate dependent factors like thermal expansion. However, the climate dependent factor seems to be more influential. Therefore, the impact of sea level rise also varies depending on geographic location as well as socio-economic factors like population density, livelihood option, poor infrastructure, inadequate policy and inefficient technology. Apart from land erosion, sea level rise is likely to put gravest threat by land desertification through salinity intrusion. Irrigated water demand is highly affected by salinity intrusion in surface water (Shahid, 2010) and salt accumulation in the root zone of soil affects plant growth in coastal soil (Yadav, et al. 2009). Besides constraining agricultural production, salinity limits the fresh water availability for drinking purpose and industrial production.

Bangladesh, a low-lying deltaic land, is particularly vulnerable to sea level rise and its associated hazards. SAARC Meteorological Research Council (SMRC) found that the trend of sea level rise in Hiron point, Char Ganga and Cox's Bazar, three tidal stations of Bangladesh, is 4.0 mm/year, 6.0mm/year and 7.8 mm/year respectively based on 22 years' historical data (cited *in* Rahman and Alam, 2003). Any increase in sea level may intrude much longer distance in inland as the topography of the coastal zone in Bangladesh is relatively low-lying (Karim and Maimura, 2008). A substantial area of coastal land in Bangladesh has already eroded. It has been found that the sea level rise of 0.5 meter over the last 100 years has eroded approximately 162 sq. km. of Kutubdia, 147 sq. km. of Bhola and 117 sq. km. of Sandwip (CCC, 2007).

Being an agrarian country, 60% people of Bangladesh are directly or indirectly dependent on agriculture for their livelihood with the contribution of 20% of its GDP (BCCSAP, 2009). The dominant land use in coastal Bangladesh is also for agriculture. The gross and the net-cropped area in the coastal zone of Bangladesh is 144,085 and 83,416 hector respectively (Islam, 2004). However, the net-cropped area of coastal zone in Bangladesh has been decreasing over the years due to various purposes and the most common one is the land inundation and salinity intrusion by tidal water. Fresh water reduction along with intrusion of saline water is perhaps the most devastating consequence of climate change in the coastal Bangladesh. Already, 830,000 million hectares of land have been identified which are affected by soil salinity at different degrees (CCC, 2007). It is estimated that a net reduction of 0.5 million metric tons of rice production will take place due to a 0.3 meter sea level rise in coastal areas of Bangladesh (World bank, 2000).

Even though salinity intrusion is a slow process but the impact is devastating. The rate of salinity intrusion is faster than was predicted a decade ago. NAPA of Bangladesh (2005) warned that the impact of saline water ingression in estuary and underground water is likely to be accelerated by sea level rise, land subsidence and low flow river condition. World Bank (2000) predicted a 1 m sea level rise at the end of the century which would affect 17.5% of total land mass of the country. It implies that the future sea level rise will bring further land under inundation and therefore, salinity will intrude to more inlands.

Coastal zone of Bangladesh is comprised of 19 administrative districts stretching into 147 upazilas, delineated based on the tidal fluctuations, cyclone and storm surge risk and salinity intrusion. Among the upazilas, 48 from 12 districts face the coast or lower estuary and known as exposed coast and the rest 99 upazilas that are behind the exposed coast are known as interior coast. The upazilas in the exposed coast have already met or crossed the threshold limit of the three parameters such as tidal movement, salinity, cyclone risk. However, the upazilas in interior coast have met or exceed any two or one of the three parameters. (PDO-ICZMP, 2003)

The interior coasts, which already met the threshold limit of tidal movements, are highly vulnerable to salinity intrusion especially in the dry season when a low flowing condition prevails in the river and fresh water of river becomes insufficient to counterpart salinity that intrude in the river water through tidal movement. The interior coast like Shariatpur, adjacent to the lower Meghna, already met the threshold limit of tidal movement and experienced some sorts of salinity in surface water during the dry season and high tide. Withdrawal of water from upstream river system by dam and barrage and rising temperature, decreasing rainfall during dry season and sea level rise due to climate change, have a strong influence over fresh water distribution and tidal penetration that results into salinity intrusion. Salinity intrusion affects fresh water availability into the river systems and therefore, deteriorates usability of drinking and irrigation water. The lower Meghna is subjected to salinity intrusion mainly from decreasing fresh water flow in the dry season and hence, saline water penetrates into the river. Generally, a mixture of fresh water and saline water prevail in an estuary. The Meghna estuary also shows the similar characteristics. During the dry season, the saline water progresses to landward more extensively, whereas, it is pushed out towards bay in the wet season. Fresh water input, depends on seasonality largely, has direct impact on Salinity distribution along with water circulation and sediment exchange.

Salinity is increasingly considered as a hazard for the crop production in Shariatpur district, particularly during dry season and the farmers experience a significant yield loss over the couple of years. Under the circumstances, the study intended to measure the present level of salinity, more specifically, irrigation water salinity, and its impact on agricultural production. This study also predicts the future scenario in terms of salinity level in surface water and its potential impact on agricultural activities and livelihood.

1.1 Hypothesis: salinity intrusion in interior coast adjacent to the lower Meghna is evident and it limits the agricultural activity in that particular area.

1.2 Objectives: The study aims at

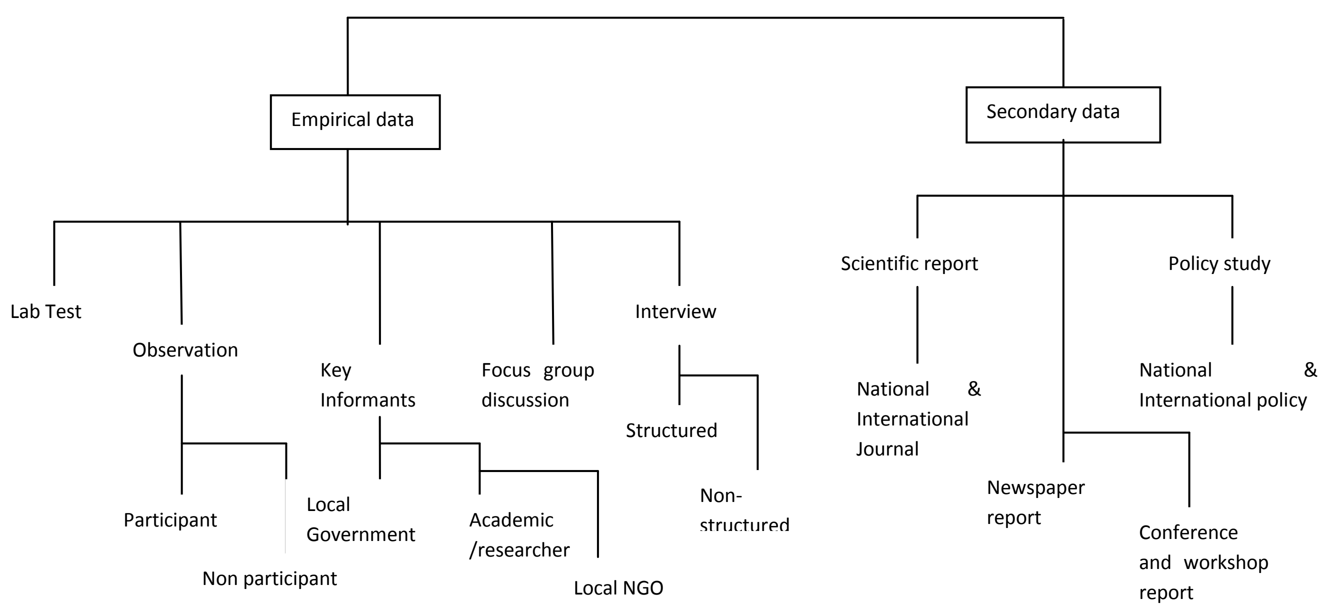
- Exploring the causes of salinity intrusion in the area adjacent to the lower Meghna.
- Measuring the present level of surface water salinity.

- Assessing and quantifying the impact on agriculture.
- Identifying the solution to address the problem associated with salinity ingression.

2. METHODOLOGY

The study employed both qualitative and quantitative approaches to collect and analyze data. Although, both primary and secondary sources were used, the study focuses more on primary intervention which has been done through FGD, key informants interview, case study, household interview, personal observation and the laboratory report. Moreover, Arc GIS 9.2 software has been used to show salinity coverage under different future scenarios. The secondary information has been collected through assessing a number of scientific and policy study. The review of secondary literature helps to identify the level of salinity in previous years in different coastal district in Bangladesh and what impacts it have laid on agriculture. The data collection for the study has been framed according to the following structure:

Figure: 1 Method of data collection



Source: Developed by authors, 2011

2.1 Lab Test:

The study intended to explore the existing salinity level in surface water. Both physical and chemical properties of water samples were analysed in the laboratory of Bangladesh University of Engineering and Technology (BUET). A total of 3 samples were collected, among them 2 were from the river Jayantia, a branch of the Meghna River, at in-point, out-point of Panchkathi village. The third one is collected from a water body derived from Jayantia River adjacent to Panchkathi village. Generally, the villagers use surface water for irrigation.

2.2 Key Informant interviews (KII):

The key informants were selected based upon their expertise on the relevant subject matters required for analyzing the issue rigorously. For the current study, four Key Informants Interviews were taken from public (BUET) and private (North South University) universities, GO (SRDI) and local NGO (SDS) respectively. Key informants were interviewed face to face and over telephone using semi-structured questionnaire. Apart from questionnaire, their comments were also taken into consideration.

2.3 Focus Group Discussion (FGD):

Using qualitative approach, one Focus Group Discussion was conducted comprising both men and women. Focus group helps to gather a wide range of information in a relatively short time. The participants of the FGD were selected using snowball sampling, comprised of 12 people including subsistence farmer, small landholders and sharecroppers. The rationale behind snowball sampling is to find people with a specific range of knowledge or skill. This sampling helps to select individual or group from different places. Therefore, more connection can be built through mutual conciliator. The participants were asked question regarding the climate related hazard, livelihood, agricultural production, income generation, and food security and adaptation technique applied in the locality. The data collected from FGD were crossed checked by the interviewee from different households.

2.4 Households Interview:

60 households were interviewed throughout the study. A semi-structured questionnaire was used to collect data of the impacts of salinity on crop yield, livelihood and health. The interviewees were selected using simple random sampling technique. In this technique, each and every household of a given size has an equal probability to be selected. Therefore, SRS may minimize the bias and make the result accurate. The randomness of this technique sometimes fails to select a representative proportion.

2.5 Data analysis

Qualitative data: Qualitative analysis configures observation and narrative explanation rather than numbers. Therefore, conceptualization is required to bring order of understanding in a systematic manner. To analyze and interpret narrative data, three steps were followed as developed by Taylor et al. (2003) which are : 1. Get to know the data, 2. Focus the analysis, 3. Categorize information.

Quantitative data: Quantitative data analysis involves the following steps:

Data organization: The questionnaire/forms has been organized in one place, and checked whether they are completed. The irrelevant and inappropriate questionnaire/forms and irrelevant answer has been screened out.

Calculation: Using SPSS software, data has been analysed to find out frequency, percentage of people's response and correlation between salinity and agriculture.

2.6 Limitation of the study

Farmers in the study area grow different crops whose yield potential is different. To estimate the yield loss and decline in crop size, the respondents were asked the common questions. Both farmers and wage labourers were asked the same questions regarding affect of salinity in agriculture but the farmers, who are directly involved in crop growing, the answer was more reliable than others. However, in the paper, we have used the average of the response which reduces robustness of the study. Moreover, samples were taken only from three villages which have been used to construct a general scenario for the interior coast, more specifically Shariatpur district. Such small number of sample does not reflect the whole scenario of the interior coast or even the district, but the study could open a new window in climate change research for coastal Bangladesh which demands more comprehensive study involving multidisciplinary approach. The whole study was conducted within six months. Due to budget constraints, the sample size was small. However, data were rechecked and compared with established literature to maintain the rigor of the study.

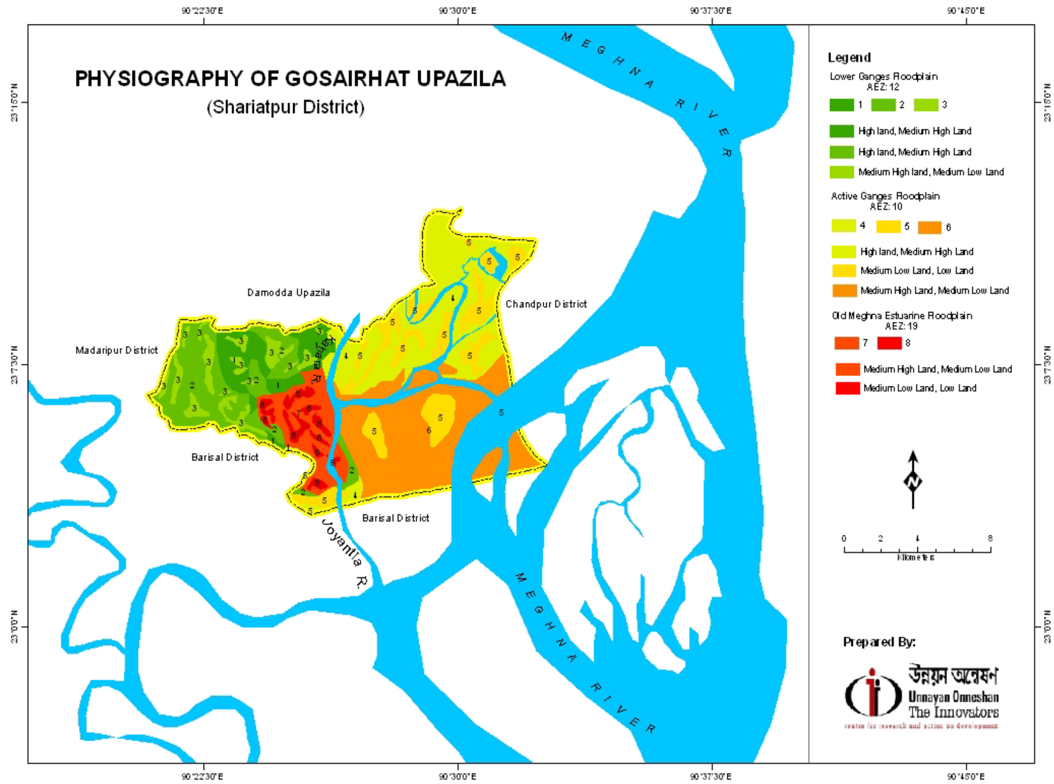
3. DESCRIPTION OF THE STUDY AREA

The study has been conducted at Panchkathi, Char Bhuinya and Kulchuri Patarchar village of Gosairhat Upazila under Shariatpur district. Among them Panchkathi and Char Bhuinya are under Nolmuri union and the Kulchuri Patarchar is under Kuchaipotti union near the river Jayantia, a branch of the Meghna river.

3.1 Geographical location of the study area:

Gosairhat is located between 23° 05′ and 23° 10′ north latitude and between 90° 20′ and 90° 34′ east latitude on the western part of the lower Meghna River. The lower Meghna is one of the largest river systems in the world that conveys the combined flow of Ganges, Brahmaputra (Jamuna) and Meghna through the estuary to the Bay of Bengal. The quantity of discharged water through the lower Meghna to the Bay of Bengal is the 3rd highest around the world (Ministry of Water Resource 2003).

Figure: 2 The map of the study area



Source: Unnayan Onneshan, 2011

3.2 Physical Condition of the study area

Coastal areas are classified based on proximity to the Sea and indicators like tidal movement, salinity and cyclone risk. Depending on the above stated parameter, 133 upazilas of 19 districts have been labeled as coastal upazila. Among them 48 upazilas have already met or crossed the threshold limit of the three parameters and known as exposed coast. All of them are under cyclone risk at high or low level and face the sea or the Meghna estuary. The rests of the upazilas are known as interior upazila and they met or cross the threshold limit of two indicators either like, tidal movement and salinity or any one of them and are usually situated behind the exposed upazila and free from the risk of cyclone. (PDO-ICZMP 2003)

According to this delineation of coastal zone, the study area is located at the interior coast and belong the following characteristics of coastal upazila (Table: 1).

Table: 1 The status of three parameters (tidal movement, salinity and cyclone risk)

District code	District	Upazila code	Upazila	Soil Salinity (dS/m)	Surface water Salinity (dS/m)	Ground water Salinity (dS/m)	Salinity status above threshold	Average tidal fluctuation over the year (m)	Tidal movement Above threshold	Cyclone risk status
86	Shariatpur	36	Gosairhat	<4	<1	<1	-	1-2	yes	-

[Salinity above threshold: soil salinity 4 dS/m, surface water salinity 5dS/m, ground water salinity 2dS/m, tidal fluctuation 0.3 m.] Source: PDO-ICZMP, 2003

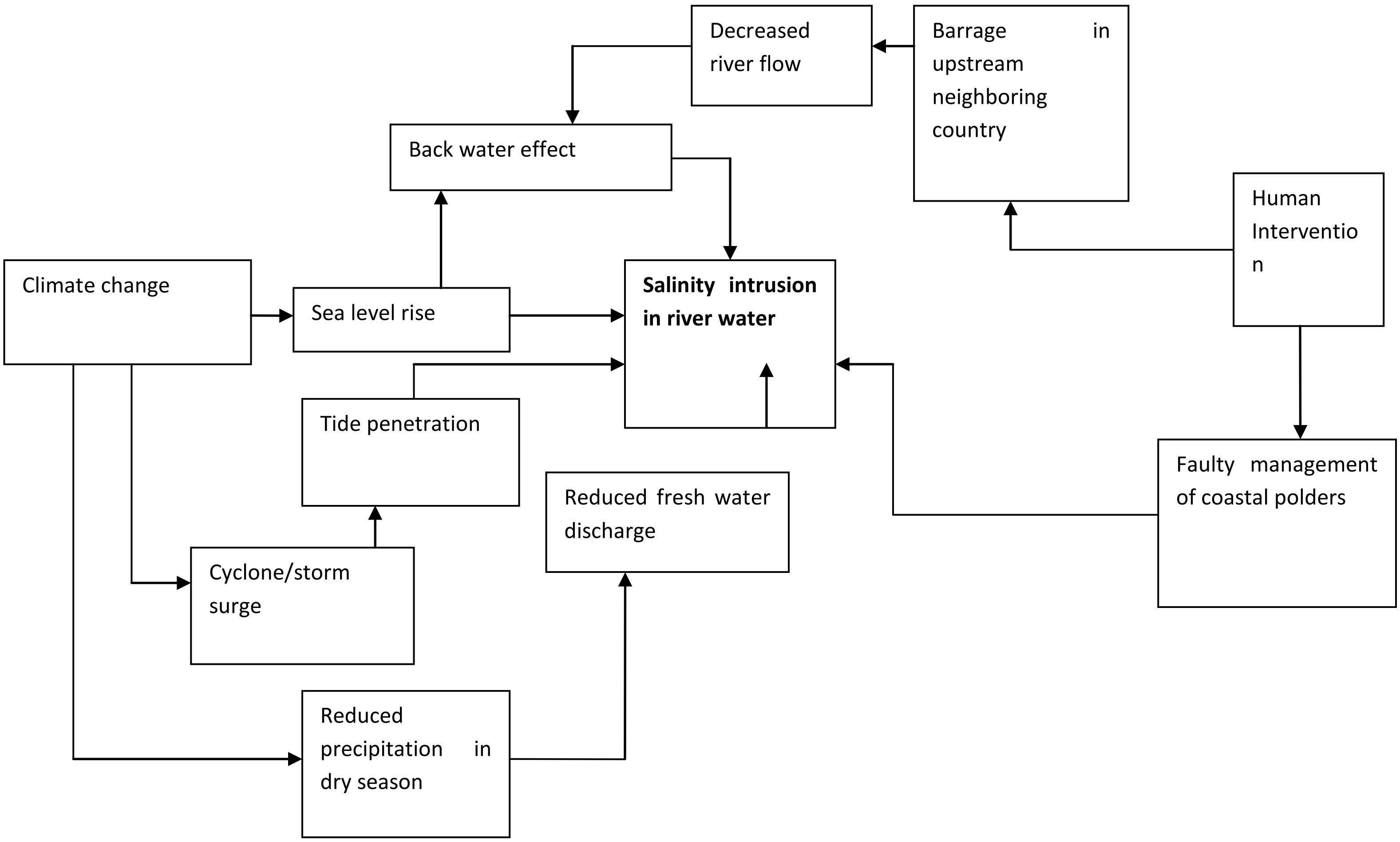
The table illustrates that the study area is an interior coast and has crossed the threshold limit of tidal movement. The salinity status is below threshold limit. However, in near future, the salinity level may cross the threshold limit.

The study area is located at old Meghna estuarine flood plain which has been categorized as Agro Ecological Zone 19. The land elevation of the study area is medium high and medium low and the soil fall under Debiddar and Burichang category from where the later one is the dominant. The pH of Burichang soil class in a medium high land is ranging 5.9-7.0. The organic matter content is medium, which is 2.3 percent. The average content of calcium, magnesium, copper, Iron and manganese is higher along with the content of Boron and potassium with low average and phosphorus with extremely low in content. On the other hand, the pH in a medium low land is ranging 6.5-7.2. The organic matter content is medium with 2.38 percent. The average content of calcium, magnesium, copper, iron and manganese is very high. The average content of boron is high and nitrogen and zinc is low. The average content of phosphorus is extremely low. (SRDI, 2001)

4. CAUSES OF SALINITY INTRUSION IN THE INTERIOR COAST

Water circulation in the coastal zone and in the Meghna estuary in Bangladesh is largely dependent on the factors like fresh water flow from the river, penetration of tide from the Bay of Bengal and the meteorological conditions like low pressure systems, cyclones, and storms surge and wind (MoWR, 2003). Both climatic and anthropogenic factors are responsible for causing salinity in the river water. However, climate induced factors such as sea level rise is the most pressing cause of salinity in coastal areas. Figure 3 illustrates causes of salinity intrusion.

Figure: 3 Causal diagram of salinity intrusion in river water



Source: Developed by authors, 2011

4.1 Anthropogenic factors of salinity intrusion:

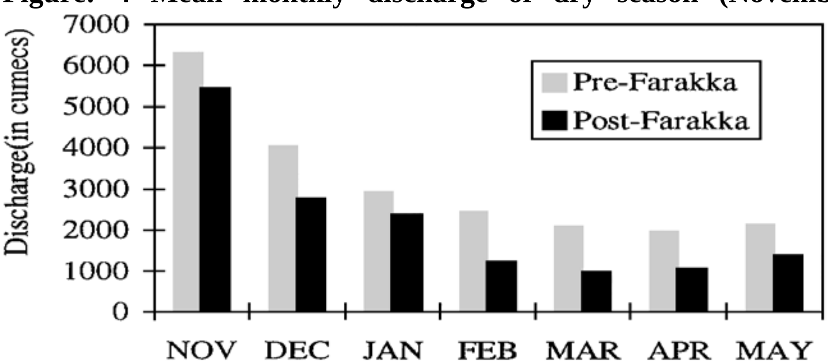
Bangladesh is formed at the confluence of the three mighty rivers: Ganges, Brahmaputra and Meghna (GBM). The basin of three river systems with an area of 1.6 million square kilometers passing through India, China, Nepal, Bhutan and Bangladesh, drains to Bay of Bengal through Meghna estuary. Different types of anthropogenic interventions in the form of dam, barrage, and water diversion channel were undertaken in this river basin during the last century. This kind of intervention withdraws or diverts a substantial amount of river water from the upstream catchments of the GBM river basin and creates a low flow condition in the downstream rivers during the dry season. Faulty management of coastal polders also accelerates inland salinity ingression.

4.1.1 Low flow condition of river by barrage in upstream neighbouring country

The water flow of the Ganges River in Bangladesh is largely influenced by the Farakka barrage. The water flow in the Ganges River in Bangladesh has been dropped a minimum 150m3/s at Hardinge bridge in 1995 from 2,0000 m3/s, which was the average minimum flow of Ganges during post Farakka period(MoWR, 2003).

Mirza (1998) observed a notable change in the hydrology of the Ganges River at post Farakka period (figure 4). He argued that the discharge during monsoon (July –October) increased whereas, during the dry season, (November-May) the discharge decreased significantly. Increased flow in the monsoon exacerbated the flooding condition and decreased flow aggravated salinity intrusion in interior coast considerably.

Figure: 4 Mean monthly discharge of dry season (November-May) in the Ganges River.



Source: Mirza (1998)

The water withdrawal system by human intervention in terms of barrage and dam in the upstream neighboring country, though situated far distant from the Meghna estuary, however, their impact is far reaching and influence the water distribution in the Meghna estuary. These kinds of interventions in terms of man-made dam and barrage have already put massive impact on sediment and water circulation in the Ganges, Brahmaputra and Upper Meghna and eventually in the estuary. The highest contributor of fresh water to the lower Meghna is the Padma River, the combined flow of Ganges and Brahmaputra (Jamuna), which provides 90% of total fresh water (MoWR, 2003). On the other hand, the contribution of fresh water from the upper Meghna to the lower Meghna is only 10% of total fresh water flow during the wet season, which is very insignificant compare to flow of the Ganges and the Brahmaputra and it becomes more negligible during the dry season (MoWR, 2003). The flow of the upper Meghna is partially regulated by another barrage built on the Barak River in its upstream.

4.1.2 Salinity intrusion due to faulty management of coastal polders

Coastal polders were built to prevent tidal intrusion aiming to boost agricultural production. However, Islam (2004) found that many polders were out of function due to undesired breaching to promote shrimp culture that resulted in crop damage. Water logging in the sluice gates of polders or dikes is likely to increase the salinity in the coastal zone. Karim and Maimura (2008) found that the exit point of polders became blocked because of riverbed rise through silt deposition after the construction of polders, resulting in empoldered areas turned into permanent water logged. They further reported that the water logging has extended to 1500 Km^2 Ganges tidal flood plain that was previously used for agriculture.

4.2 Climate Change Induced Factors

Rising temperature and fluctuation in precipitation are considered as the signs of climate change which are likely to have multiple impacts on the coastal zone of Bangladesh. World Bank (2000) predicted that the sea level might rise to 30 and 50 cm respectively with changing temperature and precipitation in 2030 and 2050 (table 2).

Table:2 The scenario of climate change in Bangladesh

Year	Sea level rise (cm)	Temperature increase (°c)	Precipitation Fluctuation compared to 1990(%)
2030	30	+0.7 in monsoon; +1.3 in winter	-3 in winter; +11 in monsoon
2050	50	+1.1 in monsoon; +1.8 in winter	-37 in winter; +28 in monsoon

Source: World Bank, 2000

In the scenario, World Bank (2000) showed that the increase in temperature in winter would be higher than that of summer and therefore, may cause higher rate of evaporation from the surface of the river in winter in the upcoming days. Moreover, fluctuating precipitation would likely to reduce precipitation in the dry season in the near future. The cumulative impact results in a low flow condition in the river. Again, sea level rise will likely to create backwater effect in the mouth of the river and exacerbate salinity in the river water.

4.2.1 Sea Level rise:

Bangladesh, having a densely populated coastal area, is highly vulnerable to sea level rise. UNEP (1989) predicted a 1.5 m sea level rise by 2030 which will inundate 16% of total land mass and effect 15 million people, whereas world Bank (2000) predicted a rise of 10 cm, 25 cm and 1 m by the year 2020, 2050 and 2100 respectively which will likely to inundate 2%, 4% and 17.5% of total land mass respectively.

Based on 22 historical data, SAARC Meteorological Research council (SMRC) has developed a trend of sea level rise in three tidal stations in the coastal Bangladesh and the trend depicts a worrying picture where on an average coastal areas experience 5.9 mm sea level rise every year.

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

Sea level rise has direct influence on salinity intrusion in the exposed and interior coast. Shamsuddoha, *et. al.(* 2007) predicted penetration of 5 ppt saline front into 40 km inland at the fresh water pocket of the Tetulia River in Meghna estuary due to a rise of 88 cm of sea level. In interior coast, the penetration of tidal water exacerbates during the dry season when the fresh water flow from river decreases. Tide intrudes into Meghna estuary through the East and West Shabazpur channel and the Hatia channel (MoWR, 2003)

4.2.2 Cyclone and Storm Surge

The coastal zone and off shore island in Bangladesh is very flat with height less than 3 m above the mean sea level. The astronomical tide is very prominent in coastal Bangladesh with higher range and therefore cyclone induced sea level rise and storm surge is likely to be very frequent. Khan, *et al*. (2010) predicted that climate change would increase the frequency of tropical cyclone with larger peak wind speeds and with heavier rainfall.

4.2.3 Back Water Effect

Backwater effect is a special type of saline water movement which takes place at the mouth of the river when fresh water is not sufficient enough to counterpart tide water moving towards river from sea. Ali (1999) identified different causes of backwater effect, among them i) South west monsoon wind ii) astronomical tides iii) storm surge are responsible for backwater effect at the mouth of the Meghna estuary . He further argued that sea level rise is the non-dynamic and long term cause of backwater effect.

4.2.4 Precipitation

Precipitation pattern is likely to be changed in south Asia due to higher temperature that results in stronger monsoon circulation (MoWR, 2003). Such fluctuation in precipitation causes flood with higher magnitude in wet season and reduces the availability of fresh water in dry season. Using Global Circulation Model (GCM), Agarwala *et al.* (2003) showed that winter temperature is in a rising trend due to climate change. On the other hand, the precipitation is likely to be increased throughout the summer monsoon. They argued that during summer air over the land gets warmer than the air over oceans which will create a further low pressure system in the land and exacerbate the monsoon. However, the winter with a small decrease in precipitation and higher evaporation will create drier condition. The combined effect of less precipitation and higher evaporation will cause a low flow situation in the river water.

5. CHEMICAL PROPERTIES OF SALINITY IN AQUATIC ECOSYSTEM

Salinity in aquatic ecosystem indicates the total amount of dissolved salts present in it. Generally, four types of cations prevail in saline water such as Sodium (Na^{+}), potassium (K^{+}), Calcium (Ca++) and Magnesium (Mg++) and 3 anions such as Chloride (Cl^{-}), Carbonate (CO3--) or Bi-Carbonate (HCO3¯) and Sulphate (SO4--). However, the most common and plentiful ions present in saline water are Sodium (Na^{+}) and Chloride (Cl^{-}). Salinity of an aqueous system can be measured by determining concentration of salt in water. Two most common ways to measure salinity are: a) Total dissolved solids (TDS), b) Electrical conductivity (EC)

Total Dissolved Solids (TDS):

Total dissolved salt is often used to determine water salinity. It is estimated by evaporating a known volume of water and then estimating the weight of the solid waste residue. Total dissolved solids are measured in the laboratory and are typically recorded in mg/L.

Electrical conductivity (EC)

The easiest and the most common method of measuring salinity is electrical conductivity. It is estimated by passing electrical current between two electrodes in the water solution and measuring how readily the current flows between the plates. An electrical current flows through the water due to this voltage and is proportional to the concentration of dissolved salts in the water. The more salts in water the more conductive the solution is, resulting a higher electrical conductivity. EC is usually expressed in micro Siemens per cm at 25°C (μS/cm).

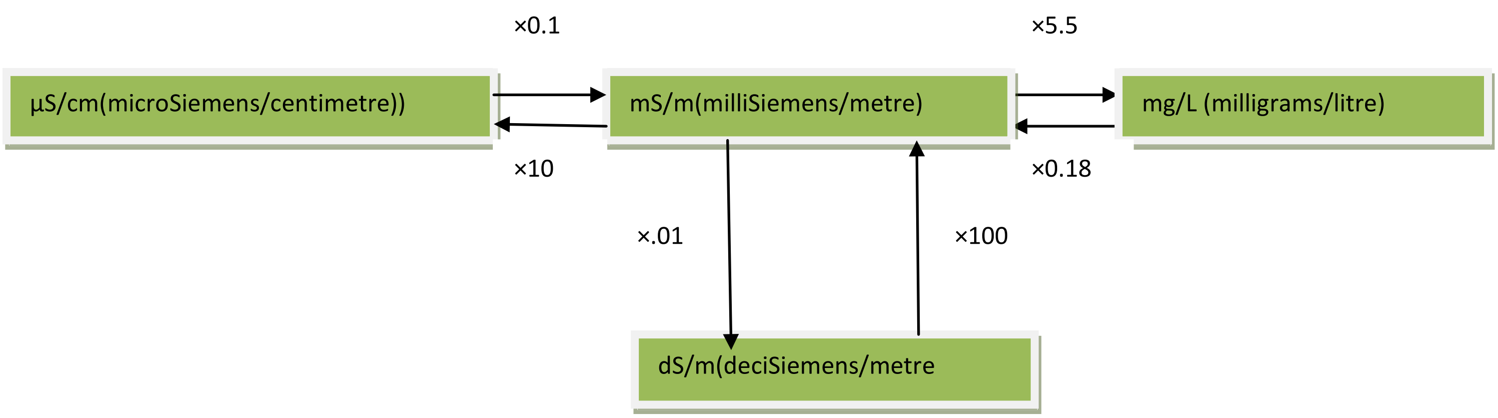
5.1 Present level of salinity in the study area:

Salinity in Irrigation Water

In this study, the salinity is determined by measuring electrical conductivity (EC) of irrigation water of the study area. The salinity has been measured in micro Siemens per cm (µS/cm) at 25°C.

The Electrical conductivity (EC) of irrigation water in the study area has been found 1305 µS/cm at 25° C.

To convert 1305 µS/cm into dS/m and ppt, the following formula has been used in this study.



If we convert µS/cm into dS/m we get,

1305 µS/cm ×0.1 = 130.5 mS/m

And, 130.5 mS/m×.01 = **1.305 dS/m** or **1.3 dS/m** (approximately)

Again, 130.5 mS/m×5.5 = 717.75 mg/l

And, 717.75 mg/l÷ 1000 = **0.71775 ppt** or **0.72 ppt** (approximately)

The present level of soil salinity in the study area is <4dS/m (ICZMP, 2003). The study considered soil salinity of 3.5 dS/m, roughly to calculate yield potentiality of crops in the study area.

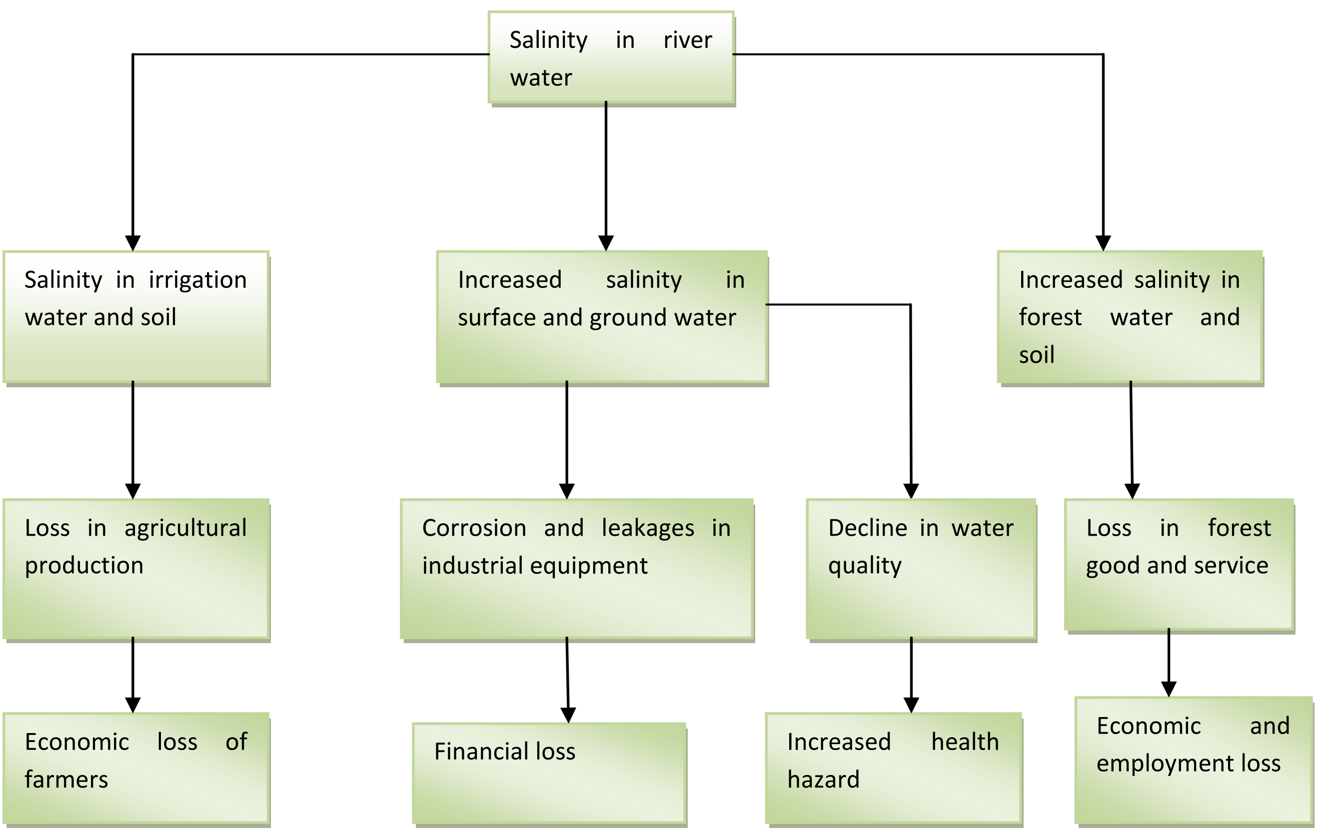
6. IMPACT OF RIVER WATER SALINITY ON LIVES AND LIVELIHOOD

Salinity intrusion in river water may cause economic loss in terms of crop yield reduction, hampering industrial production, increasing health hazard and reducing productivity of the forest species. The agriculture production is likely to decrease as saline containing water reduces plant growth through concentrating salt in the root zone of plant and resulting in nutrients imbalance and yield loss. Industrial production is reduced when saline water from river is used to cool condenser or to keep turbine running. Salinity restricts the usability of river water in industrial purpose and causes leakages in equipment and makes production loss and also increases production cost by compelling the producer to import fresh water for avoiding the corrosion and leakage. For instance, Pakshi paper mill closed down during 1993 due to salinity intrusion in the north of Khulna (Mirza, 1998). The increase of salinity in the adjacent river channels hampers the growth of the forest species. Reduction in fresh water and salinity intrusion along with soil quality depletion slow down the plant growth and reduce productivity that put adverse effect on biodiversity and the wild life.

River water with high level of salinity, when used for drinking purpose, may have numerous impacts on the health of the human and the livestock. Khan *et al.* (2011) argued that the high level of salinity in drinking water might cause an increased rate of pre-eclampsia and gestational hypertension in pregnant women. A report (SRTT, 2011) found that salinity in drinking water also causes kidney diseases like kidney stone and Rheumatism. The report further stated that the salinity has negative impacts on domestic cattle in terms of deterioration of the milk productivity and reproductive health.

However, salinity in river water has diversified impact on socioeconomic factors, the study deals only with the impact of salinity on agriculture in the study area. Therefore, the study intends to explore the present level of salinity in the irrigation water and its associated hazards in the crop production. It particularly targets the Robi season.

Figure: 5 The possible impacts of salinity in river water



Source: Adopted from Mirza (1998)

6.1 Impact of salinity on irrigation and crop production:

Salinity affected irrigation water has profound impact on crop production. Bauder, et. al., (2007) stated that the impact of irrigation water on crop production depends upon the presence of salient factors:

- Salinity or concentration of total dissolved salts
- The disproportion of sodium ion with other cations like calcium and magnesium
- Alkalinity or presence of excessive carbonate or bicarbonate more than the desired level
- pH
- Some toxic ions like: Sodium and Chloride ion, if present more than the desired level

The irrigation water parameters of the study area were compared with Soil First Consulting, US based soil conditioners supplier, set desired level and found that some of the parameters such as PH, alkalinity and chloride already exceed the desired level (Table 4).

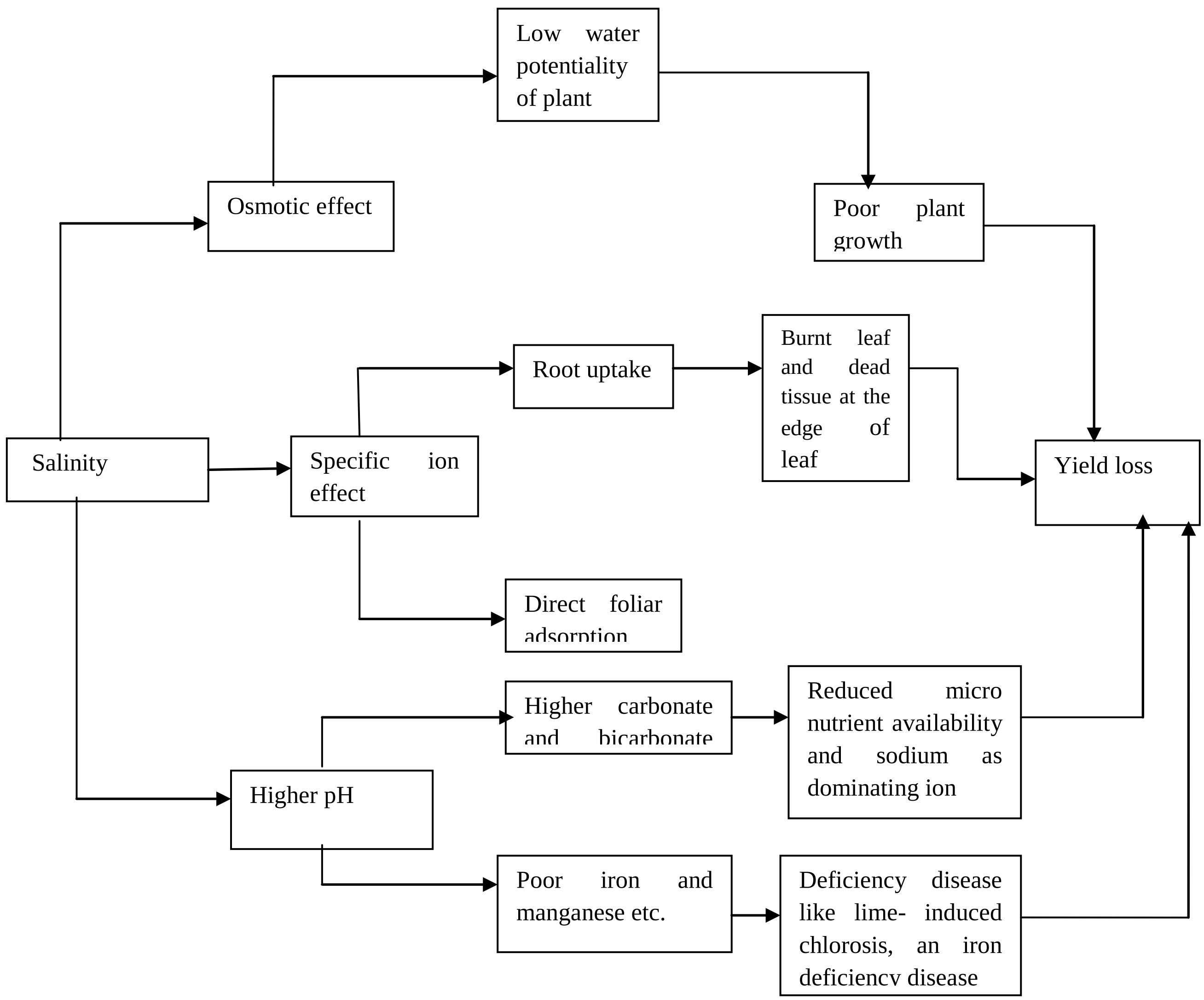
Table: 4 Irrigation water parameters in the study area

Parameter	Desired level	Present level (in the study area from the empirical study)
pH	5.5-6.0 is the ideal condition for both irrigation and tank mixing; > 7.0 can cause problems, especially in tank mixing	7.99
Salinity or concentration of salt	1.5 dS/m	1.305 dS/m
Alkalinity (carbonate)	< 50 ppm	221 ppm
Chloride ion	< 140 ppm	500 ppm
Sodium ion	0 – 50 ppm	_

Source: Column 2- Soil first Consulting (www.soilfirst.com), Column 3- Lab test report (2011)

The value of salinity though lower than the desired level, however, the role of salinity of the present level may be significant on crop production when the soil of irrigated land has already been affected by salinity.

Figure: 6 Schematic diagram of impact of salinity (Both in irrigation water and soil) on crop production



Source: Developed by authors, 2011

6.1.1 Osmotic Effect

The most common response of plant towards salinity is reduction in growth. In low to moderate concentration, salinity affects the crop production by lowering the soil water potential and increases the concentration of salt in the root zone. Low water potential indicates that plant cannot extract right amount of water from soil and maintain turgor at very low soil water condition. This effect is known as osmotic effect. Bauder (2007) argued that the yield of a crop is directly linked to the quantity of water passed through it by water transpiration. When EC gets higher, the less water is likely available to plants. Yield potential of plants, therefore, gets deteriorated with the increase of EC in irrigation water.

The current study has found that the electrical conductivity of the irrigation water is 1.305 dS/m which is slightly saline according to FAO (1992) guideline and moderately saline according to FAO (1976) guideline, whereas, according to USDA (1954), the irrigation water in the study area is highly saline (Table 5).

Table.5 Classification of irrigation water based on electrical conductivity

EC of water in dS/m (=mS/cm)			
Classification	USDA	FAO	FAO
	1954	1976	1992
non-saline	<0.25	<0.75	<0.7
slightly saline			0.7-2.0
moderately saline	0.25-0.75	0.75-3.0	2-10
highly saline	0.75-2.25	>3.0	10-25
Very high saline	2.25-50		25-45

Sea water: > 45 dS/m

Source: Schleiff (2005)

6.1.2 Ion Effect

Excessive presence of ions like sodium and chloride in irrigation water may cause toxic effects in plant growth. The toxic effects caused by specific ions may occur either when the ions are taken up by the root or when gets the direct contact with the leaves.

Some ions like chloride create toxic effect on the plant growth after a certain level. Even though chloride is an essential element for plant growth, higher concentration may restrain plant growth or can cause toxicity to some plants. Irrigation water with high chloride content is likely to reduce the availability of phosphorus to plants. Higher concentration of chloride ions also causes leaf tip burn, disruption of membrane function, obstruction in internal solute balance that hampers nutrient uptake. In the study area, chloride ion concentration in irrigation water is 500 ppm, which implies that crops in the study area are susceptible to all the effects as mentioned in the table 6.

Table.6 Chloride ion concentration and its impact on crops

Chloride (ppm)	Effect on crops
Below 70	Generally safe for all plants
70- 140	Sensitive plants show injury
141- 350	Moderately tolerant plants show injury
Above 350	Can cause severe problem

Source: Mass (1990), *cited in* Bauder 2007

However, tolerance level of chloride ions differs with crop varieties. Figure 7 presents crop varieties depending on tolerance level of chloride ions from low to high.

Figure 7: Crop order depending on chloride ion tolerance (increasing order)

Onion → Letuce → Pepper → Corn → Potato → Wheat

Sodium ions can also cause toxic effect after specified limit. Some of the toxicity symptoms of Sodium ion are leaf burn, dead tissue alongside the outer edges of leaves (Lantzke, 2004).

6.1.3 Direct foliar Adsorption

Some plants may not be responsive to root uptake of toxic ions like sodium or chloride ion, however, may be sensitive and build up symptoms when come in contact directly with the ions. The toxicity of chloride ions and sodium ions due to adsorption is visible when irrigation is carried through sprinkler method. This toxic effect causes foliar damage of some specific crops in terms of scalding or burning the leaves coming in contact with the specific ions. Damage caused by direct contacts of ions gets more severe when irrigation takes place in a hot and dry weather. (Lantzke, 2004).

The current study found that the chloride ion content in irrigation water is much higher than the desired level. Even though sodium ion concentration of irrigation water in the study area has not been estimated under the current study, it can be predicted that the concentration of sodium ion would be higher as that of chloride ion is higher. The farmers of the study area claimed that they have been experiencing some of the impacts of salinity such as early yellowing of leaves, burning leave tip, early aging of plant etc. which may create dropping down of leaves in premature stage and therefore, reduce the rate of photosynthesis.

6.1.4 pH, alkalinity and nutrient deficiency

Bauder (2007) recommended the ideal pH range for irrigation water as 6.5-8.4 and warned that pH above 8.5 might speed up the corrosion of irrigation system. pH level increases due to higher concentration of carbonate and bicarbonate ions and make the irrigation water alkaline. Higher carbonates and bi-carbonates in irrigation water create insoluble minerals with calcium and magnesium ions leaving sodium ions as the dominant ions in the solution. Higher alkalinity in irrigation water reduces micro nutrient availability.

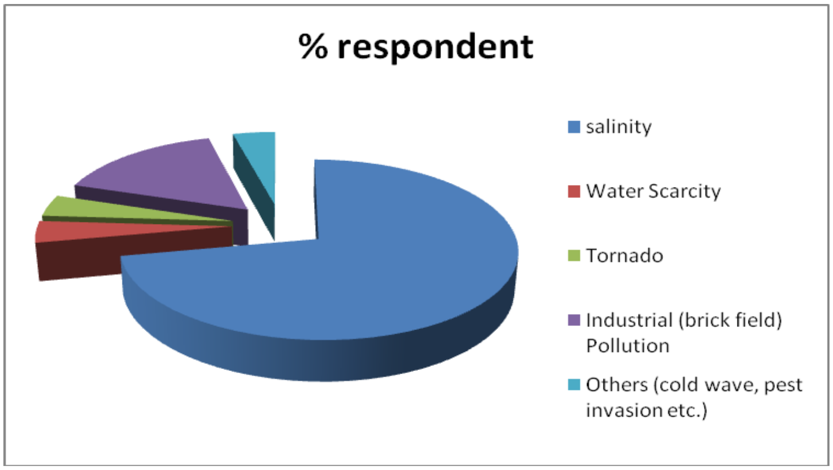
The study found that the pH level is 7.99 and the concentration of carbonate ion is 221ppm, which is much higher than the desired level. Higher concentration of carbonate ion in irrigation water results in increased concentration of sodium ions in the root zone, and due to their toxicity, photosynthesis process hampers when concentrated in the stomata of leaves.

Irrigation water with higher pH contains high level of carbonate, bi carbonate and sodium ion. Higher pH containing irrigation water when applied to land is likely to increase the soil pH as well as sodium level at the same time decline the rate of water infiltration and drainage by blocking the pores with lime and other dispersed particle(Gale et al.2001). When pH of soil increases, the deficiency of micronutrient like iron, manganese etc may occur to the plant. As for example, an iron deficiency disease named “Lime Induced Chlorosis” may arise by high pH with the symptom of yellow-white leaves on plants (Hoffman, 2010).

7. EVIDENCE OF SALINITY INTRUSION IN THE INTERIOR COAST AND ITS IMPACT ON AGRICULTURE

The impact of salinity intrusion is evident according to the knowledge of the local people. Among the respondent, 72% agreed upon the fact that salinity is the most prevalent hazard for their crop production during the dry season. The local people stated that they could test salinity in the drinking water which they collect from swallow tube wells. They argued that they experienced a decline in the crop production in the last 5 to 6 years. According to them, the salt intrudes in their land when they irrigate their land. The respondents acknowledged that they use water from their adjacent water bodies like from the branches of the lower Meghna and the Jayantia River, which they collect by low lift pump when tidewater intrudes during irrigation period. However, some of the respondents believe that apart from natural hazards, some manmade hazards like emission from brickfield could have some impacts on the reduction of the crop production in their locality. Water scarcity, according to some of the interviewees, could be a hazard in terms of availability of fresh water. 4% of the respondents argued that they are in crisis of fresh water and both their drinking and irrigation water are not fresh enough because of the presence of salinity.

Figure: 7 Obstacles for agricultural production in the study area in dry season



Source: Authors' own calculation from Unnayan Onneshan's field visit, 2011

Agriculture is the main source of livelihood in the study area. Among the households, sharecropper appeared as the highest number and they grow Boro rice in the dry season. Apart from Boro rice, other cereal crop (wheat), some tuber crop, vegetable, pulse crop, oil seed and spice and fruit crop are being practiced in the study area (table7).

Table.7 The crop practiced in the study area

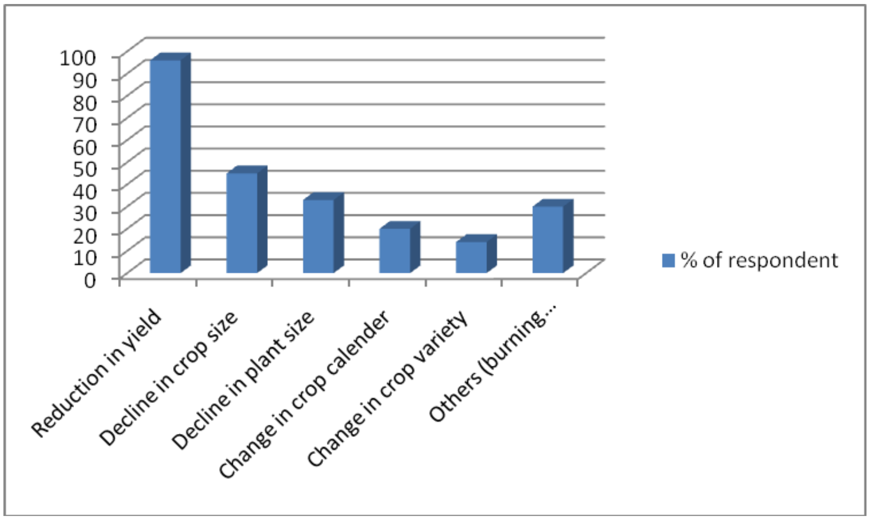
Cereal crop	Tuber crop	Vegetable	Pulse crop	Oil seed	Spice and Fruit Crop
Boro rice	Potato	Amaranth	Moshur dal	Mustard	Onion
Wheat	Radish	Data Shak	Khesari dal		Garlic
	Sweet potato	Pumpkin			Chilli
		Okra(ladies finger)			Coriander

Source: Unnauan Onneshan's field visit, 2011

7.1 Impact on crop production

The impact of salinity on crop production is already visible in the study area. Most of the respondents in the study area already experienced yield reduction (figure 8). Moreover, some of the respondents added decline in crop size as the impact of salinity. Some respondents reported the impacts like burning leaf tip or early yellowing of leaf. A small number of respondents reported that they have changed the crop variety to cope up with increasing salinity. (Figure 8)

Figure: 8 The impact of salinity on crop production



Source: Authors' own calculation from Unnayan Onneshan's field visit, 2011

The most pressing problem faced by the farmers in the study area is yield loss. However, the yield loss is not uniform for all food crops. Different crops respond to salinity differently even at a same level. FAO (2011) sets the threshold value for different crops in response to salinity and their yield potentiality. Threshold value is the value of soil salinity level at which plants start experiencing the impact of salinity in terms of yield loss. Based on the salt tolerance limit, different crops have different threshold value. The higher the threshold value, the more a crop is tolerant to salt and the lower threshold value indicates less tolerant to soil salinity. Table 8 presents threshold value of different winter vegetables and the corresponding percent yield loss.

Table.8 The threshold value and percent reduction of some winter crops on different soil salinity

Crop	% in yield reduction based on different soil salinity (EC in dS/m)		
	0%	10%	25%
Onion	1.2	1.8	2.8
Beans	1.0	1.5	2.3
Potato	1.7	2.5	3.8
Sweet potato	1.5	2.4	3.8
Carrot	1.0	1.7	2.8
Radish	1.2	2.0	3.1
Pepper	1.5	2.2	3.3

Source: FAO, 2011

The yield potentiality of crops is calculated on the basis of per unit increase of soil salinity (EC in dS/m) from their threshold value. The formula of yield potentiality developed by Grattan (2002) has been applied to estimate the yield potentiality in this study. The formula is:

%yield=100-b (ECe-a),

Where a= threshold limit, b= percent of yield loss with the increase in one unit of salinity above the threshold limit, ECe: Average soil salinity in the root zone

To calculate the yield potentiality (table 9), the current study has considered soil salinity at root zone as 3.5 dS/m based upon ICZMP (2003) study where they estimated soil salinity for the particular upazila below 4 dS/m.

Table.9 The yield potentiality of some winter crops

Crop	Yield potential (%)
Onion	72
Beans	66.66
Potato	80.56
Sweet potato	79.2
Carrot	70.58
Radish	74.7
Pepper	77.27

Source: Adapted from FAO (2011), ICZMP (2003) and Grattan (2002)

7.2 Reduction in yield in the study area

Under the current study, 60 households were interviewed to collect information of the farmers who are directly involved in crop production or indirectly involved in agriculture as wage labourer or other activities. While answering the question on yield loss due to salinity, respondents' opinion varied even with the same crop. Therefore, the mode value of the frequency of the respondents' opinion regarding yield loss was taken into account to calculate the amount of crop reduction. The study found that the vegetable crops are more sensitive to the present level of salinity than the cereal crop. Both high yielding and local variety are being practiced in the locality. However, local varieties seemed more likely to have yield reduction than the high yielding variety. In case of the cereal crop, most of the respondents were found practicing high yielding verity rice. On the other hand, in case of vegetables and other non-cereal crops, local variety seemed predominating according to the opinion of the respondents.

Table.10 Yield loss of different winter crops according to the opinion of the local people

YIELD LOSS																							
Rice		Wheat		Potato		Master Seed		Sweet Potato		Amaranth		Data Shak (Local name)		Lentil		Radish		Chili		Onion		Kheshari	
No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal	No. of respondent	Response in kg/decimal
29	No loss	32	No loss	5	No loss	6	No loss	5	No loss	16	No loss	3	No loss	12	No loss	7	No loss	7	No loss	9	No loss	17	No loss
12	1	18	2	12	4	19	2	17	3	*25*	*1*	5	2	14	2	12	3	12	2	10	2	15	3
15	2	10	5	15	5	10	4	14	4	19	2	11	3	9	3	15	5	*19*	*3*	19	2.5	*18*	*5*
4	5	-	-	7	8	*25*	*5*	3	6	-	-	19	4	*18*	*4*	*26*	*7*	14	5	*22*	*4*	10	6
				21	*10*	-	-	*21*	*7.5*	-	-	*22*	*5*	7	6	-	-	8	6	-	-	-	-

Source: Authors' own calculation from Unnayan Onneshan's field visit, 2011[The brown and blue colours indicate the mode value of the number of respondent against yield loss. In each row, 60 responses have been categorized on the basis of their answer. The answer has been categorized from no loss to the highest loss)]

The study also attempted to calculate yield loss of some winter crops compared to 2004-2005 based on people's observation and found that except rice and wheat, all crops showed yield loss (Table 11).

Table.11 Percent reduction of yield (kg/decimal) of some winter crop based on local knowledge

Crop	Yield kg/decimal (2004-2005)	Yield loss kg/decimal (2010-2011)	% yield loss
Onion	12	4	33.33
Radish	27	7	25.92
Chili	20	3	15
Potato	45	10	22.22
Sweet Potato	35	7.5	21.428
Mustard seed	20	5	25
Amaranth	13	1	7.69
Green leaf (Data shak/Local name)	25	5	20
Pulse (Lentil)	15	4	26.66

Source: Authors' own calculation from Unnayan Onneshan's field visit, 2011

Amacher *et al.*, (2000) found that fruits, vegetables and ornamental crops are more sensitive to salt than cereal crop. The similar trend has been observed in the current study.

Case Study 1

Mr. Babul Bepari of Panchkathi village Gosairhat, is a sharecropper. He is 40 years old and he has a wife, 3 sons and 2 daughters. He cultivates 20 decimal of land and has to share 50% of the total production with the landowner. He grows local variety crops. His family lives on rice earned from the shared land. They also live by vegetables from his homestead garden. His family takes protein once a week occasionally. During Robi season, Mr. Bepari cultivates Boro rice. Four to five years back, he used to produce 0.4 metric ton in his cultivated land and shared 0.2 metric ton with his landowner. He used to store his share of rice for household purpose for the whole Boro season. But recently, his production has reduced drastically and in the last year, he was able to produce only 0.08 metric ton from the same area of land in the dry season, where he had to share 0.04 with the landowner. This amount of rice is not sufficient to his family for the whole season and he had to spend 3000 (approximately) taka to purchase rice for the rest of the season. He managed additional money by constraining his budget from other household expenditures; especially from buying protein (meat and fish). Declining food production in the dry season compels him to limit his food diversity which ultimately leads his family members suffering from malnutrition.

High yielding variety of rice and wheat has been practiced in the dry season and these crops are likely to be less sensitive to the present level of salinity. However, local variety of cereal crops is more responsive to present level of salinity and showing a declining trend in production. However, the effect of soil salinity differs depending on the factors like type of the soil, slope of the field, method of irrigation, management of salinity, timing of irrigation, fertilizer and manure practice.

By calculating the yield potentiality of different winter crops in the study area and comparing them with that of the yield potentiality originated from the secondary source, it has been found that both of the yield potentialities are very proximate to each other. However, there is small decline of yield potentiality in the study area compared to the yield potentiality of secondary source (table 12).

Table.12 The yield potentiality of winter crop from the secondary source and the study area

Crop	Yield potential (%) (Using secondary source)	Yield potential (%) (Using the yield loss data from the local peoples' observation)
Onion	72	66.67
Beans	66.66	-
Potato	80.56	77.78
Sweet potato	79.2	78.57
Carrot	70.58	-
Radish	74.7	74.08

Source: Column 2 adapted from FAO (2011), ICZMP (2003) and Grattan (2002) and Column 3 authors' own calculation, 2011

This is because, apart from the salinity hazard, cold wave, pest invasion and industrial pollution mainly from brick filed are also some hazards prevalent in the dry season according to the opinion of the local people. However, the effect of soil salinity may also differ depending on the factors like type of the soil, slope of the field, method of irrigation, management of salinity, timing of irrigation, fertilizer and manure practice. These factors may also play an important role to make difference between the yield potentiality found from the study area and from other sources.

Table.13 Total yield loss against the total cultivable land of different winter crop

Crop	Total cultivable land (ha)	Yield loss (ton/ha)	Total yield loss (ton)
Onion	30	0.988	29.64
Potato	200	2.47	494
Sweet potato	87	1.85	160.95
Master seed	1229	1.235	1517.8
Chilli	2100	0.741	1556.1
Pulse (Lentil)	300	0.988	296.4

Source: Column 1(DAE, 2010) Column 2 and 3 from authors' own calculation.

7.3 FUTURE SALINITY SCENARIOS AND ITS IMPACT ON FOOD SECURITY

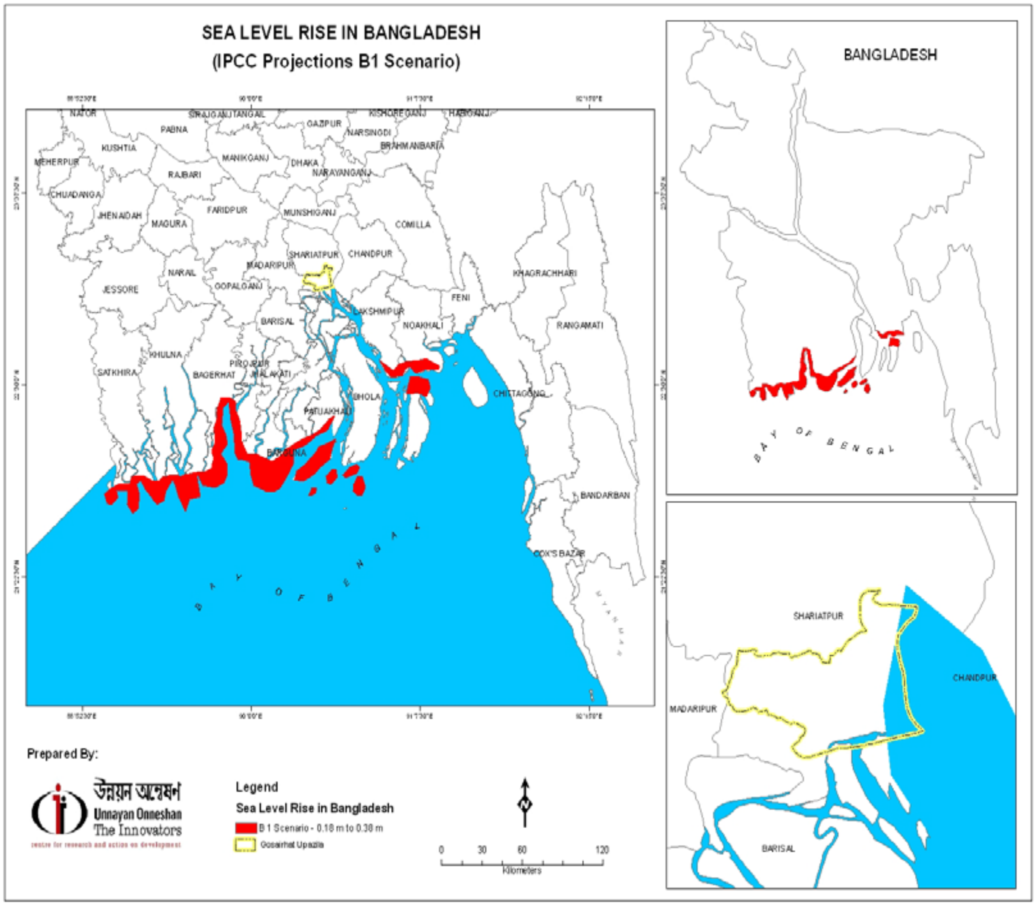
It seems that the present level of salinity in the study area is below the threshold limit of some cereal crops like rice (high yielding variety) and wheat etc. However, the vegetables, pulse, oil seed and other non-cereal crops have shown a considerable decline at the present level of salinity. Any increase in the sea level is likely to bring more area under tidal inundation. It has been found from different scenarios of sea level rise projected by World Bank (2000), IPCC (2007) that the new area will be saline effected, and the existing areas will experience an increased level of salinity in future. When the level of salinity in soil or surface water crosses the tolerance limit of rice and wheat, a huge loss may occur and therefore, the food security and the livelihood of the study area will be under gravest threat.

7.3.1 Future projection based on IPCC scenarios

Due to the effect of global warming, the temperature is showing an increasing trend over the decades and around 0.2°C /decade has been estimated for the coming two decades for a range of SRES scenarios described in the "IPCC Special Report on Emissions Scenarios". Even when the emission of green house gases and aerosols are kept stable at the level of 2000, a further warming approximate to 0.1 degree/decade would be expected due to current concentration of GHGs in the atmosphere. Therefore, the possible cause of sea level rise like thermal expansion is more likely to influence the rise in the sea level. Any increase of sea level will cause more seawater movement to inland and new area would be subjected to tidal penetration.

IPCC (2007) at its Fourth Assessment Report (AR4) has predicted six scenarios for global average sea level rise at the end of the 21st century against the global warming. The scenarios are B1, A1T, B2, A1B, A2, A1FI. The current study has considered four scenarios such as B1, B2, A2 and A1FI to project future salinity condition and its likely impact on the study area.

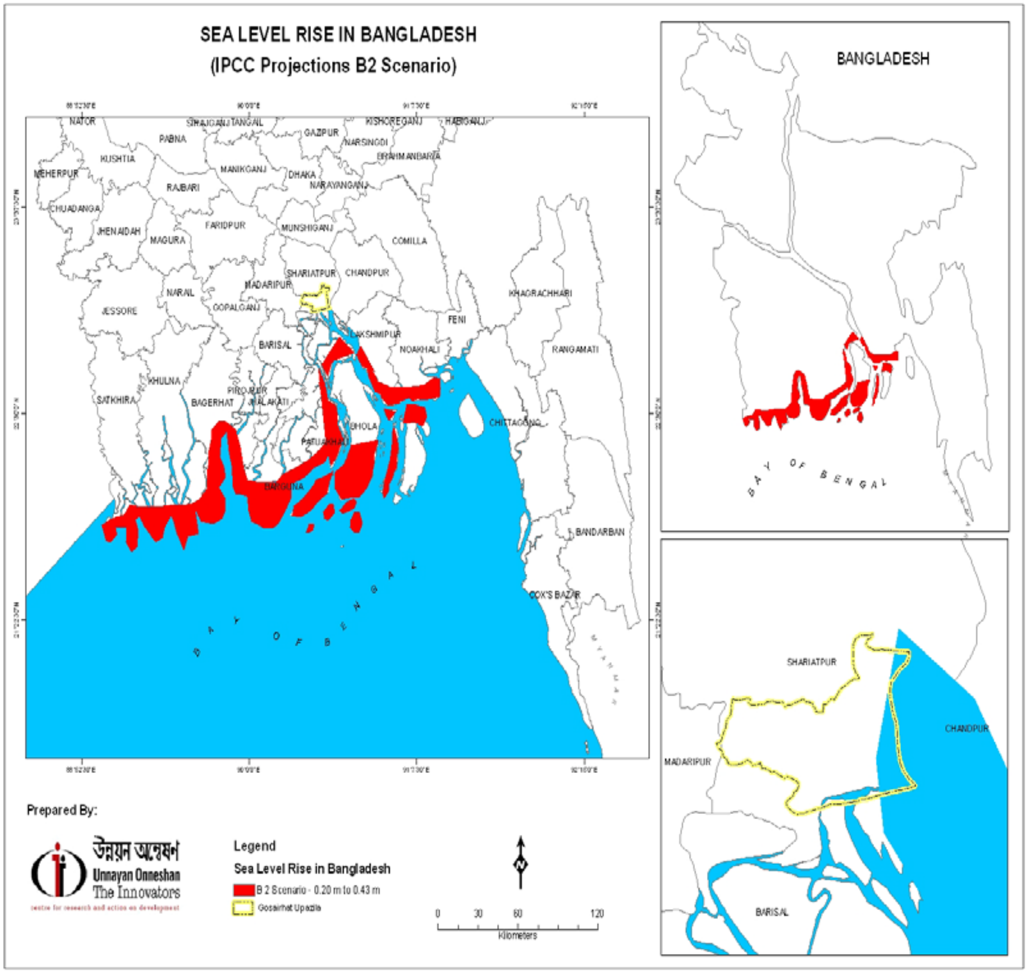
Figure: 9(I) Future scenarios B1 on IPCC prediction



Source: Unnayan Onneshan, 2011

B1 scenario: The scenario has been predicted for the year 2099 against the best estimated temperature increase of 1.8°C (the likely range is 1.1-2.9) compared to the year 1980-1999 (the upper end of the sea level rise has been counted),and the emission at 600 ppm. Under this low ambitious scenario, the Gosairhat upazila seems to be less affected by further tidal inundation. However, still there is risk of salinity increase due to seawater intrusion in the lower Meghna and the Jayantia River during high tide scenario.

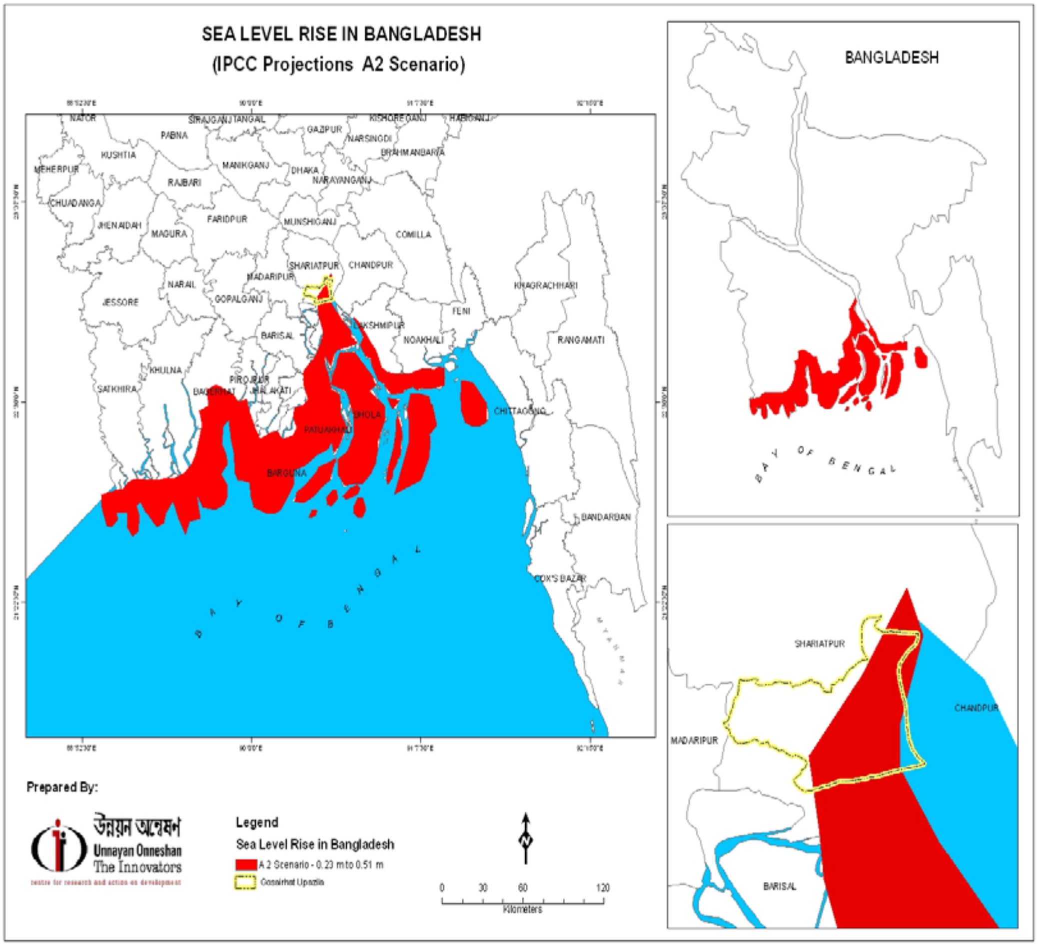
Figure: 9(II) Future scenarios B2 on IPCC prediction



Source: Unnayan Onneshan, 2011

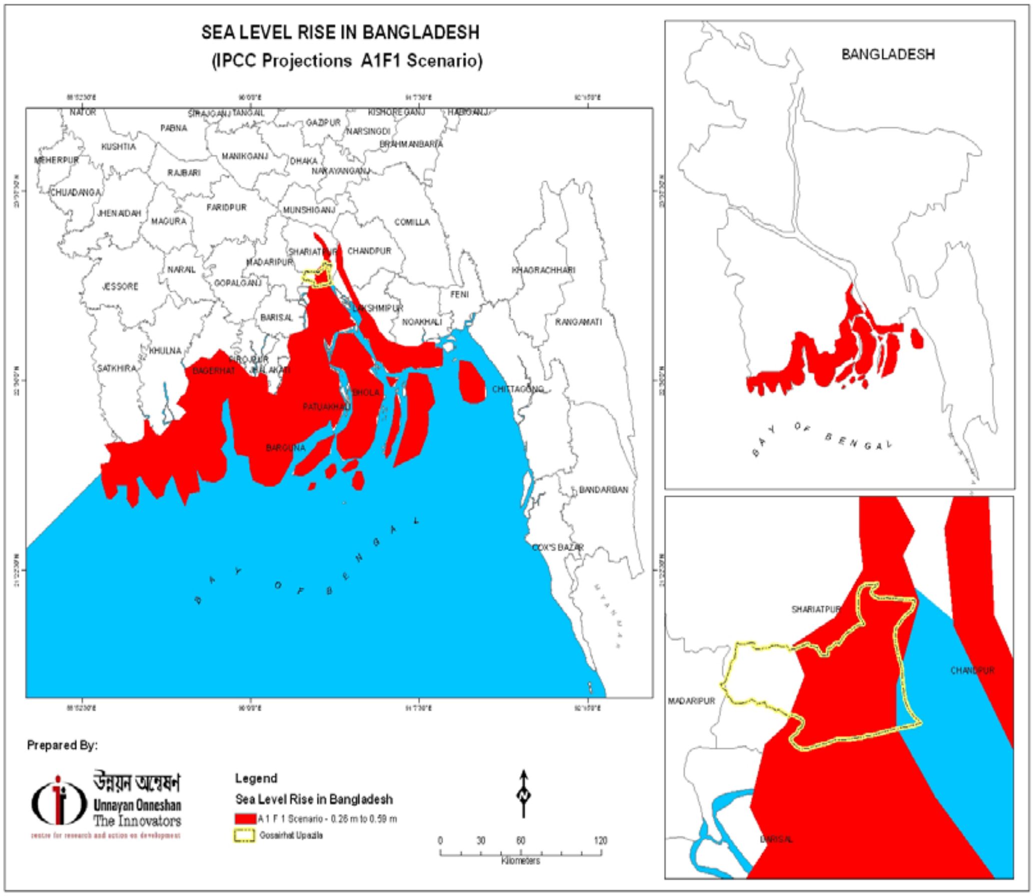
B2 scenario: The scenario has been predicted for the year 2099 against the best estimated temperature increase of 2.4°C (the likely range is 1.4-3.8) compared to the year 1980-1999 (the upper end of the sea level rise has been counted) and the emission at 800 ppm. The land area of Gosairhat is also likely to be beyond the threat of tidal penetration. However, salinity movement towards the water bodies, adjacent to the study area will be continued through the lower Meghna and the Jayantia River under the scenario.

Figure: 10(I) Future scenario A2 on IPCC prediction



Source: Unnayan Onneshan, 2011

A2 scenario: The projection of global average sea level rise at the end of the century has been projected against the best estimated temperature (3.4° C) increase. The likely range is 2.0-5.4 compared to the year 1980-1999 (the upper end of the sea level rise has been counted). The scenario is estimated against the emission 1250 ppm. According to the scenario, 41.63% of the total land area of Gosairhat upazila will be under the coverage of tidal inundation at the end of the century. It implies that more area will be saline affected and existing saline effected area will experience an increased salinity level. Under this scenario, it is projected that Boro rice and wheat production will be declined approximately 15354.38 MT and 355.50 MT respectively in 2100 against the base year 2010.



Source: Unnayan Onneshan, 2011

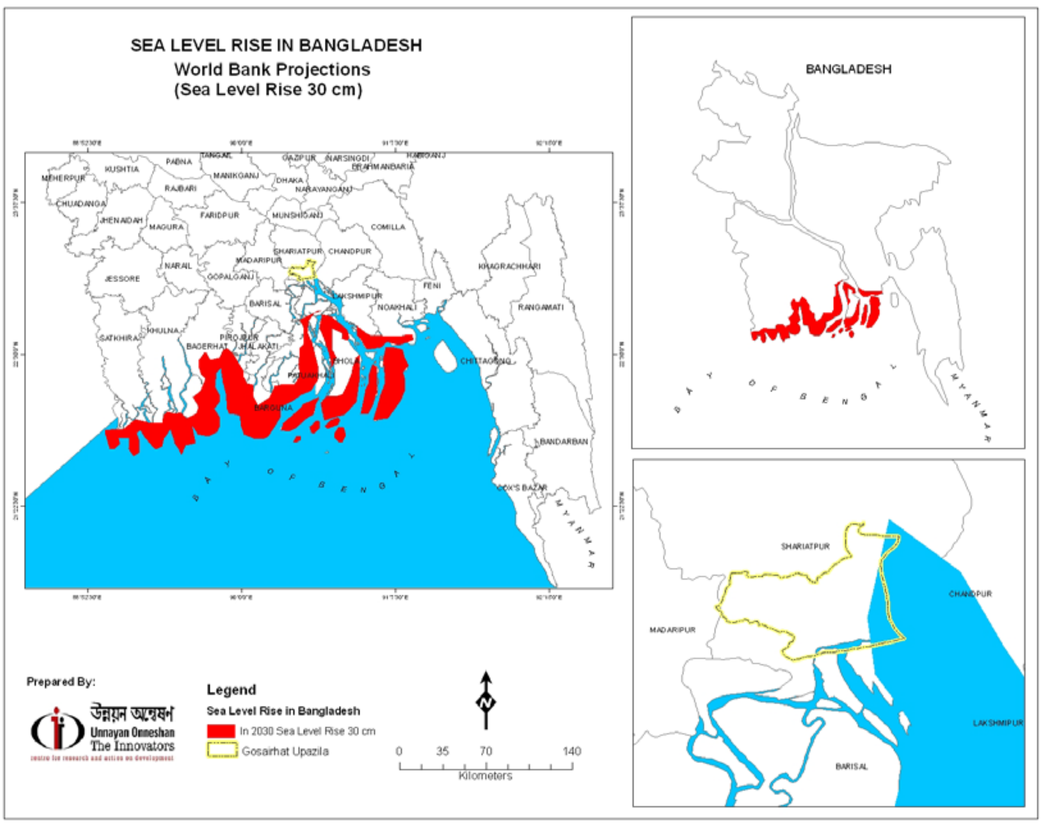
A1FI scenario: The scenario has been projected against the emission 1550 ppm and the best estimated temperature 4° C compared to the year 1980-1990 where the likely range of temperature is 2.4°C-6.4°C. The tide will move through the most part of Gosairhat and will be extended to northern part of Shariatpur district. Under this scenario, it is assumed that 79.3% area of Gosairhat will be penetrated by tidal water. Consequently, the area would experience a drastic decline in Boro rice and wheat production. It is projected that by the year 2100, the study area will experience 29249.30 MT of Boro rice and 677 MT of wheat against the base year 2010 under A1FI scenario.

IPCC scenario A2 and A1FI warn for a bleak future where the study area is likely to experience drastic decline in rice and wheat production by the 2099 against base year 2010. Therefore, a huge number of people in the whole country are likely to experience hunger and will lose their accessibility to food. Considering per day intake of rice and wheat as 416.01gm and 26.09gm respectively (HIES, 2010), it is estimated that approximately 102526 may face food insecurity due to rice shortage and 37859 people may face food insecurity due to wheat shortage respectively under A2 scenario at the end of the century. On the other hand, 195308 and 72098 people will face food insecurity under A1FI scenario for the decline in production of rice and wheat respectively at the end of the century.

7.3.2 Future Projection Based on World Bank Scenario

Targeting Bangladesh, World Bank (2000) produced sea level rise scenarios for the year 2030 and 2050 based on the increase in temperature and precipitation fluctuation compared to the year 1990. Based upon World Bank's sea level projection, the current study also produced two scenarios on sea level rise and its probable impact for the study area at 2030 and 2050 respectively (Fig. 11) .

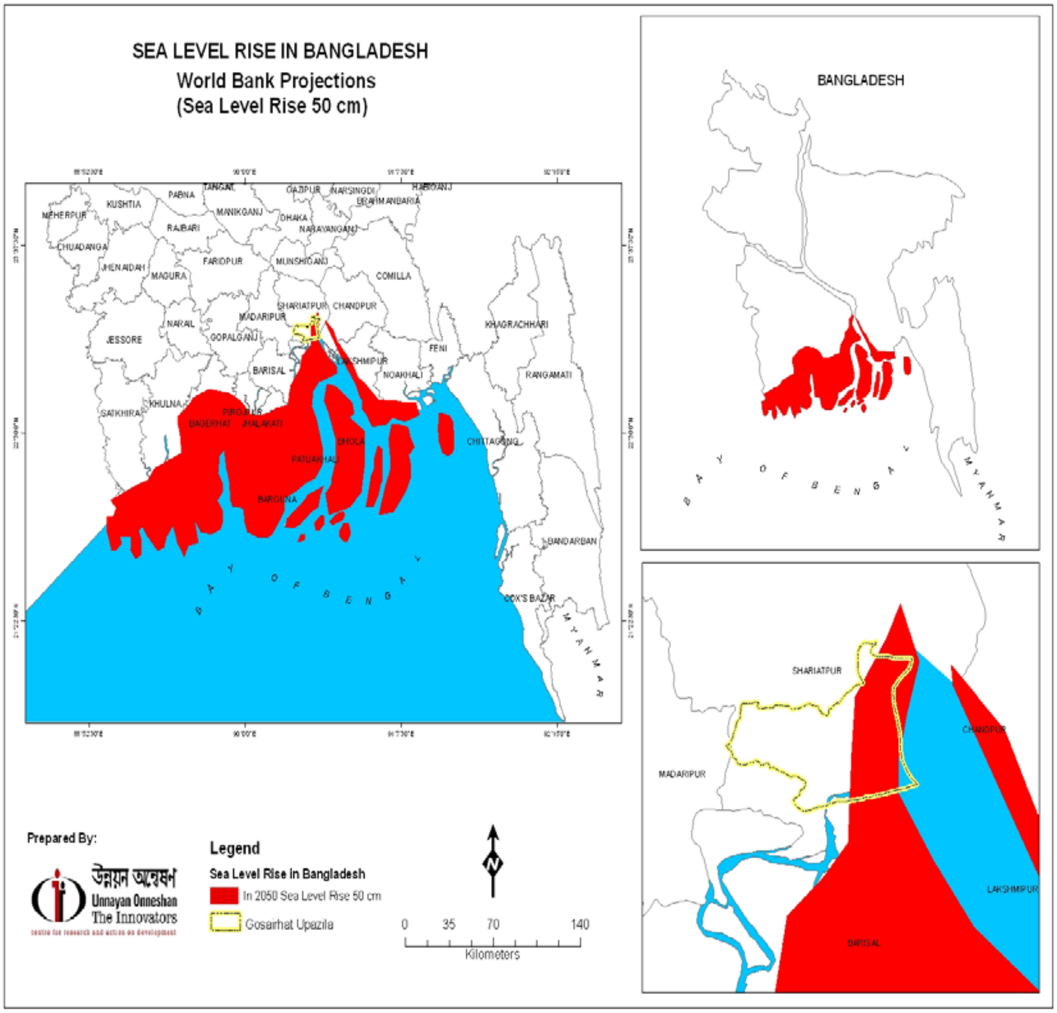
Figure: 11(I) Future scenario based on World Bank (2030) prediction



Source: Unnayan Onneshan, 2011

According to the World Bank (2000) prediction of sea level rise by 2030, the land area of Gosairhat is less subject to tidal inundation. However, salinity may increase from current level due to tidal penetration in the lower Meghna and the Jayantia River.

Figure: 11(II) Future scenario based on World Bank (2050) prediction



Source: Unnayan Onneshan, 2011

On the other hand, 2050 scenario shows significant area coverage under tidal penetration, which is approximately 42% of total land area. This scenario implies that the study upazila will experience a decline in Boro rice and wheat of 15491.86 MT and 358.68 MT respectively in 2050.

Considering per capita daily intake of rice and wheat as 416.01gm and 26.09gm respectively (HIES, 2010), World Bank scenario for the year 2050 implies that 103445 and 38198 people per year may face shortage of rice and wheat respectively.

7.3.3 Future Projection based on the current salinity level

In the study area, the concentration of salinity shows an increasing trend over the years. Existing salinity concentration of surface water has been estimated as 1.3 dS/m through sample test which is 0.4 dS/m higher than the earlier estimation by ICZMP (2003). Taking into account the salinity increase trend over the 8 years, it is projected that at the end of 2030, the salinity level may be close to 2.3 dS/m, if other factors remain constant. However, the desired level of salinity in irrigation water is 1.5 dS/m (www.soilfirst.com). An increased level of salinity from the desired level will deteriorate the quality of irrigation water and increase the leaching requirement of a crop. Higher leaching requirement will make the production coast higher. Moreover, after a certain level of salinity, irrigation water will lose its leaching capacity.

8. SOLUTION TO ADRESS THE SALINITY PROBLEM

Theoretically, salinity in soil is not difficult to manage. Leaching[1] salt from soil is a widely used practice for soil salinity management which can be either natural or artificial. Naturally, rainfall contributes to leach salt from soil surface but in dry season when rainfall is insufficient, the artificial process or irrigation should be applied. To manage salinity, more water needs to be applied other than regular water requirement of the crop. However, there is a high risk of increasing salinity content at root zone in case of irrigation with saline contaminated water.

In case of high concentration of salinity in root zone, deep-water irrigation is required. If soil salinity is too high comparing to the desired level of a certain vegetable in its root zone and the root is 12 inch depth, 6 inch of water is capable of leaching salinity by 50% and 12 inch of water is capable of leaching salinity by 80% and 24 inch by approximately 90 %(Amacher et al., 2000). Irrigation method and adequate drainage are also influential aspects of managing soil salinity. Simple surface water run-off cannot leach soil salinity rather water should be drained through soil. Therefore, deep tillage is required to ensure internal drainage as it is very important to break up the restraining layer that delays water movement. In this regard, sprinkler irrigation provides a better control of water application rates. Flood irrigation can also be used in an effective manner if the sites are plain and water application is controlled.

Irrigation water quality has a great influence on crop production as well as on soil salinity management. Irrigation water contains various dissolved minerals. However, the minerals or

[1] Grattan (2002) defined the leaching process as “Leaching is the process of applying more water to the field than can be held by the soil in the crop root zone such that the excess water drains below the root system, carrying salts in it.”

salts and their concentration as well as composition vary largely depending on the source of irrigation water. Surface water is the principal source of irrigation water in the study area. The electrical conductivity of the irrigation water in the study area has been estimated as 1.3 dS/m. Bauder *et al.*, (2007) has estimated 2,000 lb of salt for each acre foot of water with electrical conductivity 1.15 dS/m. Therefore, leaching is highly required especially during winter in the study area. To calculate the leaching fraction or requirement for the different winter crops, the following equation developed by FAO (2011) is applied. To estimate the leaching requirements, the salinity in irrigation water and threshold limit or crop tolerance to soil salinity ought to be known. The equation is:

LR= ECw/ 5 (ECe)- ECw [*Where, LR= the minimum leaching requirement needed to control salts within the tolerance (ECe) of the crop with the ordinary surface method of irrigation]*

ECw= Salinity of the applied irrigation water in dS/m

ECe= average soil salinity tolerated by the crop as measured on a soil saturation extract.]

Leaching fraction is a percentage of water that needs to be applied in the field so that it can drain the root zone. Leaching fraction of 1/10 or 10 percent indicates that if 1 acre-foot of water is applied in 1 acre of land, the water drains below the root zone is 0.1 acre-foot (Grattan, 2002). Applying the above stated formula, the leaching requirement of some major winter crops of the study area have been given below.

Table.14 Leaching requirement for different winter crops

Crop	Leaching Requirements for 100% yield potential	Leaching Requirements for 90% yield potential
Onion	0.27	0.168
Beans	0.35	0.20
Potato	0.18	0.116
Sweet potato	0.209	0.12
Carrot	0.35	0.18
Radish	0.27	0.149
Pepper	0.25	0.13

Source: Authors' own calculation, 2011

The leaching requirement of different crops varies according to their threshold limit or tolerance to soil salinity. The leaching requirement may also vary on the percent of yield a producer desires. The more percent of yield a producer desires, the more leaching is required. The tolerance values of different crops of a certain geographic area should be used as a guide for the farmer or producer to choose what crop they should produce to have the optimal production from that physical condition. In the study area, neither the agricultural office nor the farmers are informed about the salt tolerance limit nor they have any chart; rather, the study used tolerance value of different winter crops from other countries' experience. The crops, which have a higher threshold value, are likely to have lower leaching requirements and therefore, will require a less amount of irrigation water. On the contrary, low tolerance value requires high leaching that means that more water is needed to increase the yield potentiality which results into high production cost. Moreover, salinity in irrigation water also influences the soil salinity and its pH. Higher pH in soil is likely to create a deficiency of nutrient like phosphorus, iron etc. To reclaim the nutrients, appropriate fertilizer should be applied against the deficiency of certain nutrient. For example, to address the deficiency disease named 'Lime –induced Chlorosis', an iron deficiency disease, Iron Sulphate needs to be applied in the soil (Gale *et al*., 2001). High pH due to high salinity usually causes carbonate and bi carbonate salt to be insoluble and therefore, creates calcium and magnesium ion deficiency with the dominance of Sodium ion. To address the problem, Gypsum or Calcium Sulphate could be applied to release Calcium ion and replaces Sodium ion (Gale *et al.*, 2001).

Timing of irrigation is another important factor in managing salinity. A dry and hot day is likely to evaporate more water from soil and therefore, cause more salt to be concentrated in the plant root zone. Therefore, for irrigation, a cool and humid weather or night is preferable. The frequency of irrigation should be increased in case of a hot and dry weather to address salinity stress.

9. CONCLUDING REMARKS

Salinity concentration increases in soil due to a range of factors like type of soil, slope and draining system of field, irrigation method and management, practice of manure and fertilizer (Bauder, 2007). The exposed coast and some areas of the interior coast in Bangladesh have already exceeded the threshold limit of tidal movement and salinity intrusion (ICZMP, 2003). Even though, Gosairhat upazila, an interior coast, has already crossed the threshold value of tidal fluctuation but it is still below the threshold limit of salinity intrusion. However, the salinity levels both in soil and surface water in the area is in an increasing trend. Climate change has been accelerating the salinization process through sea level rise and increased evaporation from higher temperature. Rising sea level is likely to penetrate more seawater to inland and bring more area under the coverage of tide infiltration. Cyclone and storm surge is also likely to increase the height of tidewater onto the river and the frequency of cyclone has already shown an increasing trend due to climate change. Bangladesh has already been ranked in the topmost vulnerable countries to cyclone in terms of the number of the population exposed (UNDP, 2004 cited *in* BCCSAP, 2009). Moreover, the concentration of salinity in river water is also likely to be increased when the magnitude of tidewater onto the river will be more. An increasing trend of salinity concentration in the river water has already been found in the study upazila. The study area experiences salinity due to tidewater movements in different canals of the lower Meghna that crosses the upazila. Moreover, higher rate of evaporation from soil also contributes to increasing salt concentration in soil. Therefore, salinity problem becomes acute in hot and dry season than that of wet season. Furthermore, a trend of decreasing rainfall in winter has already been predicted (World Bank, 2000) which will hinder natural leaching process of soil salinity. IPCC (2007) predicted an approximate 59 cm of rise in the sea level by the year 2099 relative to the year 1980-1999 (considering the upper end of the sea level rise). In that scenario, a significant land area in the lower Meghna, including the study area of Gosairhat, will experience a tidal water inundation and therefore, salinity concentration in both soil and water will increase into many folds along with some permanent water logged areas. Present salinity concentration has already put a threat to the crop production and a significant yield loss has already been observed in the dry season. In the changing scenario of the sea level rise, it has been predicted that the increasing concentration of salinity will create more pressure to the farmer by reducing yield on one hand and threatening livelihood, income generation and food security on the other hand.

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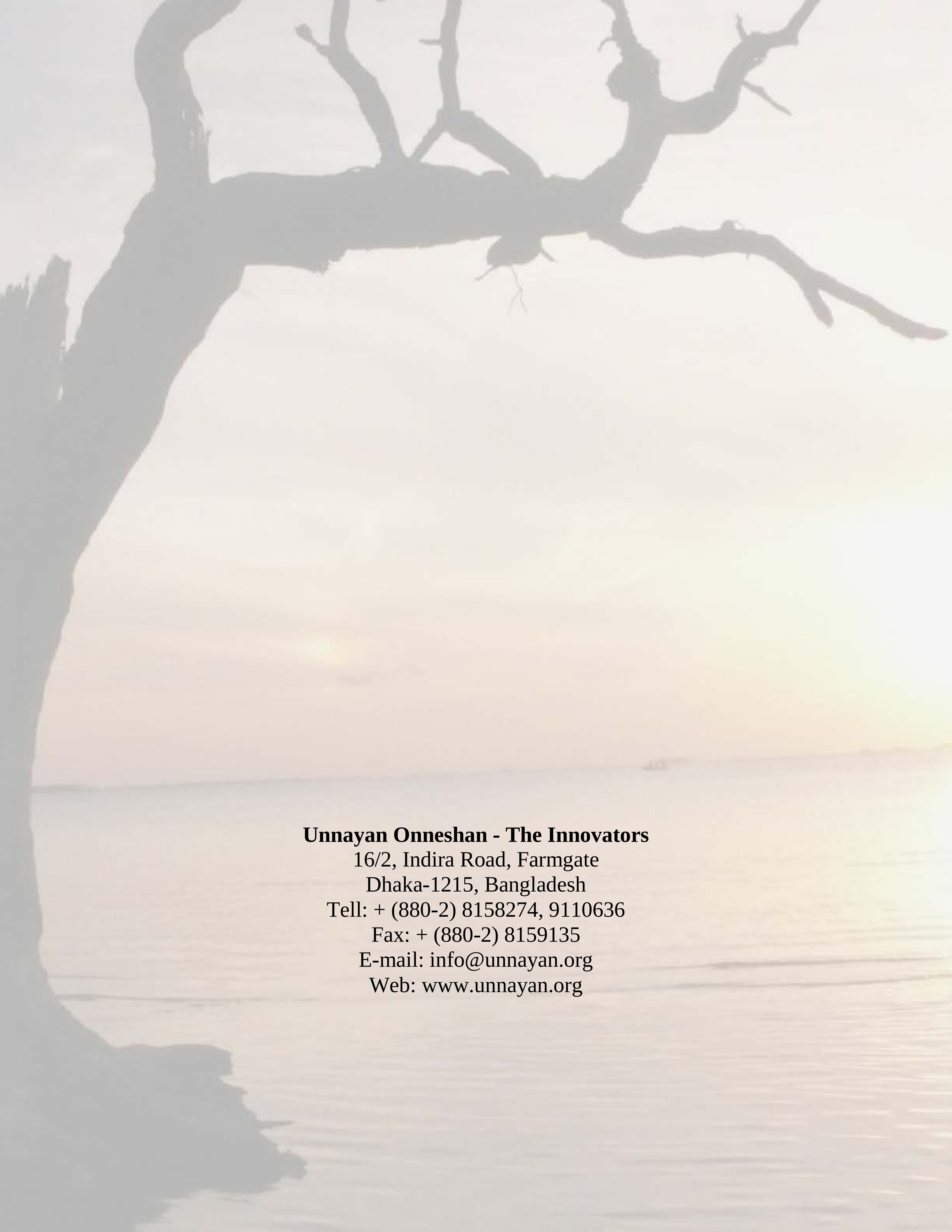

Unnayan Onneshan - The Innovators
16/2, Indira Road, Farmgate
Dhaka-1215, Bangladesh
Tell: + (880-2) 8158274, 9110636
Fax: + (880-2) 8159135
E-mail: info@unnayan.org
Web: www.unnayan.org