# Salinity Risk to Agricultural Landuse due to Sea Level Rise: A Case Study in Dhalua Union of Barguna Sadar Upazila

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**Post Graduate Diploma**

**in Water Resources Development**

**Institute of Water and Flood Management**

**BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY**

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by

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**In partial fulfillment of the requirement for Post Graduate Diploma in Water Resources Development**

**Institute of Water and Flood Management**

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The project report titled **‘Salinity Risk to Agricultural Landuse due to Sea Level Rise: A Case Study in Dhalua Union of Barguna Sadar Upazila’** submitted by Md. Abdullah Al Baky, Student ID: 1009281002, Session: October 2009, has been accepted as satisfactory in partial fulfillment of the requirements for Post Graduate Diploma in Water Resources Development on June 2013.

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**CANDIDATE'S DECLARATION**

It is hereby declared that this report or any part of it has not been submitted elsewhere for the award of any degree or diploma.

…………………………..

Md. Abdullah Al Baky

Student ID: 1009281002

*Dedicated to*

*.......................................................................*

*My beloved parents*

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# ABBREVIATIONS

| Term | ABBREVIATIONS |
| --- | --- |
| Aman | Aman is a one kind of paddy variety which usually sowed mid March to mid August and harvested time is Mid Nov. to Mid December. |
| ASTER | Advanced Spaceborne Thermal Emission and Reflection Radiometer |
| Boro | Boro is a one kind of paddy variety which usually sowed mid November to mid February and harvested time is April to May. |
| BWDB | Bangladesh Water Development Board. |
| Ca | Calcium |
| Cl | Chlorine |
| ESRI | Environmental System Research Institute. This organization provides GIS related services. |
| GEBCO | General Bathymetric Chart of Ocean |
| GPS | Global Positioning System |
| HYV | High Yielding Variety |
| K | Potassium |
| Kharif | Winter Crop Season |
| Mg | Magnesium |
| mha | Mega Hector |
| Na | Sodium |
| SAARC | South Asian Association of Regional Cooperation |
| SC-55 | South Central – 55 |
| Spline | An Interpolation Technique |
| SRTM | Shuttle Rudder Topographic Mission |
| TDS | Total Dissolved Solid |

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# ABSTRACT

Gradual increase of areal extent of saline water with sea level rise in coastal region may cause a serious alarming situation for agriculture. Salinity affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases the total yield is lost. In this study, historic high tidal water level data in the study area shows a rising trend which indicates the increase of areal extent of tidal inundation in future. In addition, concentration of salinity shows an increasing trend over the years in the area. So there is a possibility of having consequence of increasing saline water concentration as well as areal extent of saline water with different levels in future. In this connection, the present study shows, the agricultural land use risk from salinity perspective due to sea level rise from 2015 to 2030 in Dhalua Union under Barguna Sadar Upazila. The study findings also show that, all water level stations are observing a rising trend which also influences on high tidal inundation extents in different years. Inundation extent will become more than doubled estimated to 9.64 sq. km to 20.58 sq.km from the year 2015 to 2030. In 2015, about 38% of total agricultural land will be inundated by peak high tidal inundation which will be also more than doubled in 2030. There is an inverse relationship exist between high tidal water level and salinity (Ec) level. Peak high tidal inundation with sea level rise induced salinity concentration will be decreased in future. The Dhalua union occupies a total 25.16 sq. km of agricultural land of which, in 2015, 17.52 %, 12.67 %, and 8.50 % agricultural land will be under moderate, high and very high risk categories respectively. In 2020, about 0.299 sq.km of agricultural land will be under low risk of salinity (441 – 680) which is absent for 2015 and on the other hand, no agricultural land will be found under very risk of salinity. Moderate risk of salinity area will be significantly increased amounted to 47.45 % of total agricultural land in 2020. In 2025, 75.31 % of total agricultural land will be under low risk of salinity. Almost 95 % of the inundated crop area will be exposed by very low risk of salinity and remaining will be under low risk of salinity in 2030.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the Study

Tidal effect in coastal region of Bangladesh is one of the noteworthy problems especially for farmer groups. On the other hand, for shrimp and salt cultivators saline water caused by tidal water intrusion is beneficial. But gradual increase of areal extent of saline water in coastal region will cause a serious alarming situation for agriculture. Salinity affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases the total yield is lost (Haque, 2006). In southwestern coastal region of Bangladesh salinity has gone at such a level where normal agriculture is difficult if not impossible. As a result, almost total cultivable areas in the region are used for shrimp cultivation. At present, from salinity perspective, the southeastern coastal part is not as much vulnerable as the southwestern coastal part. About 15 % and 60 % of arable land (total 1.0 mha of croplands) of southeastern and southwestern Bangladesh, respectively are affected by salinity during dry periods (Rahman, 2006).

The worse situation in southwestern part has caused mainly by low upstream fresh water flow carried by Gorai – Madhumati - Kobadak Rivers. But comparatively, more fresh water coming from the Meghna – Kirtankhola - Paiyra and Bishkhali Rivers makes the southeastern coastal part more liveable than southwestern coastal part. But high tidal water level data at southwestern coastal zone shows a rising trend which indicates the increase of areal extent of tidal inundation in future at those regions. Moreover, impact of sea level rise is also accelerating this problem. Otherwise, concentration of salinity shows an increasing trend over the years in the coastal part. Taking into account the salinity increasing 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 (Seal and Baten, 2012). So there is a possibility of having consequence of increasing saline water concentration as well as areal extent of saline water with different levels in future. As a result, coastal agricultural landuse would be fallen in risk from salinity perspective.

The proposed study will show the agricultural land use risk from salinity perspective in future. For this study, Dhalua union under Barguna Sadar upazila of Barguna district has been chosen. The study area is situated on eastern bank of the Bishkhali River of which at southern side Bishkhali, Paiyra and Bay of Bengal confluence is located. In the study area, saline water enters from western and southern part. This study will help make a basic foundation for coastal zone management from the salinity perspective.

## 1.2 Objectives of the Study

The objective of the study is to evaluate the coastal agricultural land use risk from salinity perspective due to sea level rise.

The followings are the specific objectives to achieve the main objective:

1. To prepare the agricultural land use risk maps due to high tidal inundation, and.
2. To evaluate spatial variation of water salinity levels and the associated agricultural risk in the study area.

## 1.3 Organization of the Report

This report is divided in six chapters. Chapter one describes background and objectives of the study. Chapter two provides a literature review relevant to the study objectives. Chapter three presents a description of the study area. The description includes information on climate, river system of the region, water resources system, etc. Chapter four explains the tools and methodology followed in the study in data collection and analysis. Results of the study are presented in chapter five along with discussion of the results. Chapter six includes conclusion and recommendations of the study.

## 1.4 Limitations

1. Data availability was one of the major constraints of the study. Delineation of high tidal inundation in the study area is mainly based on extrapolated water level data derived from time series analysis of 30 year. More data analysis may change the extrapolated water level value which in turn effect on inundation depth and extent.
2. Hydraulic model couldn't be done for the study purpose. Instead of this interpolation technique has been adopted which does not consider internal drainage system.
3. More historic data on water salinity could lead a better extrapolation analysis for finding the future salinity concentration in the river system. But it was not possible due to having lack of available data.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

As a part of literature survey, reports on salinity risk to agricultural land use of different areas were studied for baseline ideas and planning. For the general knowledge, different reference books, existing reports and articles based on salinity, agriculture and sea level perspective of coastal region of Bangladesh were followed and studied. Articles and reports on high tidal inundation mapping using GIS and possible sea level rise causes of it were also collected from the website and the different journals.

## 2.2 Salinity Problem

Salinity means the presence of major dissolved inorganic solutes like $Na^{+}$, $K^{+}$, $Mg^{2+}$, $Ca^{2+}$, $Cl^{-}$etc. in aqueous solution. The presence of soluble salts in the groundwater and surface water bodies as well as in the soil is one of the major environmental problems worldwide. Salinity causes many economic and environmental costs. These include reduction in agricultural productivity, decline in the quality of water supplies for drinking, irrigation and industrial use, loss of biodiversity in both terrestrial and aquatic ecosystems and also damage to urban infrastructure. The United States Department of Agriculture estimates that, worldwide, 10 million hectares of arable land is lost due to irrigation salinity every year (USDA, 2000).

Researcher and scientist have classified salinity level class depending on various aspects like drinking water quality purpose, agriculture and irrigation purpose etc. However, two salinity classifications, one is on quality characterization of water and another is water salinity for irrigation purpose has been included here.

Karim and Hussain (2006) showed the quality characterization of water which is given in Table 2.1.

Table 2.1: Quality Characterization of Water

| Class | ECw,µS/cm | Quality characterization |
|---|---|---|
| 1 | < 1500 | Extra fresh |
| 2 | 1500-3000 | Fresh, slightly saline |
| 3 | 3000-5000 | Brackish, moderately saline |
| 4 | 5000-10000 | Saline |
| 5 | 10000-15000 | Highly saline |
| 6 | >15000 | Excessive saline |

(ECw,dS/m) means Electrical Conductivity of water at $25C^0$ expressed in deci-Siemens per meter. J. W. Bauder et al. (2008) divided water salinity into three classes for irrigation purpose as given in Table 2.2.

Table 2.2: Water Salinity for Irrigation Purpose

| Salinity class | Salinity (ECw, µS/cm) | TDS (mg/L) |
|---|---|---|
| None | < 750 | < 450 |
| Moderate | 750-3000 | 450-2000 |
| Severe | >3000 | >2000 |

Increasing salinity is one of the most significant environmental problems posing around the globe. The sea level rise is also exacerbating the situation of salinity incursion for the coastal regions in many parts of the world including Bangladesh.

## 2.3 Salinity Situation in Bangladesh

Water and soil salinity are normal hazards in the coastal area of Bangladesh. Water salinity is making the lives of people miserable. In Bangladesh, coastal areas constitute about 2.5 million hectares which amount to about 25 percent of the total cropland of the country. Of this, nearly 0.84 million hectares are affected by varying intensities of salinity, resulting in very poor land utilization (Karim, 2006). The areas are traditionally restricted the cultivation of Aus, Boro (HYV) and dry season Rabi crops.

Maximum soil salinity was observed in pre-monsoon, whereas, minimum was in monsoon in coastal districts. It is observed that soil salinity starts increasing from post-monsoon and continued to increase in pre-monsoon when it reaches the highest level. The eastern part of the sundarbans categorized to moderately saline to saline and in the west belongs to highly saline (20-56 µmhos/cm) (Banglapedia, 2006). Soil salinity shows a rising trend towards west from northeast. In case of seasonal variation, it shows an upward trend in February and reaches a maximum level in April-May but during monsoon (June) it declines sharply. The presence of salt water in the rivers upstream of the estuaries makes the use of groundwater near the river problematic, as there is a risk that salt water will be drawn into the aquifer.

Negative effects of increasing salinity are not limited to economic activities, such as productivity of agricultural crops, and availability of water suitable for industrial uses, river water salinity has also significant implications for the natural environment, such as functioning of the Sundarban ecosystem, sedimentation rates in tidal rivers, and human health. Human health is especially influenced by saline water if it is used for drinking as well as domestic purposes. With the increased density and distribution of salinity, cholera germs are getting favorable habitat and spreading in the coastal area. *Vibrio cholerae* is the causing microbe of cholera that survive longer with salinity level ranging from 2.5 ppt to 30 ppt and need Sodium ion ($Na^+$) for growth which is supplied from sea water intrusion (Sarwar and Mahbub, 2005).

Bangladesh has been identified as one of the most vulnerable countries to the impacts of global warming induced accelerated sea level rise. Taking the greenhouse gas-emission scenarios from 3rd IPCC, it is estimated that the global rise in sea level from 1990 to 2100 would be between 9 and 88 cm (IWM and CEGIS, 2007). In Bangladesh, 10 cm, 25cm and 1 m rise in sea level by 2020, 2050 and 2100; affecting 2%, 4% and 17.5% of total land mass respectively (Sarwar and Mahbub, 2005). Both water and soil salinity along the coast will be increased with the rise in sea level, destroying normal characteristics of coastal soil and water.

Apart from sea level rise reason of salinity increase, withdrawal of upstream flow of freshwater also significantly increases salinity in Bangladesh. Distributaries of the Ganga River, Gorai - Madhumati, and Baleshwar are the main sources freshwater to the coastal belt. Those rivers are vital for keeping the state of salinity to tolerable limits in different coastal regions. Studies show that a maximum of 5,000 cusec of steady fresh water in the Gorai are required to hold the salinity of Khulna zone below 1,000 µmhos/cm level (Banglapedia, 2006). During Pakistan period, Farakka Barrage was constructed by India, about 18 km upstream near Monohorpur, to save Calcutta Port from silting, but in turn the process causing huge dry season freshwater cutoff resulting salinity increases in southwestern Bangladesh. In response to this, in December 1996, a 30-year Ganges Water Sharing Treaty was signed between Bangladesh and India.

The flow reduction by the barrage had caused excessive siltation, a rise in riverbeds which in turn reduce the conveyance capacity of the river channels, resulting in aggravated floods during the monsoon. The offtake of the Gorai River, the main distributary of the Ganges in Bangladesh, got choked every year as early as January, making dry period freshwater deficiency resulting sea water intrusion towards north from south causing salinity intrusion. It is also reported that, several upazilas of Bagerhat district such as Kachua, Mollahat, and Fultali south of the Sundarbans were known to be non-saline in the pre-Farakka period which have began to develop soil salinity during the low flow seasons of 1980s (Uddin et al, 2011). Banglapedia (2006) suggests that, in 1983, the 500 micro-mhos (salinity) line reached about 13 km north of Kamarkhali (Upazila of Faridpur) and 17,100 micro-mhos salinity was also observed at Khulna.

## 2.4 Sea Level Rise and Salinity Problem in Bangladesh

Climate change and consequent sea-level rise have aggravated the salinity dilemma. As sea level continues to rise the associated effects of permanent inundation is likely to increase the salinity near coastal areas. Khan and Awal (2009) showed from an estimation by Water Resource Planning Organization in 2006, it is predicted that about 14, 32 and 88 cm sea-level rise will occur at 2030, 2050 and 2100, respectively which may inundate about 8, 10 and 16% of total land mass of Bangladesh. A study shows a more specific picture in coastal zone, by SAARC Meteorology Research Centre showes that Hiron Point, Char Changa and Cox's Bazar raised 4.0 mm/year, 6.0 mm/year and 7.8 mm/year respectively, observing tidal gauge record of the period 1977-1998 (SMRC, 2000). At base line situation i.e. 0 (zero) rise in the sea level a total of 1572085 ha land is inundated in 16 coastal districts due to monsoon flood (Khan and Awal, 2009). Further rise in sea-level will expand inundation areas where Patuakhali, Khulna and Barisal regions would be the most affected.

A direct consequence of sea level rise would be intrusion of salinity with tide through the rivers and estuaries. It would be more acute in the dry season, especially when freshwater flows from rivers would reduce. According to an estimate of the Master Plan Organization, about 14,000 sq km of coastal and offshore areas have saline soils and are susceptible to tidal flooding. If some 16,000 sq km of coastal land is lost due to a 45 cm rise in sea level, the salinity front would be pushed further inland. The present interface between freshwater and saline water lies around 120 sq km to 160 sq km areas will cause reduction in fish production. Pond culture in the coastal area will be affected by intrusion of salt water into ponds. Shrimp farming in the coastal area is a profitable business which is likely to be endangered because of increase in salinity (COAST, 2009).

Salinity affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. The dominant crop grown in the saline areas is local transplanted Aman rice crop with low yields. The cropping patterns followed in the coastal areas are mainly Fallow-Fallow-Transplanted Aman rice. Fertility status of most saline soils range from low to very low in respect to organic matter content, nitrogen, phosphorus and micronutrients like zinc and copper. The crop yields obtained in these soils are also low (Karim, 2006). In addition, scarcity of quality irrigation water during dry season limits cultivation of Boro rice and Rabi (winter) crops, and Aus cultivation during kharif-1 (March-July) season (Karim, 2006).

## 2.5 High Tidal Inundation and Salinity Mapping and Associated Risk to Agriculture

For inundation mapping from point elevation data source, simple interpolation technique can be applied. The point feature datasets can be interpolated and converted to 1m resolution ArcGIS grid format datasets using the Topo to Raster tool located in the ArcGIS Toolbox (Tait et al, 2007). Collins et al. (2007) suggests, the Topo to Raster tool in ArcGIS 3D analyst results in a connected drainage structure and correct representation of ridges and streams. Future water level data estimated from gauge stations and field observation of specific locations can be used as height source in Topo to Raster interpolation technique. The interpolation method is specifically designed for the creation of hydrologically correct DEM (ESRI, 2007).

Another interpolation technique, Spline can also be used for surfaces generation as the technique estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points (ESRI, 2007). The study area surface behaves as almost flat surface. The Ganges-Brahmaputra delta is almost plain land where the elevation ranges from 15m in the north to nearly a meter in the south and the gradient of the delta surface is about 0.016m/km (Banglapedia, 2006).

For developing inundation maps, Geographic Information System (GIS) Software can also be used. GIS has widely been used to map and model surface water and flood hazard (Aziz et al, 1998 (as cited in Dewan, A.M. 2004)). Digital Elevation Model (DEM) based flood extent with depth, an integral part of GIS can be adopted for flood hazard study. To get flood map of a study area, flood elevation generated from water level data, is subtracted from ground elevation data (Dewan et al, 2004). The main disadvantage of the method is unavailability of interpolated water level surface during subtraction with interpolate land elevation surface. For obtaining flood extent it is necessary to have both interpolated water level and land elevation surfaces as flooding is a continuous phenomenon. So that and interpolation is the procedure of estimating the value of properties at unsampled points or areas using a limited number of sampled observations.

In order to resolve the methodological gap, interpolation technique at GI system can be applied using water level data of different stations in order to generate interpolated water level surface generation. There are number of interpolation techniques, designed for particular purpose, available in ArcGIS framework. One of is Kriging interpolation, which has been developed based on statistical models that include autocorrelation (ESRI, 2007). But for water level surface generation, the technique will not be appropriate as there is no statistical relation between the different stations in real scenario. On other hand, another interpolation technique, Spline is used for land surfaces generation, as the technique estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points (ESRI, 2007). But for interpolating a hydrologically correct surface only Topo to Raster method available in ArcGIS 9.3.1 is used (ESRI, 2007).

# CHAPTER THREE

# STUDY AREA

## 3.1 Selection of the Study Area

The study area covers whole Dhalua union in Barguna Sadar Upazila under Barguna District (Figure 3.1) which is an area of 39.88 sq, km. Surrounding considered water level stations are Patharghata at the Bishkhali and Amtali, Mirzaganj at Buriswar Rivers. The Buriswar River is on the east and the Bishkhali River is on the western side of the study area. In these rivers water levels for both high tides and low tides become lowest in January- April and highest in late August- September (Figure 3.2 and Figure 3.3).

In the study area the north-western part is at elevation between 4.0 and 5.5 m Mean Sea Level (MSL) but the south-western is at lower elevation ranging from 4.5 to 5.0 m (msl) and settlement lies between the elevations ranging from 6-7m (msl) in this area. The main water related problems are related to salinity intrusion, drainage impediment and shortage of surface water in dry season. The area experienced drastic events of SIDR in 2007. Both the rivers have hydraulically direct connection with Bay of Bengal at south and the Meghna River at far north.

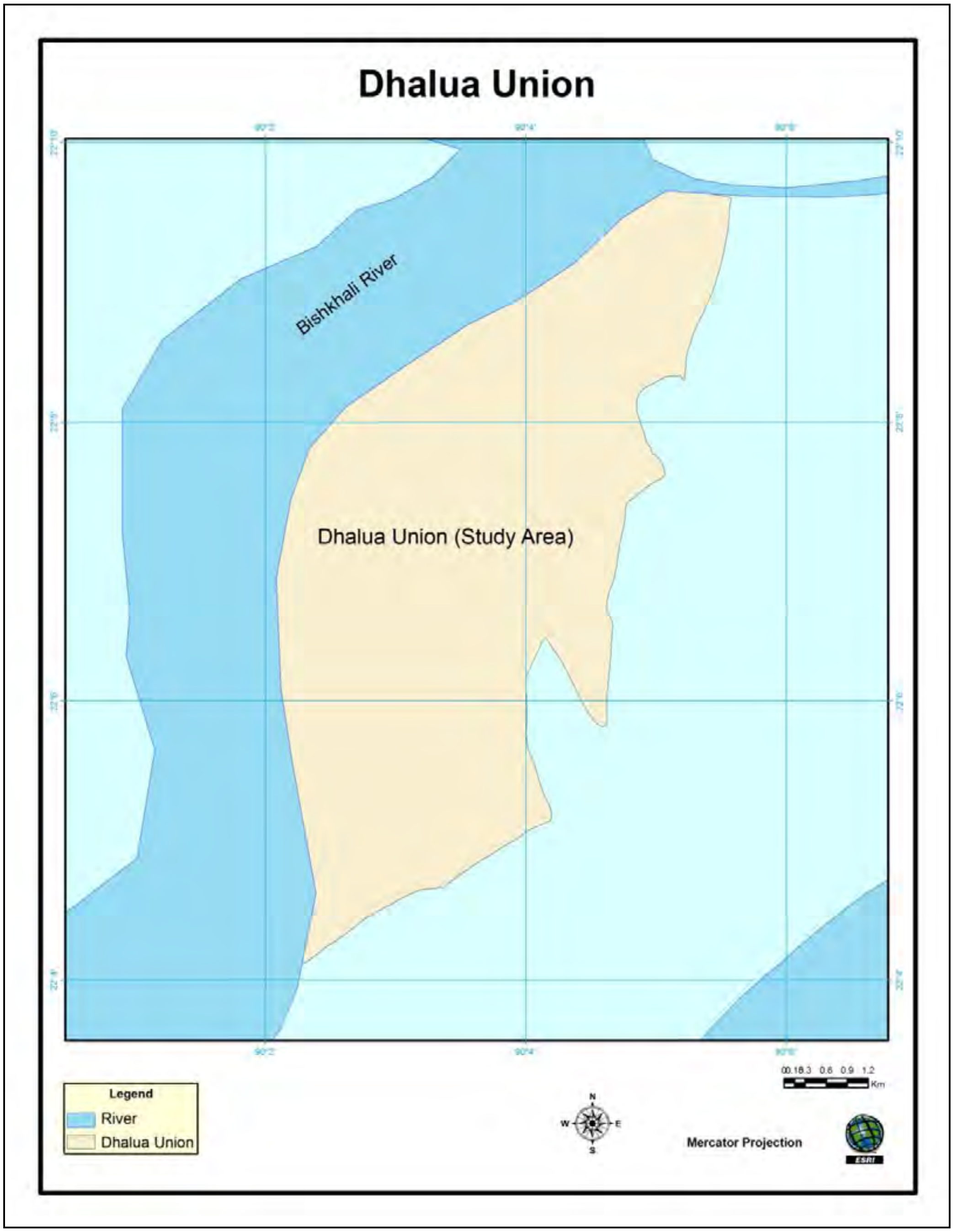


Figure 3.1: Dhalua Union, Barguna Sadar Upazila, Barguna

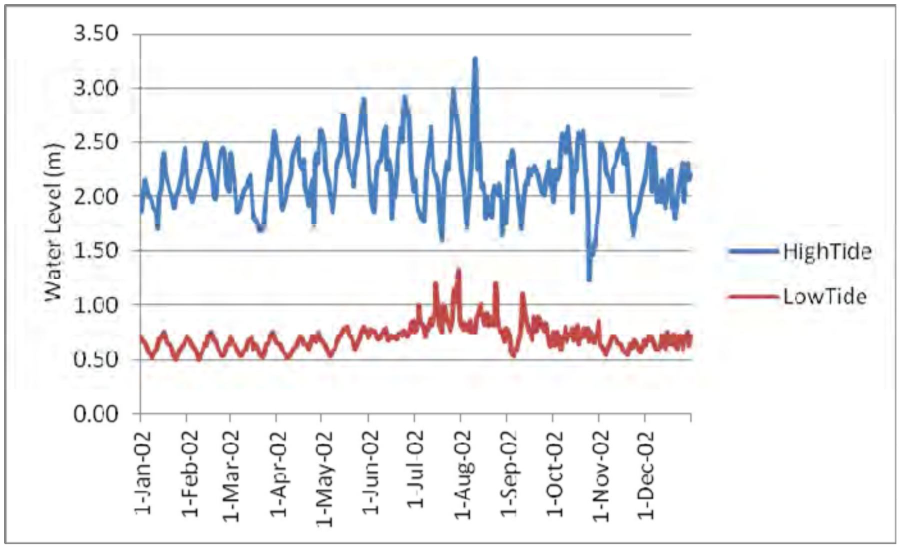


Figure 3.2: High Tide and Low Tide at Amtali Station, 2002

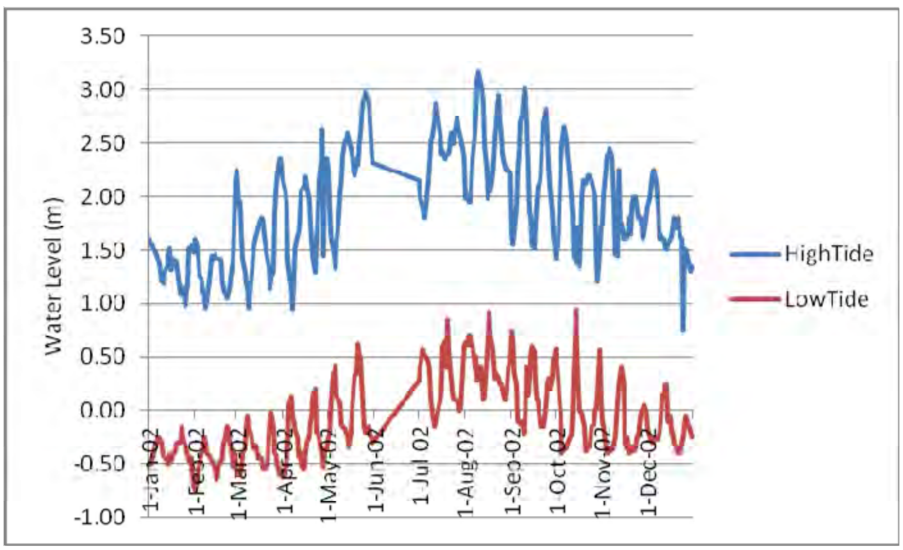


Figure 3.3: High Tide and Low Tide at Patharghata Station, 2002

As the study area located at the tip of the southern part of Bangladesh saline water intrusion becomes higher compared to fresh water intrusion coming from north. So, the study area faces salinity problem extremely. Due to extreme salinity, irrigation water becomes polluted which hampers the crop production in the study area. In addition, sea level rise exaggerates this problem. So, the study focuses on the future salinity risk to agricultural areas due to sea level rise.

## 3.2 Location of the Study Area

The study area is located in the estuarine environment of the Buriswar and the Bishkhali River with the Bay of Bengal confluence. According to Master Plan Organization (1986), this study area falls under SC-55 catchment area of Bangladesh and which is about 39.88 sq.km. The study area is bounded by the Bishkhali River on west, The Buriswar River on east, Bay of Bengal on south. The union consists of five mauzas with a population of 23683 (BBS, 2001). About 49% of the Dhalua union population is landless which is 5% less from coastal statistics (Ministry of Water Resources, 2005). Percentage of marginal farmer is 57% which is 4% more from national figure (Ministry of Water Resources, 2005). The agro-climatic condition with fertile soil gives the study area a rich potential for diversified agriculture and other economic activities but the salinity in irrigation water suffers agriculture extremely.

## 3.3 River System and Hydrologic Measuring Stations

The Bishkhali and Buriswar River is about 43 km and 50 km in length within Barguna Sadar Upazila respectively (Banglapedia, 2006). The study area occupies the Bishkhali River about 13 km. Both the rivers meet with the Bay of Bengal at south (Figure 3.4). A distributary of the Bishkhali River named Barguna River originates at Dhalua union and passes through Barguna Paurashava. Otherwise, an intricate system of channel network has been found in the study area. Due to having numbers of channels, the irrigation system is fully dependent on surface water. So, the agriculture of the study area is at risk to salinity impact. Moreover, as the location of the area is southern tip of the country and closest to the Bay of Bengal, sea level rise exaggerate this problem extremely. Furthermore, an embankment is located at the western part of the study area but due to having sluice gates at the embankment, saline water intrudes from the Bishkhali River through channels in the area. There are three water level stations of Bangladesh Water Development Board (BWDB) are located in the study area (Figure 3.5). The water level stations are Amtali (SW 20), Mirzaganj (SW 19) and Patharghata (SW39).

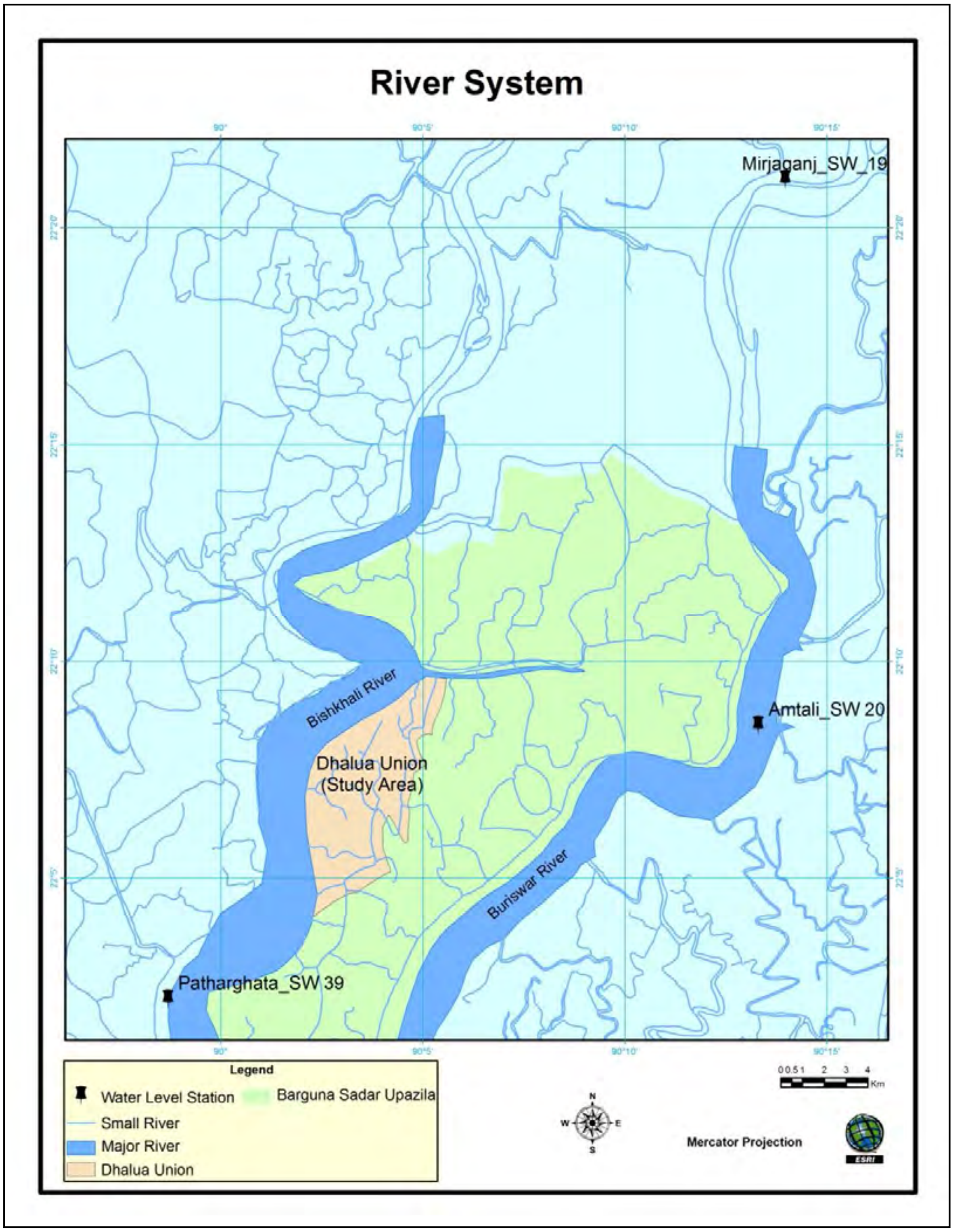


Figure 3.4: River System and Hydrologic Measuring Stations

### 3.3.1 Surface water

The hydrological regime in the Dhalua and surroundings is governed by the Bishkhali River to the west by the khals draining the interior. Tides in the Bishkhali River range from avg. 1.53 m during the dry season and 1.42 m during the wet season. Regulators on the embankments control the connections of the khals with the concerned rivers. Active river erosion is observed in the Bishkhali River.

### 3.3.2 Groundwater

Subsurface lithological data reveals that, this zone is consisted of alteration of thin sand and clay/silty clay layers and totally devoid of any type of peat. Thickness of clay/silty clay layers ranges from 3 to 10 meters and that of sand layers ranges from about 3 to 15 meters (Rashid and Ahsan, 2011). The main aquifer is characterized by high porosity and moderate to high permeability and is separated from the composite aquifer by a clay layer.

## 3.4 Climate

The study area has four distinct seasons. The monsoon and the dry season are the main seasons, separated by transition seasons. The southwest monsoon lasts approximately from June to September, and covers the main rainy season. More than 90% of the annual rainfall (average 1467 mm/year) occurs during this period. In an average year the potential evapotranspiration exceeds rainfall between October and April. Rainfall in the early and late monsoon periods is highly variable. In the study area, annual average maximum temperature is 37.1C˚ where as the annual minimum temperature is 11.2C˚.

## 3.5 Land Use and Cropping Pattern

The land in the study area is mostly agricultural. The land use of the area comprises agriculture, forest, rural settlement, water bodies and others. The statistics of the major land coverage has been in Table 3.1. The land coverage map of the study area has been presented (Figure 3.5).

Table 3.1. Land Use of the Study Area

| Land use | Area (sq.km) |
|---|---|
| Cropping Land | 25.16 |
| Forest | 0.29 |
| Rural Settlement | 9.68 |
| Water bodies | 4.81 |

*Source*: Landsat Image

In the study area, rice is the most important food crop whenever Aman and Boro (Rabi) crops are the traditionally dominant cropping pattern of the study area. Other major crops include sugarcane, oilseeds, lentil, potato, sweet potato, jute, betel leaf, sesame etc. In Kharif I


Figure 3.5: Land Use Map, Dhalua Union

(March-June) local broadcast Aus and broadcast Aman are the dominant crops with minor crops of oilseeds and fruits. In Kharif II (July-October) broadcast Aman continues to grow in lowlands. Local transplant Aman and high yielding variety (HYV) transplanted Aman are grown mostly in high lands. In the Rabi season (November-February), Lentil, Mustard, Gram, Chilli, Brinjal, Bean, Sesame, Onion, Garlic, Sugarcane, etc. are planted in addition to HYV Boro. Fruits like banana, papaya, and guava are grown year-round.

## 3.6 Topography and Physiography

Major part of the study area lies in the lower Meghna River flood plain and the estuarine environment of the Bay of Bengal. The lands of the district is almost flat having mild slope (0.40 – 1.14 degree) from north to south-east (Figure 3.6). The surface elevation profiles also show that the slope ratios are 0.103 $mkm^{-1}$ and 0.688 $mkm^{-1}$ towards north to south and west to east direction respectively. The study area is located under the physiographic unit called Ganges Tidal Floodplain (Banglapedia, 2008). The sediments are mainly non-calcareous clays, but they are silty and slightly calcareous on riverbanks and in a transitional zone in the east adjoining the lower Meghna (Banglapedia, 2006).

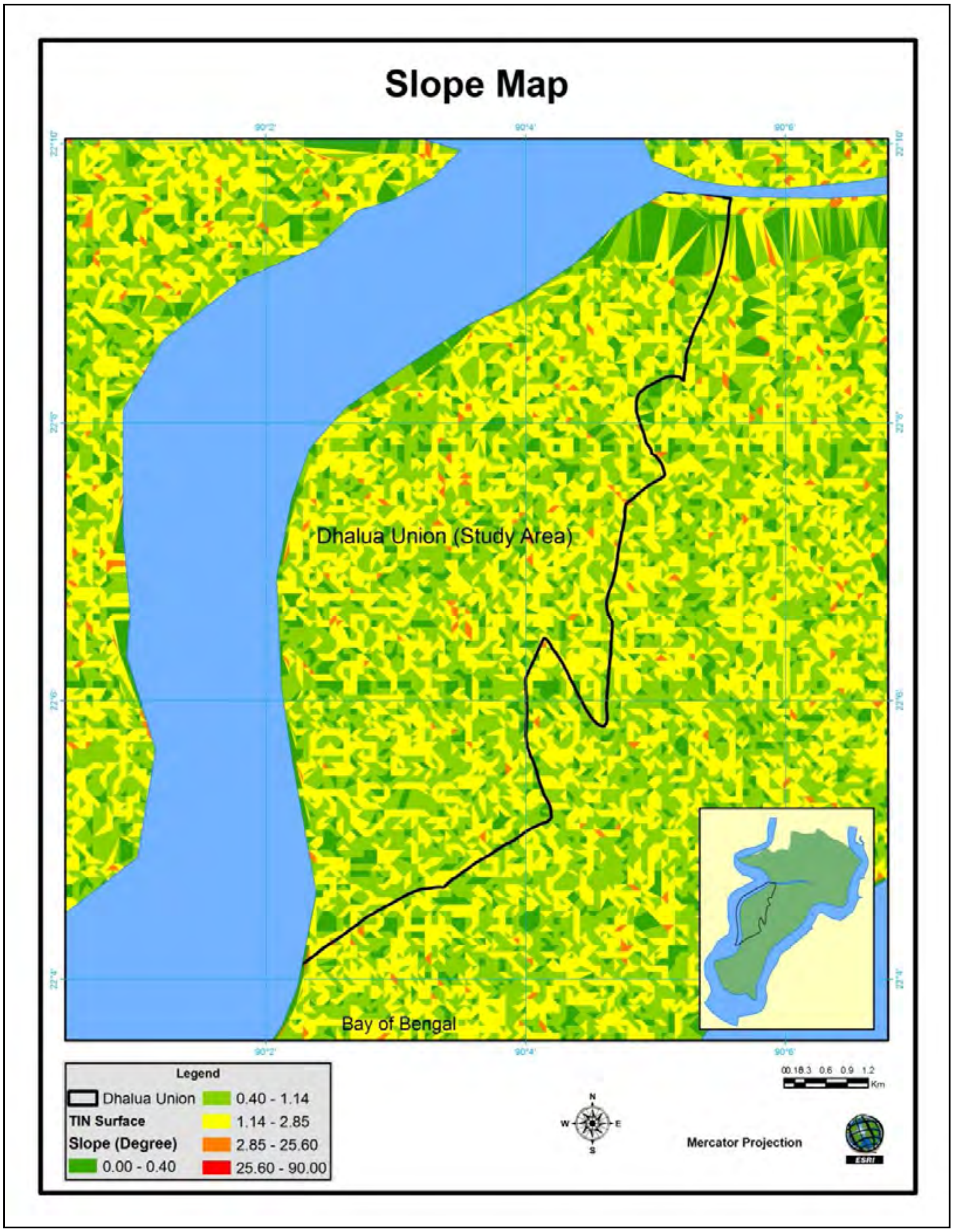


Figure 3.6: Slope Map, Dhalua Union

# CHAPTER FOUR

# METHODOLOGY

## 4.1 Introduction

This chapter presents the sequential order and description of different steps followed during the study. The methodologies employed in the study are study area delineation, future high tidal mapping, agricultural land use mapping and finally finding spatial variation of salinity in different agricultural risked zones in the delineated study area. Prior to the above mentioned methodologies, both secondary and the primary data collection have been made. Figure 4.1 shows a flow chart presenting the methodology followed for the present study.

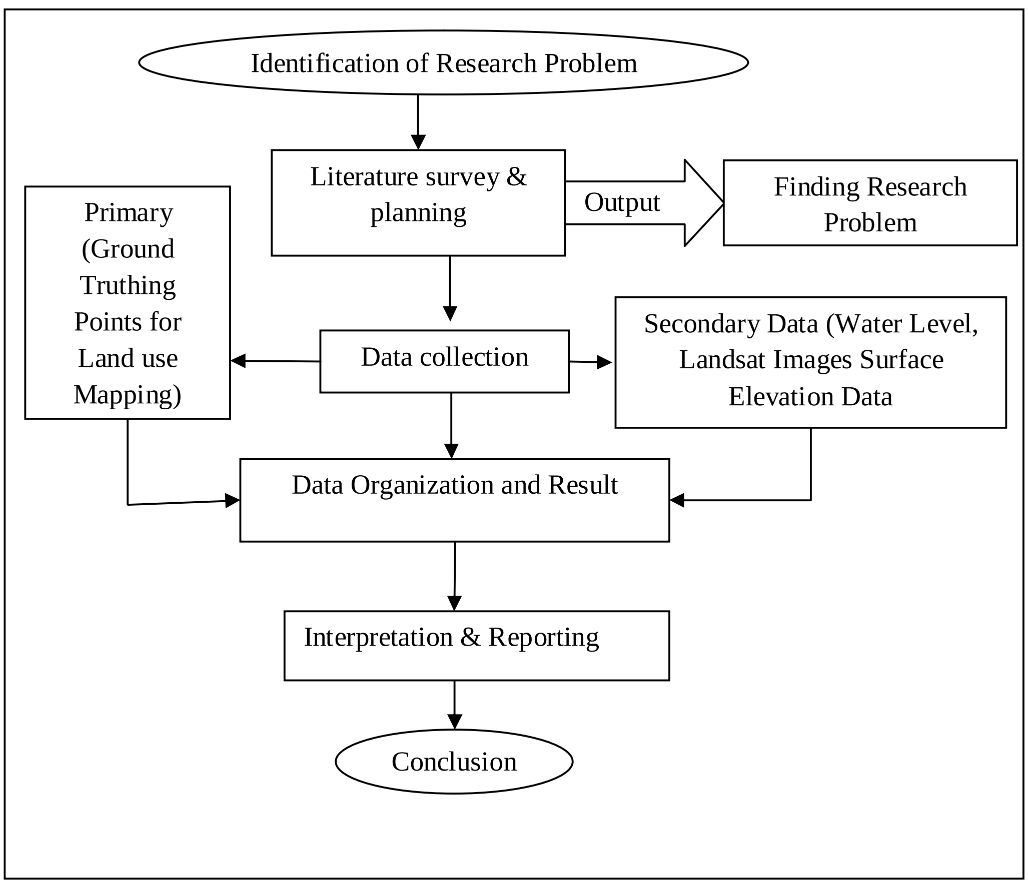


Figure 4.1: Methodology Flow Chart of Present Study

## 4.2 Data Collection

### 4.2.1 Primary data

Primary data includes GPS reading of different land coverages at two seasons of a year. The seasons include dry (March) and monsoon (June) periods. As the agricultural land coverage becomes changed due to seasonal cropping practice in the study area, it has been necessary to have an idea on changing behavior of agricultural areas prior to the area delineation. Followings are the guidelines which have been followed during the task at field level.

- As much as possible GPS readings have been collected.
- During data collection, higher precision has been maintained.
- By keeping in mind the field variation nature of crop practices GPS data have been collected accordingly.
- For verification of the collected data, google earth transformation has been done.

Moreover, number of group discussions has been completed in the study area to verify the results obtained and the observed water level information.

### 4.2.1 Secondary data

Any research work requires the combination of field data (primary data) and the existing data (secondary data) on the particular study area. The degree of water salinity in the study area coming from the Bishkhali and Buriswar Rivers has been estimated based on the secondary data sources. In addition, to get inundation extent, water level data of mentioned rivers have been collected from existing gauge stations. Otherwise, to obtain the surface behavior, SRTM data sources have been collected. For land use mapping, landsat images of dry and the monsoon periods have been collected.

The following secondary data has been used in this research (Table 4.1)

Table 4.1: Collected Secondary Data and Sources

| **Data** | **Source** |
|---|---|
| Salinity | BWDB |
| Water Level | BWDB |
| Surface Elevation | SRTM |
| Satellite Image | Landsat |

## 4.3 Data Organization and Result

In data organization part, following number of steps involved to obtain the study results.

### 4.3.1 Future high tidal inundation mapping

Point feature datasets can be interpolated and converted to 1m resolution ArcGIS grid format datasets using the Topo to Raster tool located in the ArcGIS Toolbox (Tait et al, 2007). The Topo to Raster tool in ArcGIS 3D analyst results in a connected drainage structure and corrects representation of ridges and streams (Collins et al, 2012). Future peak high tidal water level data derived from time series analysis of peak high tidal water level data of gauge stations have been used as height source in Topo to Raster interpolation technique. Estimation of sea level rise comes from regression analysis of historic dataset of water level of selected gage station. So, therefore, high tidal water level for future years derived by extrapolation from regression analysis has carried the sea level rise impact. The interpolation method is specifically designed for the creation of hydrologically correct DEM (ESRI, 2007). Spline interpolation technique has been used for land surface generation as the technique estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points (ESRI, 2007). In the current study SRTM elevation data has been used as height source. Elevation difference between water level and land surfaces has been considered as inundation depth.

### 4.3.2 Agricultural land use risk mapping

Overlay operation by ArcGIS 9.3.1 has been done within agricultural land use and inundation extent. The resulted common area has been considered as land area where high tidal inundation would be occurred in future.

### 4.3.3 Spatial variation of salinity in different agricultural risk zones

In the study area, salinity data of different stations has been collected for different years and then regression analysis has been done to establish relation between high tidal water level and salinity level . In that case, due to having insufficient salinity data ($EC_W$) at corresponding peak high tidal water level, only monsoon period has been considered for salinity ($EC_W$) and high tides. In this context, salinity surface of different years has also been generated by spline interpolation technique from the $EC_W$ data derived from regression equation between high tides and salinity during monsoon. Then overlay (intersect) operation has been done between agricultural land use risk map and the salinity surface. The intersected area shows the future spatial variations of salinity level in different agricultural risk zone due to sea level rise. It can be noted that, 100 % and 50 % crop yield potential of rice will be influenced at 7.6 dS/m $EC_W$ and 4.8 dS/m $EC_W$ (Ayers and Westcot, 1994). So, above those mentioned values will be termed as risklevel of salinity in the Dhalua union.

# CHAPTER FIVE

# RESULTS AND DISCUSSIONS

## 5.1 Future High Tidal Inundation Mapping

In the preparation of inundation maps by interpolation technique, future peak high tidal water level data have been used as a height source. Prior to develop inundation interpolation, future peak high tidal water level data have been estimated from trend analysis of historic data series of each water level station. In this present study, years of 2015, 2020, 2025 and 2030 have been considered for estimating future peak high tidal water level data. Figure 5.1, Figure 5.2 and Figure 5.3 show the estimation of future peak high tidal water level at three stations.

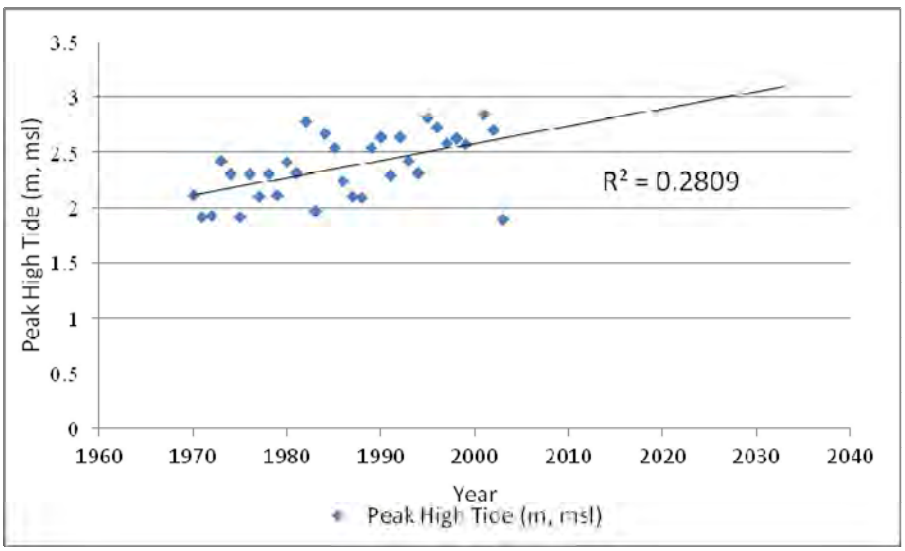


Figure 5.1: Future Estimated Peak High Tidal Water Level at Patharghata Station

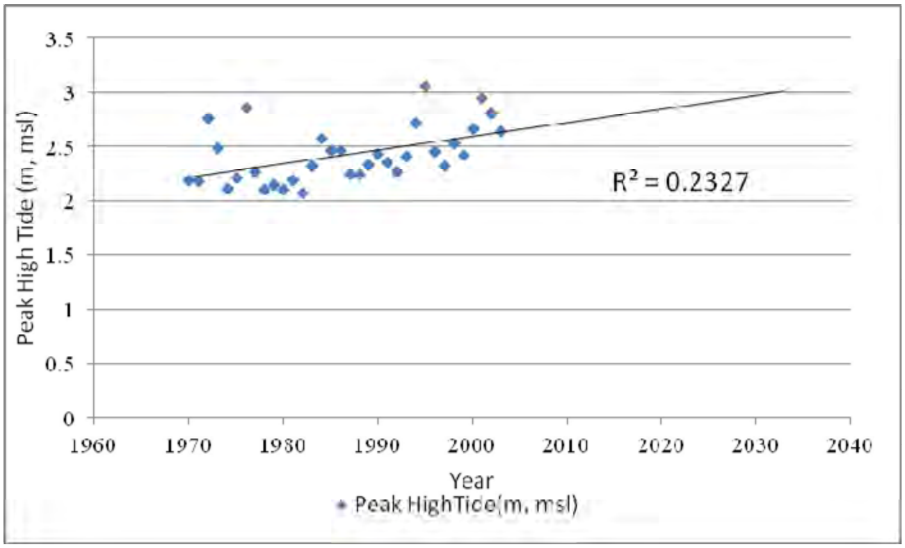


Figure 5.2: Future Estimated Peak High Tidal Water Level at Amtali Station

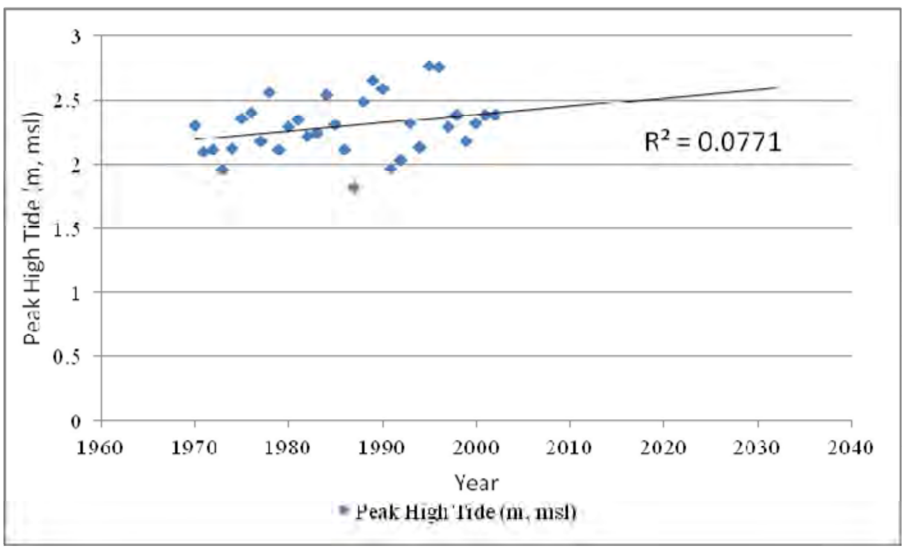


Figure 5.3: Future Estimated Peak High Tidal Water Level at Mirzaganj Station

Three water level stations have been considered because of having the larger area into consideration. In addition, in order to make hydraulically connection between the study area and existing river network those three stations have been considered. Furthermore, Mirzaganj at Burishwar River have no statistical significance in variation of peak high tide with time as shown in Table 5.1. Figure 5.4 and Figure 5.5 show the inundation maps and inundation extent for the year of 2015, 2020, 2025 and 2030 respectively. Increases of inundation extent with time shows a linear trend as Figure 5.5 suggests. Inundation extent will become almost double from the year 2015 to 2030. It is noticeable from Figure 5.6 that the northern portion of the Dhalua union will remain flood free in future.

Table 5.1: Regression Parameters at Different Water Level Stations

| Name of the River | Name of the River Station | Correlation coefficient, R | Ratio of the mean square for the regression to the mean square error of the residuals (F ratio) | *p* value | Statistically significant (if $p < 0.05$ then yes) |
|---|---|---|---|---|---|
| Bishkhali | Patharghata (SW39) | 0.511 | 10.64064802 | 0.002758834 | Yes |
| Burishwar | Amtali (SW20) | 0.461379 | 8.383589 | 0.006880488 | Yes |
| Burishwar | Mirzaganj (SW19) | 0.291243 | 2.780532366 | 0.105823718 | No |

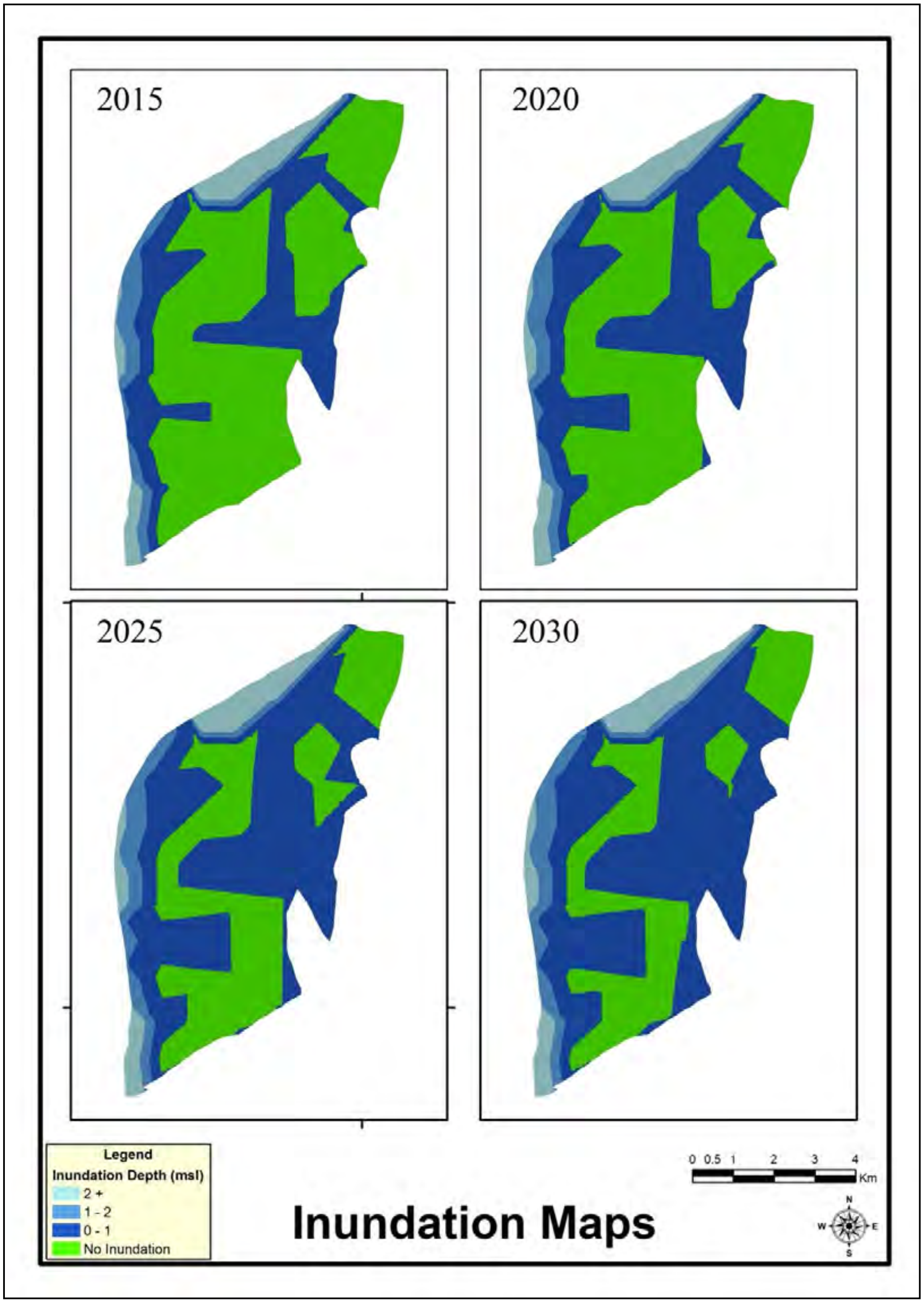


Figure 5.4: Peak High Tidal Inundation Maps at Different Years

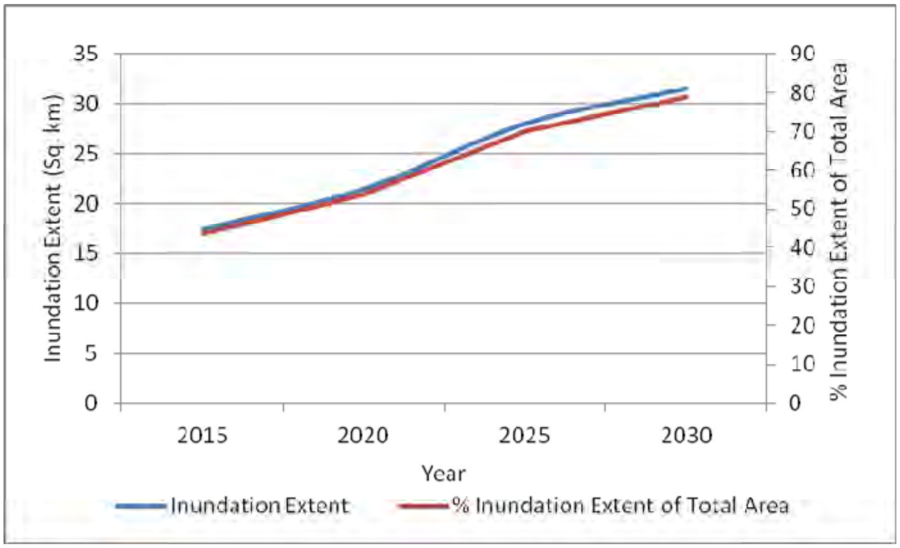


Figure 5.5: Peak High Tidal Inundation Extent in Different Years

## 5.2 Agricultural Land Use Risk Mapping

After overlay operation between agricultural land and inundation layers for different years maps have been generated (Figure 5.6), which can be termed as hazard maps. Figure 5.7 shows the peak high tidal inundation extent on agricultural land for different years. Inundation extent will become more than double from 9.64 sq. km to 20.58 sq.km during the period from year 2015 to 2030. In 2015, about 38% of total agricultural land will be inundated by peak high tidal inundation and by 2030 this figure will be about 80%.

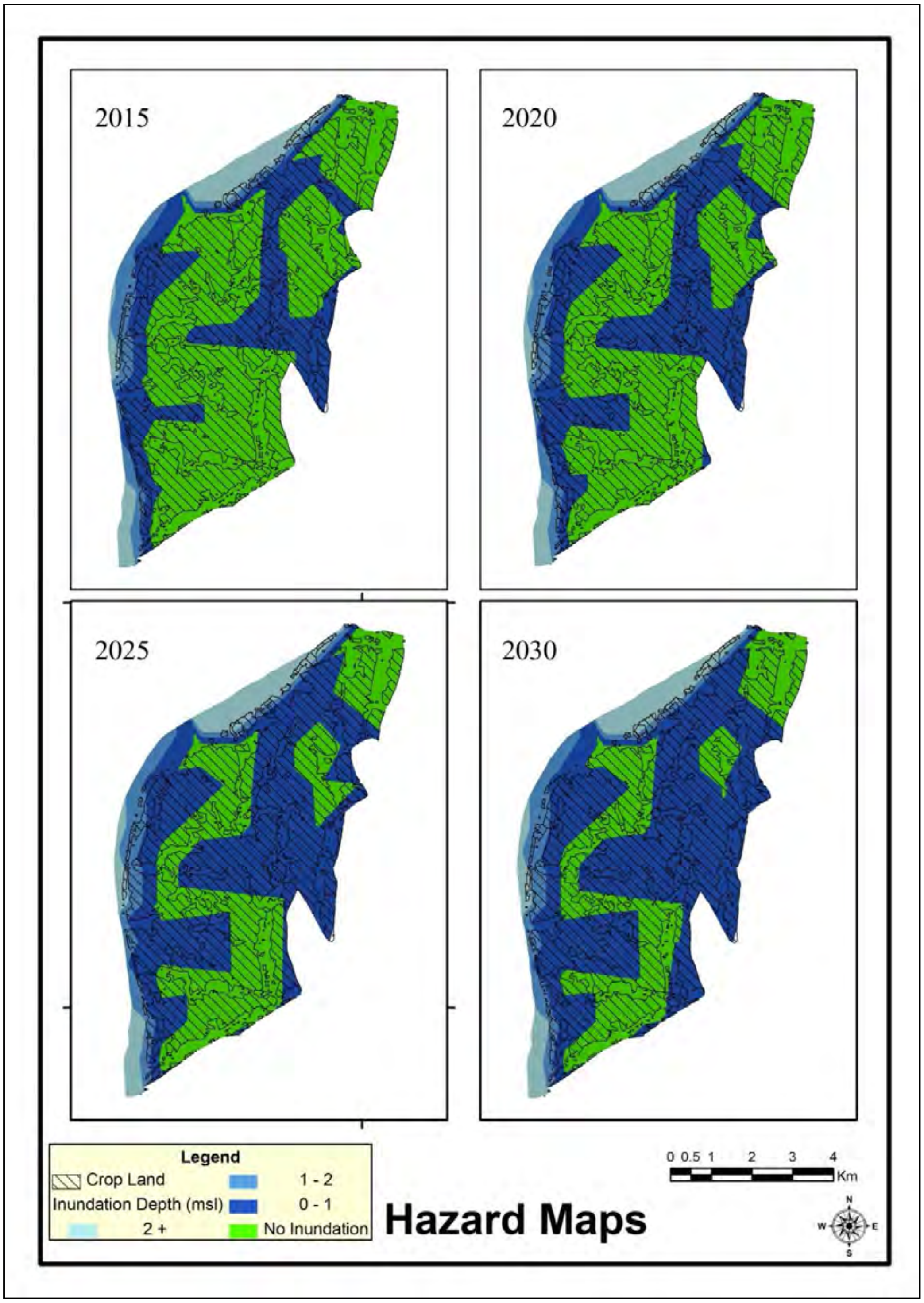


Figure 5.6: Peak High Tidal Inundation Hazard Maps and Agricultural Land

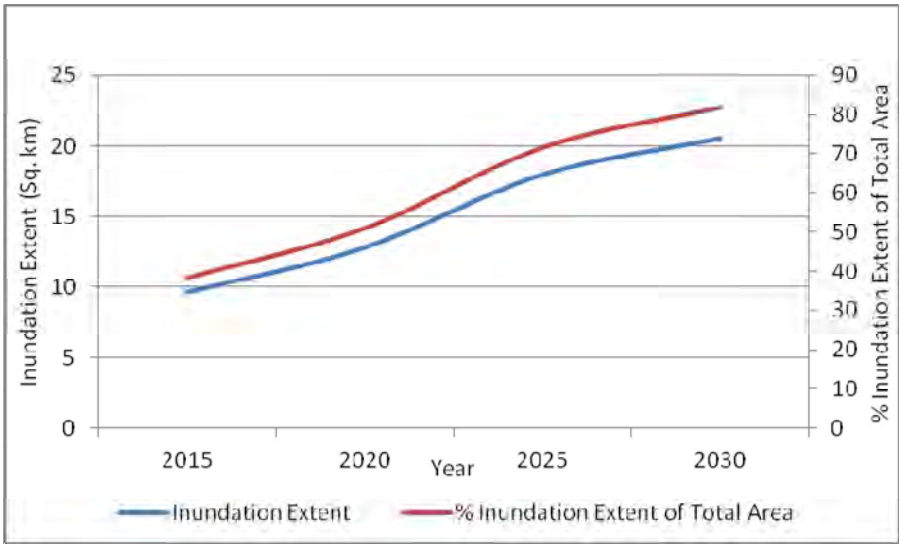


Figure 5.7: Peak High Tidal Inundation Extent at Agricultural Land in Different Years

## 5.3 Spatial Variation of Salinity in Different Agricultural Risk Zones

Due to have insufficiency of salinity data ($EC_W$) at corresponding peak high tidal water level date, only monsoon period has been considered for salinity ($EC_W$) and high tides in case of regression analysis. From the regression equation, salinity level has been estimated at the year of 2015, 2020, 2025 and 2030. Figure 5.8, Figure 5.9 and Figure 5.10 show the regression analysis between $EC_W$ and high tidal water level during monsoon. Amtali and Mirzaganj at Burishwar River have no statistical significance as Table 5.2. The estimated values of ECw have been presented in table 5.3. The estimated value has been generated using the water level value derived from figure 5.1, igure 5.2 and igure 5.3. Interpolated salinity ($EC_W$) surface maps during peak high tides for the year of 2015, 2020, 2025 and 2030 have been generated (Figure 5.11) from the estimated value presented in Table 5.3. For all years, peak high tides $EC_W$ towards from south to north and from the year of 2015 to 2030 in the study area. Finally, for each year, overlay operation has been carried out between the interpolated salinity surface (Figure 5.13) and the peak high tidal inundated surface (Figure 5.6).

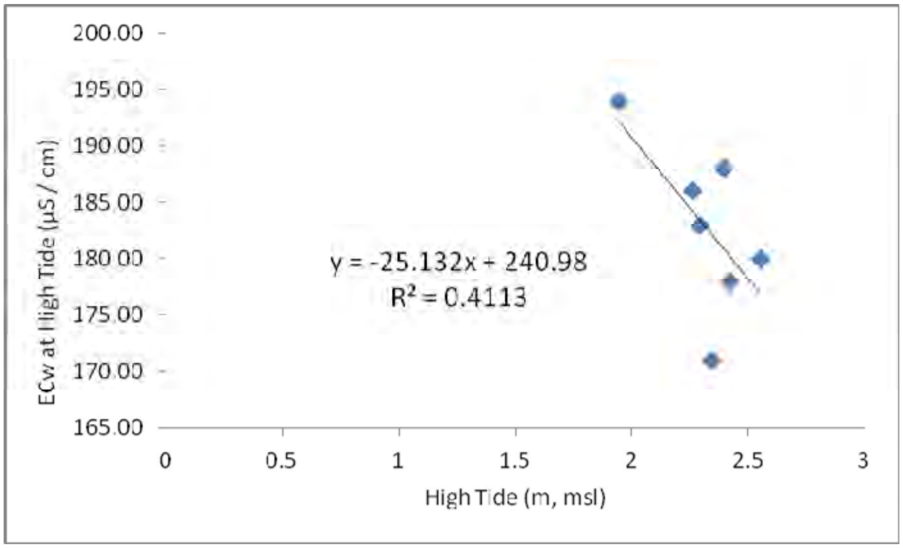


Figure 5.8: Regression Analysis between $EC_W$ and High Tidal Water level, Amtali

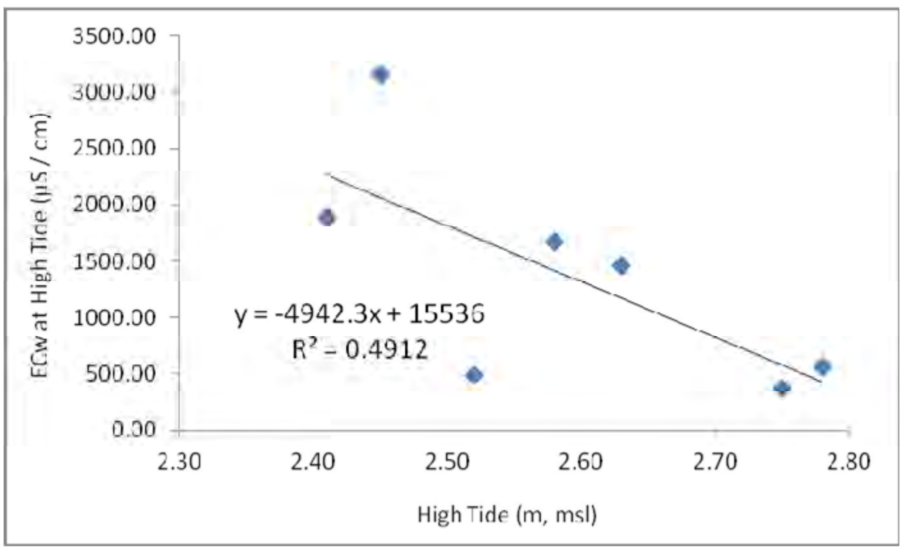


Figure 5.9: Regression Analysis between $EC_W$ and High Tidal Water level, Patharghata

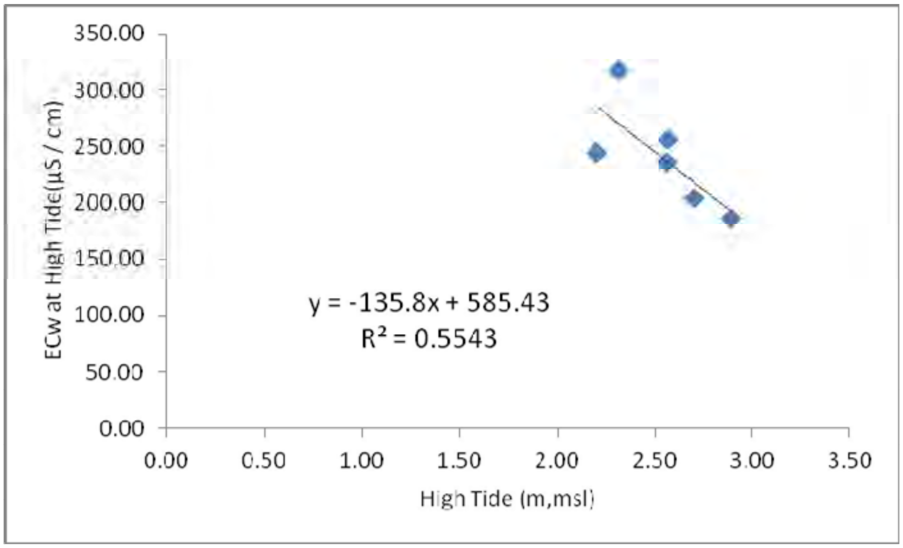


Figure 5.10: Regression Analysis between $EC_W$ and High Tidal Water level, Mirzaganj

Table 5.2: Regression Trend Analysis of Salinity ($EC_W$) and High Tides

| Name of the River | Name of the River Station | Correlation coefficient, R | Ratio of the mean square for the regression to the mean square error of the residuals (F ratio) | *p* value | Statisticall y significant (if $p < 0.05$ then yes) |
|---|---|---|---|---|---|
| Bishkhali | Patharghata (SW39) | 0.924637 | 23.57751 | 0.008305 | Yes |
| Burishwar | Amtali (SW20) | 0.641787 | 2.801449 | 0.169493 | No |
| Burishwar | Mirzaganj (SW19) | 0.766226 | 4.265721 | 0.130822 | No |

Table 5.3: Estimated Salinity level ($EC_W$) (µS / cm) with Sea level Rise impact

| **Station Name** | **2015** | **2020** | **2025** | **2030** |
|---|---|---|---|---|
| Amtali (y = -25.132x + 240.98) | 171.86 | 169.35 | 168.09 | 165.58 |
| Patharghata (y = -4942.3x + 15536) | 1697.56 | 1203.33 | 709.1 | 214.87 |
| Mirzaganj (y = -135.8x + 585.43) | 245.93 | 241.85 | 239.14 | 232.35 |

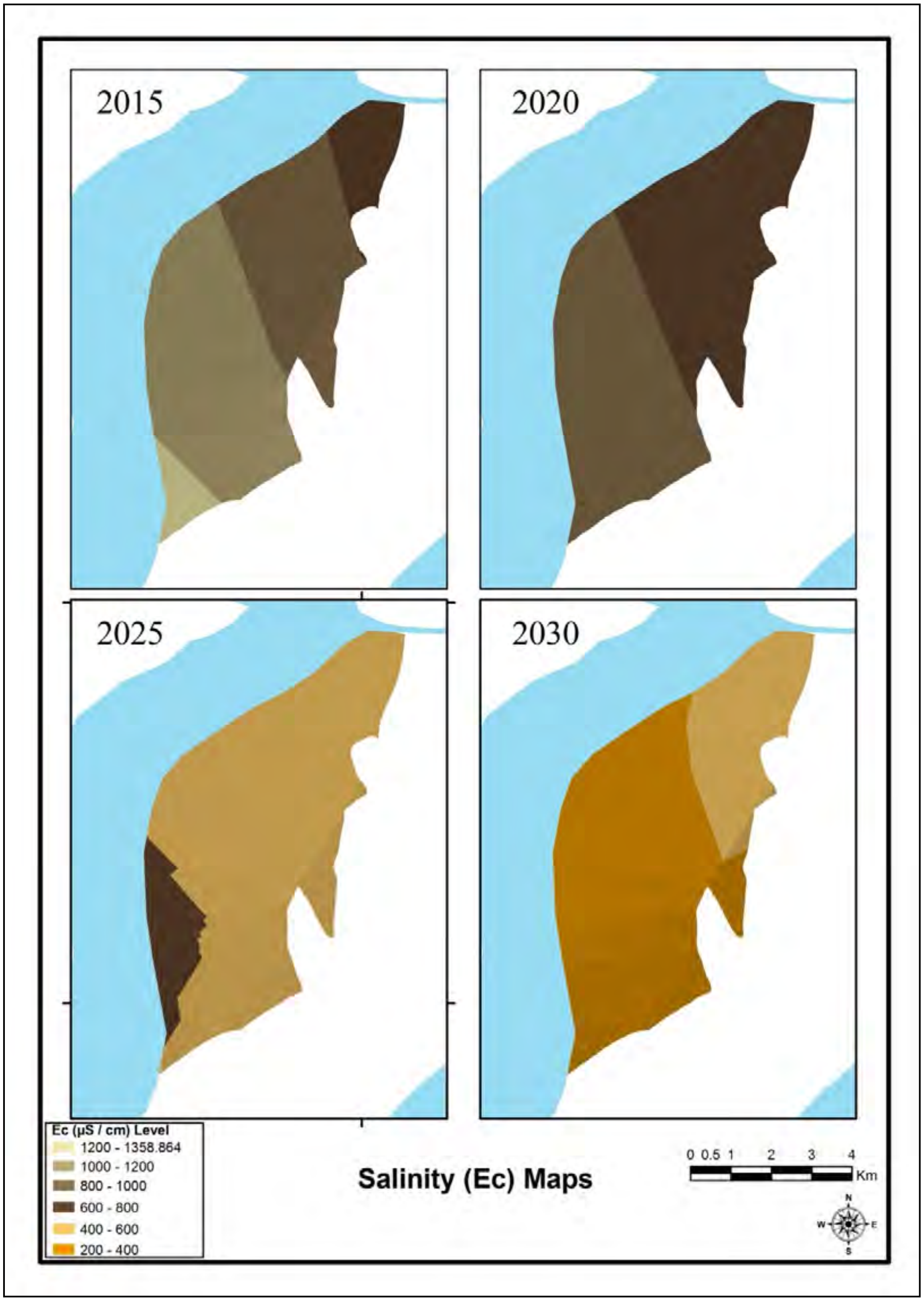


Figure 5.11: Interpolated Salinity (ECw) Surface Maps at Different Years

The considered zones of salinity in cropping land would be, where the zones are inundated by high tides and occupied with crops. So finally, the selection of high tidal salinity risk map would be based on the following rule considering the inundation surface and land use map (Figure 5.12).

**Salinity Map = [Inundation depth > 0 and Landuse = "Crop Land"]**

Peak high tidal inundation with sea level rise induced salinity concentration will be decreased in future in the Dhalua union according to the Figure 5.12. The main cause behind this is, almost all the peak high tidal water level regression line shows a rising trend and furthermore, peak high tide induced inundation extent increases in future. Because of having inverse relationship between high tidal water level and salinity (Ec), salinity concentration will be decreased in future in the study area. The salinity risk classification is shown in Table 5.4. The classification is based on obtained ECw and adjacent agricultural land in the study area.

Table 5.4: Salinity ($EC_W$) Risk Classification

| **Categorizes** | **$EC_W$ (µS / cm)** |
|---|---|
| Very Low Risk | 200 - 440 |
| Low Risk | 441 – 680 |
| Moderate Risk | 681 – 920 |
| High Risk | 921 – 1160 |
| Very High Risk | 1161 - 1400 |

Figure 5.13 shows, the level of salinity risk in the year of 2015, 2020, 2025 and 2030. Table 3.1 shows that, the Dhalua union occupies a total 25.16 sq. km of agricultural land of which, in 2015, 17.52 %, 12.67 % and 8.50 % agricultural land will be under moderate, high and very high risk respectively according to Figure 5.13. As there is a general trend obtained from Figure 5.12 that, salinity concentration will be decreased in future, in this connection, in 2020, about 0.299 sq.km of agricultural land will be under low risk of salinity which is absent for 2015 and on other hand, no agricultural area will be found under very risk of salinity. Moderate risk of salinity area will be significantly increased amounted to 47.45 % of total agricultural area in 2020. In

2025, 75.31 % of total agricultural land will be under low risk of salinity. Almost 95 % of the inundated crop area will be exposed by very low risk of salinity (200 – 440) and remaining will be under low risk of salinity in 2030. Finally, it can be said that during monsoon, peak high tides induced salinity extent will be increased in future but concentration will be decreased.

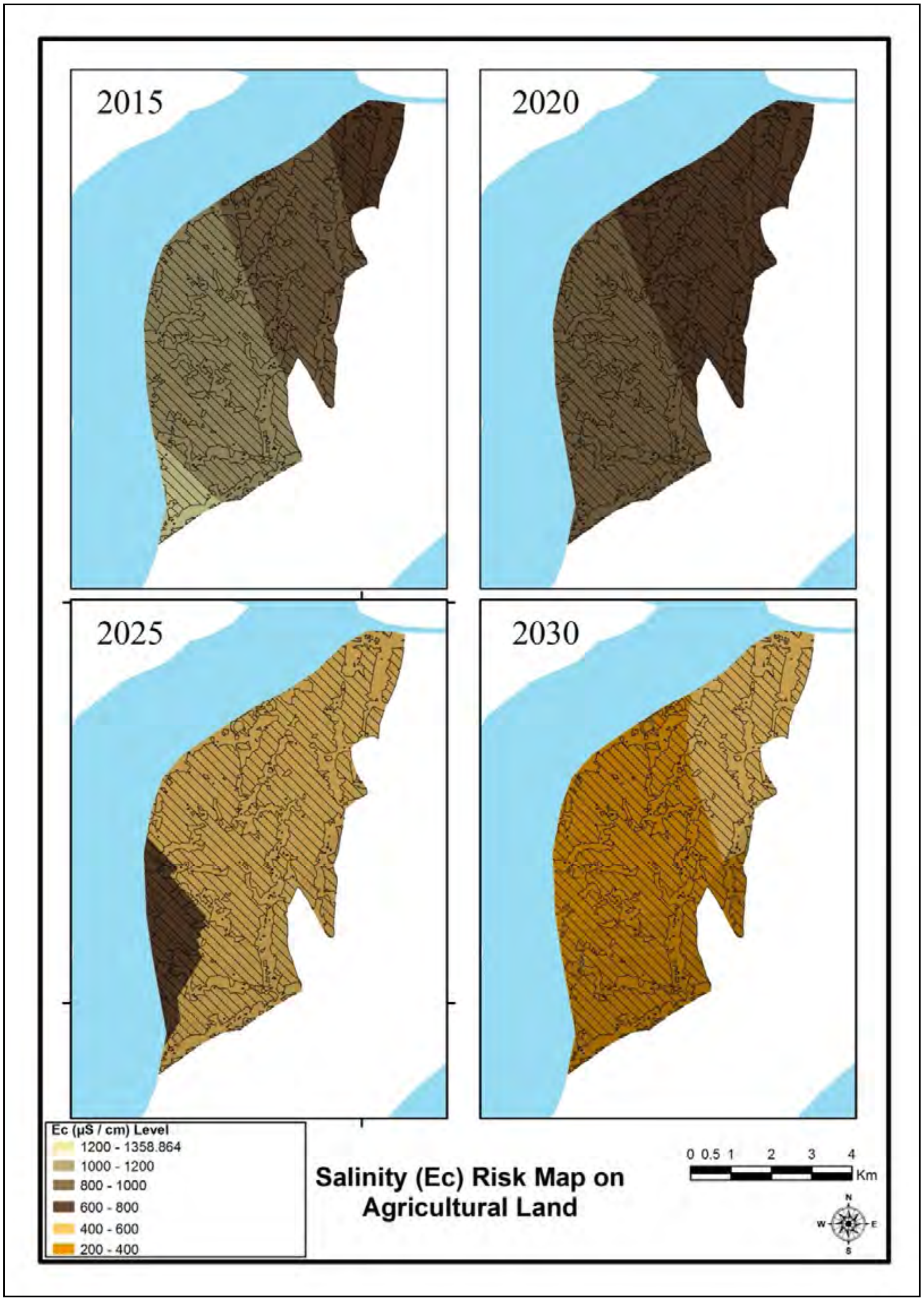


Figure 5.12: Salinity (ECw) Risk Map in Agricultural Land at Different Years

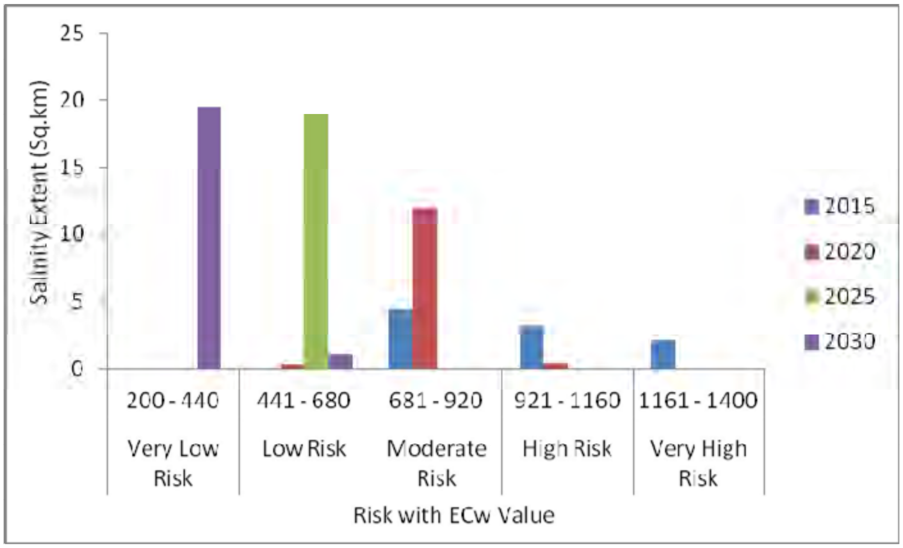


Figure 5.13: Salinity Risk on Agriculture at Dhalua Union (agricultural land area)

# CHAPTER SIX

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

Historic high tidal water level data at south central coastal zone shows a rising trend which indicates the increase of areal extent of tidal inundation in future. In addition, concentration of salinity shows an increasing trend over the years in the area. So there is a possibility of having consequence of increasing saline water concentration as well as areal extent of saline water with different levels in future. In this connection, the present study shows, the agricultural land use risk from salinity perspective due to sea level rise in Dhalua Union under Barguna District. Based on the current study, the following specific conclusions may be made:

1. Inundation extent will become more than double from 9.64 sq. km to 20.58 sq.km during the period from 2015 to 2030.
2. In 2015, about 38% of total agricultural land will be inundated by peak high tidal inundation which will be also more than double in 2030.
3. There is an inverse relationship exist between high tidal water level and salinity (Ec) level.
4. Peak high tidal inundation with sea level rise induced salinity concentration will be decreased in future.
5. The Dhalua union occupies a total 25.16 sq. km of agricultural land of which, in 2015, about 17.52 %, 12.67 % and 8.50 % will be respectively under moderate, high and very high risk.
6. In 2020, about 0.299 sq.km of agricultural land will be under low risk of salinity which is absent for 2015 and on other hand, no agricultural area will be found under very risk of salinity.
7. Moderate risk of salinity area will be significantly increased amounted to 47.45 % of total agricultural area in 2020.
8. In 2025, 75.31 % of total agricultural land will be under low risk of salinity.

9. Almost 95 % of the inundated crop area will be exposed to very low risk of salinity and remaining will be under low risk of salinity in 2030.

**6.2 Recommendations:**

The following recommendations are made for future study:

1. Internal drainage system should be considered for inundation mapping.
2. Other climatic variables especially rainfall should be accounted for both inundation and salinity study.

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