Future Economic and Livelihood Impact of Storm Surge Disaster under Climate Change Context in a Selected Polder

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

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ABBREVIATION AND ACRONYM

ADB	Asian Development Bank
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BIWTA	Bangladesh Inland Water Transport Authority
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CB	Crossing Boundaries
CEGIS	Centre for Environment and Geographic Information Services
CEP	Coastal Embankment Projects
CERP	Coastal Embankment Rehabilitation Projects
DAE	Department of Agricultural Extension
DEM	Digital Elevation Model
DFID	Developing For International Development
DoL	Department of Livestock
DoC	Department of Cooperatives
DoF	Department of Fisheries
DoE	Department of Environment
DMB	Disaster Management Bureau
DPHE	Department of Public Health Engineering
EU	European Union
FCD	Flood Control Drainage
FCDI	Flood Control, Drainage and Irrigation
FGD	Focus Group discussion
GIS	Geographic Information System
GOB	Government of Bangladesh
GOC	Gate Operating Committee
GWP	Global Water Partnership
HYV	High Yielding Variety
HWL	High Water Level
ICZMP	Integrated Coastal Zone Management Plan
IPCC	Intergovernmental Panel on Climate Change

ISDR	International Strategy for Disaster Reduction
IUCN	International Union for Conservation of Nature
IWFM	Institute of Water and Flood Management
IWM	Institute of Water Modeling
IWRM	Integrated Water Resources Management
KII	Key Informants Interview
LGED	Local Government Engineering Department
M&E	Monitoring and Evaluation
MDG	Millennium Development Goal
MoWR	Ministry of Water Resources
NGO	Non Government Organization
NWMP	National Water Management Plan
NWPo	National Water Policy
O&M	Operation and maintenance
PRA	Participatory Rural Appraisal
PDO	Program Development Office
PWD	Public Works Datum
RVCC	Reducing Vulnerability to Climate Change
SAWA	South Asian Water Fellowship
SRES	Special Report on Emissions Scenarios
SRDI	Soil Resource Development Institute
SSWR	Small Scale Water Resources
T. Aman	Transplanted Aman
TNO	Thana Nirbahi Officer
UP	Union Parishad
UN	United Nation
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UNISDR	United Nations International Strategy for Disaster Reduction
WARPO	Water Resources Planning Organization
WB	World Bank

GLOSSARY

Aman	Monsoon season rice (direct-seeded or transplanted)
Aus	Rain fed rice in the pre-monsoon season (direct-seeded or transplanted)
Beel	Natural depression (pond) subject to flooding
Boro	Irrigated rice grown in the dry season
Floodplain	Lower land along rivers and khals inundated during flood season by river floods
Gher	Shrimp farm
Khal	Narrow natural or artificial water channel
Kharif I	Cropping season during pre-monsoon (March-June)
Kharif II	Cropping season during monsoon (July-October)
Parishad	Local government institution
Rabi	Cropping season during winter (October-March)
Union	Administrative unit—subdivision of an upazilla
Union Parishad	Local government institution at union level
Upazilla	Administrative unit—subdivision of a district (formerly thana)

ABSTRACT

Coastal area is rich with lots of resources like forest, fisheries, wetland, agricultural land, shrimp farm, salt farm, etc., on which the livelihoods of marginal population depend. About 108 polders and numerous sluice gates have been constructed by Bangladesh Water Development Board (BWDB) under the Coastal Embankment Project (CEP) in the early 60s for increasing agricultural return. The increasing salinity intrusion, sea level rise, cyclone, and storm surge flood along with population pressure strike properties, life and livelihoods of the coastal community. This research deals with the storm surge disaster that affects economy and livelihood of the coastal community at present and in future. This study has been conducted on Polder no-5 including Shyamnagor and small parts of Kaligonj upazilla under Satkhira district that were severely affected by cyclone ‘Aila’. Scarcity of basic needs like drinking water, food, sanitation facility, health care, shelter, livelihood opportunity and subsequently outbreak of diseases like diarrhea and skin diseases forced the affected population to move elsewhere. This study articulates not only the present land use impact of the last cyclone induced storm surge disaster ‘Aila 2009’ but also estimates the impact of future coastal flooding especially in 2030, 2050 and 2100. In this study, storm surge disaster ‘Aila’ is considered as a representative event for comparative analysis.

This study has been conducted on the basis of projection for SRES-A1B scenario of AR4, IPCC. About 6.1m surge height has been accounted for cyclone ‘Aila’. This research estimates that the surge height will be 6.9m in 2030, 7.2m in 2050 and 7.5m in 2100 considering the effect of climate change. GIS has been used for spatial analysis to DEM data (30m) of the study area to determine the inundated area of the polder in future. Inundated area for cyclone ‘Aila’ is 22.7% in 2009 which may increase to 41.4% in 2030, 64.2% in 2050 and 86.3% in 2100. This study also estimates future inundated area due to overtopping.

Different PRA tools like Focus Group Discussion (FGD), Group Discussion (GD), Social and Resource Mapping, Trend Analysis, Pie Charts and (KII) have been used to generate the information regarding the research. This research translates the inundation related losses from different economic sectors to livelihoods. Rice production has declined by 38% in 2009 from the average production. But in future it may decline by 64% in 2030, 89% in 2050 and almost 100% in 2100. Fish production has been reduced by 50% after last disaster which may be reduced further to 85% by future disaster (*e.g.* 2100). Destruction of forest cover, livestock and infrastructure are also estimated for the projected years. Most of the livelihood opportunity will be decreased for future storm surge disaster. Only wage labor, temporary fishing and seasonal migration will be the way of sustaining livelihood during future storm surge disasters.

CHAPTER ONE
INTRODUCTION

1.1 Background Information

About 400 natural disasters occur per year, which affect around 200 million people. This number is twice reported 20 years back. In particular, hydro meteorological events are increasing; most likely as a result of climate change (ISDR, 2009). Since 1960, water related disasters killed approximately 5 million people world wide and injured millions more. During the past 20 years, the greatest numbers of disaster-related deaths have occurred in Asia (Cropper and Sahin, 2009).

Bangladesh, China and India are the most flood-prone countries in Asia due to their geography and climate (UNEP, 2002). Higher population density increases vulnerability to climate change especially water related disaster in Bangladesh (Agrawala *et al.,* 2003). At the same time, the country has low adaptive capacity because it is extremely poor (Thomalla *et al*., 2005). Two-thirds of the recorded disasters related to floods and storms has been affecting Bangladesh since 1994 (UN, 2005). Storm surges are temporary extreme sea level caused by unusual meteorological conditions particularly cyclone and often result in coastal flooding. The trend of tropical cyclones hitting the Bangladesh coast is increasing *e.g*. at the rate of 1.18 per year from 1950–2000 (Islam and Peterson, 2009). Vulnerability of Bangladesh to cyclones/ storm surges may increase even more as a result of climate change (WB, 2010). Nicholls *et al.* (1995) estimated that 42 percent of the 1.9 million cyclone-related deaths occurred in Bangladesh in the past two centuries.

The cyclones generate surges up to a height of several meters, which sweep through the flat coastal region killing people, animal and destroying other fauna and flora (Karim, 2005). Embankments provide protection against flooding from smaller surges but are not designed to prevent inundation by severe surges. About 13 polders will be overtopped due to 62 cm sea level rise in the year 2080 under A2 scenario, 45% population will be exposed to medium to sever inundation (IWM and CEGIS, 2007).

During the past 200 years, 2.6 million people might have drowned during surge events in the world (Nicholls, 2003). Approximately 19.5% (391,812 km^2) of the combined coastal territory of 84 developing countries is vulnerable to inundation from a 1-in-

100-year storm surge (Dasgupta *et al.* 2009). Dasgupta *et al.* (2009) estimated on account of 10% extreme water level in future, the potential inundation zone may increase to 25.7% of coastal territory which will translate in potential inundation for additional 52 million people; 29,164 km^2 of agricultural area; 14,991 km^2 of urban area; 9% of coastal GDP and 7% of wetlands. Ten million people of Bangladesh will one day be forced to relocate because of climate change induced sea level rise accompanied by an increase in the frequency of storm surges (Glantz and Ye, 2010)

Bangladesh is already the dominant storm surge hotspot globally (Nicholls, 2006). Damage and loss from Cyclone 'Sidr' was concentrated on the southwest coast of Bangladesh. The number of deaths caused by 'Sidr' is estimated at 3,406 with 1,001 still missing, over 55,000 people sustaining physical injuries and about 2 million people have lost income and employment in the more affected districts (GoB, 2008). Cyclone 'Nargis' struck Myanmar's Irrawaddy delta in May 2008, creating the worst natural disaster in that country's recorded history. It killed over 80,000 people and affected the livelihoods of over 7 million people (UN, 2009).

The recent storm disaster 'Aila' have passed over the south west of Bangladesh and adjacent part of India with storm surge height of 2-3m above normal astronomical tide (DMB, 2009). The natural disasters like cyclone, storm surge and flood affect lives and livelihoods in the coastal zone and slow down the pace of social and economic developments in this region (PDO-ICZMP, 2005c). Therefore, it is important to study the future impact of disaster on socio-economy of the coastal community considering climate change.

1.2 Objectives of the Study

The goal of this study is to assess the increasing vulnerability of the population of the study area due to increase storm surge severity caused by climate change. The specific objectives are:

i. To review sea level rise situation in future storm surge disaster and assess its impact on coastal flooding in the selected polder for the projected year

ii. To quantify the economic and livelihood impact in present and future climate change context

1.3 Possible Outcome of the Research

The outcome of the study will help the policy makers to formulate an adaptation framework for the coastal region.

1.4 Justification of the Study

Climate change is the biggest challenge for Bangladesh. The frequency and magnitude of the natural disaster for example flood, cyclone, storm surge and drought will increase in future (Agrawala *et al.,* 2003). In case of Bangladesh, almost every natural disaster is related to water which is very much influenced by climate change. Coastal area especially the south-west region of Bangladesh is the most vulnerable to cyclonic disaster. Regarding cyclonic disaster, storm surge causes devastation to the coastal areas for example in case of cyclone 'Sidr' and cyclone 'Aila'. Consecutive surge events destroy life and properties in the coast. Natural and economic resources, infrastructure and livelihoods will be threatened by future disaster. At this stage, it is important to learn how the climate change will intensify future storm surge disaster and what will be the impact on future economy and livelihood of the coastal population.

1.5 Scope of the Study

Storm surge hits the coastal polders year after year and it causes huge damage to the economy and livelihood of the coastal community. This study emphasizes both of those two issues and anticipates their dimension of changes for the future threat. Impact on economy refers to the loss of different productive sectors. Loss of rice and fish production is quantified and the rest of productive sectors like infrastructure, forests and livestock are estimated quantitatively in this study.

Livelihood refers to the process of earning for living. Population of the study area are involved in different economic sectors for sustaining their livelihoods. This study reveals the impact of storm surge on livelihoods of the population. Changes in livelihood at present and in future due to storm surge disaster are explored in this study. Therefore, future population are estimated and their livelihood involvement in different sectors is accounted in percentage compared to the disaster 'Aila'.

1.6 Limitation of the Study

This is a comparative impact study between present storm surge disaster *e.g.* cyclone ‘Aila’ and projected year storm surge disaster to estimate the losses in economy and changes in livelihoods. To study the impact of ‘Aila’, a series of field investigation has been conducted over one and half year. Some difficulties (*e.g.* FGD, KII, etc.) have been faced during field survey due to lack of additional man power.

Polder height (4.27m PWD) is assumed to remain constant for the projected year study. This study has assumed same river water flow, sedimentation and social behavior of the community in future. Sea level rise on the coast and inland adjacent to the polder is not same but this study consider equal rise of river water level in river. For future surge height estimation, this study is guided by Nicholls *et al.* (2008) equation which expresses a gross estimation of the additional surge height during future cyclone due to climate change. Use of digital elevation model (dem-30) data is not recently produced. Effect of sea level rise will reduce the storm surge height negligibly that is not considered in this research. Future rainfall pattern is also assumed constant in this study. There is a direct relationship among climate change, temperature, wind speed, storm surge. Lack of data of water level, land slope, land use pattern lead this study try to simplify about the gross estimation of surge height level in future

Lack of secondary information makes it difficult to predict the appropriate trends of the future economic dimension. Finally, the respondents are very much affected by cyclone ‘Aila’. So it is very difficult to gather information from them through PRA.

CHAPTER TWO
LITERATURE REVIEW

2.1 Coastal Zone

The term ‘Coastal zone’ means the coastal waters (including the lands therein and thereunder) and the adjacent shore lands (including the waters therein and thereunder), strongly influenced by each and in proximity to the shorelines of the several coastal states, and includes islands, transitional and inter tidal areas, salt marshes, wetlands, and beaches (LII, 2010).

General concept and profile of Coastal Zone is described by Lunkapis (1998);

- It is a dynamic area with frequently changing biological, chemical and geological attributes.
- It is an area of high economic significance, which is often subject to fast economic development, large population migrations and urban development.
- The coastal area acts as a barrier for land-based pollution and discharges to the sea.
- The coastal areas are affected, through the coastal hydrodynamics by the actions of the sea (cyclone storms surge, coastal erosion/accretion, flooding, tsunamis etc).

There are various activities in the coastal zone. Therefore, boundaries are considered with two particular purposes in mind (Lunkapis, 1998).

- First, they are intended to “capture” state resource and economic development issues that cross the boundaries of local authorities.
- Second, the boundaries should encompass significant natural resources.

Coastal areas are important ecologically, as they provide a number of environmental goods and services. They frequently contain critical terrestrial and aquatic habitats, such as the mangrove forests, wetlands and tidal flats. Coastal natural-resource uses reflect primarily subsistence agriculture with an emphasis on food production, *e.g.* paddy rice along with some cash crops and coastal fisheries, which provide a major food and income sources.

The landmass of Bangladesh is connected to the Indian Ocean through a 700 km long coastline. The coastal zone is marked by a vast network of river systems, an ever dynamic estuary, a drainage path of a huge basin covering also parts of India, Nepal, Bhutan and China, and a saline waterfront penetrating inland from the sea. In addition to the coastal plains, there are a number of small islands that are subject to strong wind and tidal interaction throughout the year, and are inhabited by a large number of people.

The entire coast of Bangladesh can be broadly divided into three distinct geo-morphological regions (PDO-ICZMP, 2001). Nineteen southern districts facing the Bay of Bengal or having proximity to the Bay and the exclusive economic zone (EEZ) in the Bay are grouped into the coastal zone in terms of three geo-physical characteristics that distinguish them from the rest of the country; interplay of tidal regime, salinity in soil and water and cyclone and storm surge (PDO-ICZMP, 2003a). Coastal zone of Bangladesh is identified in Figure-2.1.

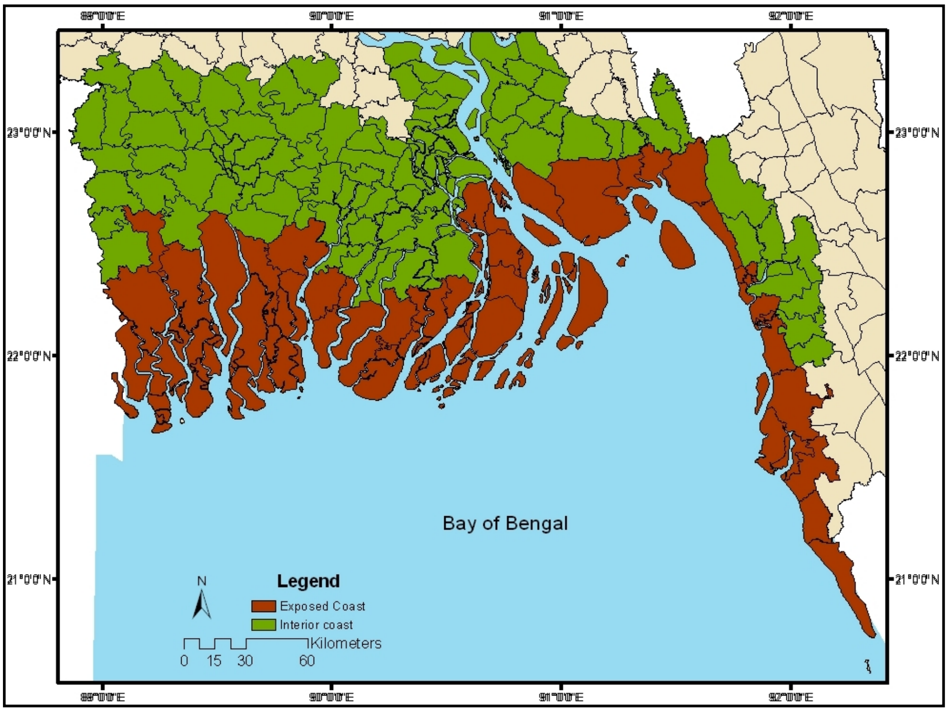


Figure 2.1: Coastal zone of Bangladesh

2.2 Polders in the Coast

Polders are special features of the coastal zone of Bangladesh. The Coastal Embankment Project (CEP) covers the coastal districts of Bangladesh and includes Cox's Bazar, Chittagong, Feni, Noakhali, Lakshmipur, Bhola, Barisal, Patuakhali, Jhalokati, Barguna, Pirojpur, Khulna, Satkhira and Bagerhat districts. The CEP is comprised of a complex network of dikes and drainage sluices and was the first comprehensive plan for providing protection against flood and saline water intrusion in the coastal area. The project was implemented between 1961 and 1978 by the Bangladesh Water Development Board (BWDB) in two phases. Phase I comprises some 92 polders providing protection to one million hectare of land. Phase II consists of 16 polders covering another 0.40 million hectare. In 1996, GOB with assistance from the World Bank (WB) and the European Union (EU) launched the Coastal Embankment Rehabilitation Projects (CERP) to undertake massive rehabilitation works for 21 coastal polders (MoWR, 2002). It has been estimated that 59 polders will be overtopped during storm surges in a changing climate by 2050 (WB, 2010).

Within the CEP, more than 4,000 km of embankment and 1,039 drainage sluices have been constructed. These embankments are intended to protect land from tidal inundation but cannot prevent overtopping and damage from cyclonic surges. In addition to increased agricultural production, these embankments have provided good road communication and contributed towards the improvement of the overall socio-economic (BWDB, 1999).

The following issues related to the polder system in the south west region identified in PDO-ICZMP (2002) is:

- Eroding embankment, too close to the shore
- No provision for hard protection
- Poor operation and maintenance
- Low quality construction
- Embankment cuts
- Faulty or missing structures
- Inside canals and outside rivers need re-excavation

2.3 Economy and Livelihood

Agriculture is the most important economic activity of the coastal area. The level of income of the coastal population is relatively lower compare to the rest of the country. More than 70% of the population is living in absolute poverty. Economically active population (15-59 years) in the coastal areas is 53% against country’s 55% of the total population. Percentage of male labor in the coastal zone is almost same as in rest of the country but it is increasing day by day in the coastal zone. The nature of occupation is quite different in the coastal zone like offshore fishing, wood collection, honey collection, shrimp farming, salt farming and others. In coastal zone, only 25.9% women between 15-49 years of age are found to be engaged as work force which is less than country's average of 28.2%. The highest 31.1% participation of female labor is found at Satkhira (PDO-ICZMP, 2005c). Employment of labor can be categorized under different economic sectors in future which are shown in the following Table-2.1.

Table 2.1: Livelihood of the coastal population in different years

Sector	**2005 Present (%)**	**2020 Change (%)**	**2050 Change (%)**
1. Agriculture, Forestry & Fishery	62.3	-5	-7
Crop & Livestock	43.7	-11	-12
Fishery	12.4	+11	+3
Forestry	6.4	+5	+1
2. Mining & quarrying	0.7	+13	+15
3. Manufacturing	7.4	+5	+5
4. Power, gas & water	0.2	+15	+15
5. Construction	2.1	+10	+10
6. Trade, hotel & services	12.0	+5	+11
7. Transport, & communication	4.5	+14	+14
8. Finance, business & services	0.7	+10	+10
9. Commodities & personal services	10.0	+10	+11

Source: PDO-ICZMP (2005c)

According to PDO-ICZMP (2005c), agricultural related livelihoods will be decreased in the future. It will decrease from 62.3% in 2005 to 59.2% in 2020 and 55.0% in 2050. In particular, livelihoods in crops and livestock sectors will be reduced from 43.6% in 2005 to 38.8% in 2020 and 34.2% in 2050 whereas fishery sectors related livelihoods will be increased from 12.4% to 13.8% in 2020 and 14.2% in 2050.

Through the study of a southwestern district, Saadat (2010) express on the basis of perception, climate change is responsible for the loss of access to livelihood capitals (Table-2.2) on which different rural communities depend.

Table 2.2: Reduction in access to livelihood capitals for different communities

	Natural Capital (%)	Physical Capital (%)	Human Capital (%)	Financial Capital (%)	Social Capital (%)
Farmer	20	12	15	21	-
Fisher	20	20	16	11	11
Labor	16	15	11	14	-
Woman	16	12	-	10	-

Source: Saadat (2010)

Farming opportunity will be decreased by 13.5% and 25.1% in years 2050 and 2080 respectively under the scenario A2, but under scenario B1 this decrease will be less (9.6% and 13.4%). Fishermen's fishing opportunity will be decreased by 8% and 15% in same years under scenario A2, whereas under scenario B1 the decreases will be about 6% and 8% (IWM & CEGIS, 2007). Agriculture in coastal area contributes about 30% to the national GDP. This contribution will be decreased by 2.1% and 3% in years 2050 and 2080 from the base year 2005 (IWM& CEGIS, 2007).

The post disaster damage and loss estimates revealed the most recent 10 year return period cyclone in Bangladesh (*e.g.* Sidr in 2007) caused a financial damage and loss of $1.67 billion. The projection of damage suggests a 10-year return period cyclone out to 2050 will result in an additional financial damage and loss of $4.560 billion in a changing climate. In addition, a conservative estimate of monetized loss from additional deaths and injuries is $1.03 billion (WB, 2010).

2.4 Vulnerability to Climate Change

The coastal zone is different from the rest of Bangladesh. According to PDO-ICZMP (2004) "the special feature of the coastal zone is its multiple vulnerabilities out of periodic cyclone and storm surges, salinity intrusion, erosion, pollution and overall lack of physical infrastructure". The Govt. of Bangladesh has already identified the zone as 'vulnerable to adverse ecological process' and as one of the three 'neglected regions' (PDO-ICZMP, 2004).

2.4.1. Sea Level Rise

The contribution of Bangladesh to green house gas emission is considered to be very negligible in the global context. A number of studies, based on Global Climate Models (GCM) – driven scenarios, suggested that the average change in temperature for the entire country over a 100-year period could be as high as 3.6^0 C (Ahmed and Alam, 1998; World Bank, 2000).

In Bangladesh, sea level rise has been considered as the main variable of climate change. According to IPCC (2007), the global sea level rise situation has been given in Table-2.3 where the Sea Level Rise (SLR) has been predicted with respect to Special Report on Emissions Scenarios (SRES). The calculated SLR is based on AOGCMs for different SRES of IPCC.

Table 2.3: Sea level rise for SRES of AR4

	Scenarios					
	B1	A1T	B2	A1B	A2	A1F1
Temperature (^{o}C)	1.1-2.9	1.4-3.8	1.4-3.8	1.7-4.4	2.0-5.4	2.4-6.4
SLR (m)	0.18-0.38	0.20-0.45	0.20-0.43	0.21-0.48	0.23-0.51	0.26-0.59

Source: IPCC (2007)

In case of Bangladesh coast, different organizations have estimated sea level rise on the basis of 3rd IPPCC report. The estimated SLR at the coast of Bangladesh is shown in Table -2.4.

Table 2.4: Projected SLR at the coast of Bangladesh

Year	**Sea level rise (cm)**		
	TAR, IPCC(2001)	SMRC	NAPA scenario
2030	14	18	14
2050	32	30	32
2100	88	60	88

Source: IPCC, (2001); SMRC, (2000); and NAPA, (2005)

2.4.2 Coastal Flooding

Ali and Ahmad (1992) estimated Bangladesh is one of the most densely populated and highly poverty stricken countries which is also a victim of frequent natural calamities like tropical cyclones, tornadoes, floods, storm surges and droughts. It's coast line extends to 720 km and 21 percent of the population lives in the low coastal belt. Any sea-level rise (SLR) will be a problem of ominous proportion for Bangladesh. About 1 meter SLR will inundate approximately 10% of the country and 1.5 meter SLR will inundate approximate 15.5% coastal land of the country.

Salinity will be increasing and navigation route within the area will be shrinking. From the past experience, coastal flood was always initiated by cyclonic storm surge. On Bangladesh coast, the increase of surge height from 7.6m to 9.2m increases the distance of inland inundation by about 13% and an increase in surge height from 7.6m to 11.3m increases inundation by about 31% (Ali, 1996). The storm surge-induced inundation area estimates indicate a potential 69% increase in the vulnerable zone with more than 3m inundation depth and 14% increase in the vulnerable zone with more than 1m inundation depth with climate change by 2050 (WB, 2010).

Major impacts of sea level rise are inundation, drainage congestion, salinity intrusion and change of surge height in the coastal zone. The impact of SLR to the southwest region was quantified and "about 11% more area (4,107 km^2) will be inundated due to 88 cm sea level rise in addition to the existing inundation area under the same upstream flow where about 84% of the Sundarban area becomes deeply inundated due to 32 cm sea level rise, and for 88 cm sea level rise Sundarban will be lost" **(**PDO-ICZMP, 2005).

According to the study of IWM & CEGIS (2007), in 2080 (SLR 15 cm) under scenario B1 about 44% people will be exposed to additional flooding due to SLR. Under scenario A2 in years 2050 (SLR 27 cm) and 2080 (SLR 62 cm) about 47% and 51% people will be at risk by flooding. However, most of the population will be at no risk of inundation or exposed to low inundation if the embankments are raised. IWM (2008) has showed the increasing inundated area of Satkhira district in 2040 compared to 2005 (Table -2.5).

Table 2.5: Inundated area of Satkhira district on the basis of land type

Land Type	Description	Flood Depth	Types of Crop	Inundated area (Km^2)		
				2005	2040	Change (%)
F0	Highland	<30 cm	HYV rice in the wet season	35.91	27.72	-22.81
F1	Medium-high	30-90 cm	Local varieties of Aus and T. Aman	121.5	127.7	5.93
F2	Medium-low	90-180 cm	Broadcast Aus and Aman in wet season	392.3	216	-44.94
F3	Lowland	>180 cm	Only broadcast Aman can be grown in wet season	1844.4	2063.9	11.91
F4	Very low	>>180 cm	Support local Boro in dry season	0.09	0.81	Significant

Source: IWM (2008)

2.4.3 Cyclone

The coastal regions of Bangladesh are subjected to damaging cyclones almost every year. They generally occur in early summer (April-May) or late rainy season (October-November). Cyclones in the South Asian Sub-Continent are presently classified according to their intensity and the following nomenclature (Table-2.6) is in use.

Table 2.6: Classification of cyclone (Choudhury, 1992)

Depression	**Winds up to 62 km/h**
Cyclone Storm	Winds from 63-87 km/h
Severe Cyclonic Storm	Winds from 88-118 km/h
Severe Cyclonic Storm of Hurricane Intensity	Winds above 118 km/h

Cyclone intensity increases with an increase in sea surface temperature (Miller, 1958). The increasing temperature instigates more water vapor in the air which provides more energy to storms and intensifies low pressure systems (Frei *et al.*, 2001). The higher sea surface temperatures, which should rise as global temperatures rise with climate change, are a major factor in the intensity of storms (Emmanuel, 2005a). Assuming a lower bound of sea surface temperature rise of 2 ° C and an upper bound of 4 ° C (according to the IPCC limits), the corresponding increases in maximum cyclone intensity would be 10 and 22%, respectively, using the threshold temperature of 27 °C (Table-2.7).

Table 2.7: Relationship of maximum wind speed (V_m) in cyclones to sea surface temperature

Sea Surface Temperature (^{0}C)	V_m(ms^{-1})	V_m/V_{27}*
27	72	1
28	75	1.04
29	79	1.1
30	83	1.15
31	88	1.22
32	93	1.29
33	99	1.38
34	106	1.47

*V_m/V_{27} is the ratio of maximum wind speed at different temperatures to maximum wind speed at 27°C. (*Source:* Emanuel, 1987)

First, they will be elevated by a rising sea level as thermal expansion and ice cap melting continues. Second, a warmer ocean is likely to intensify cyclone activity and heighten storm surges (Knutson & Tuleya, 2004; Michaels *et al.*, 2005). The destructive impact will generally be greater when the surges are accompanied by strong winds and large onshore waves. It will create more damaging flood conditions in coastal zones and adjoining low-lying areas. Some recent scientific studies suggest that observed increases in the frequency and intensity of tropical cyclones in the last 35 years can be attributed in part to global climate change (Webster *et al*., 2005; Bengtsson *et al*., 2006).

An analysis of all the cyclones that formed in the Bay of Bengal between 1881 and 1990 (110 years) shows that about 14% of them hit Bangladesh, and about 66% hit India (Ali 1996). In terms of death tolls due to tropical cyclones alone, Bangladesh suffers the most. The cyclone shelters can provide shelter to only 14% of the impacted area population, which is far below the satisfactory level (PDO-ICZMP, 2005b). During the first half of last century (1901–1950), the rate of tropical storms striking Bangladesh coast is one storm per year. Since 1950, the rate of land falling tropical storms in this area has increased, 11.8 per decade for 1950–2000 (Islam *et al.*, 2009). At present, a 10-year return period cyclone with an average wind speed of 223 km/ hr covers 26% of the vulnerable zone; estimates of this study indicate that a similar cyclone will be more intense with global warming and is likely to cover 43% of the vulnerable zone by 2050 (WB, 2010). On an average, a severe cyclone strikes Bangladesh every three years (GoB, 2009).

2.4.4 Storm Surge

Most of the casualties from cyclones in Bangladesh, as in other parts of the world, are caused by storm surges. Storm surges are the course of many coastal areas where shallow seas and severe storms are combined and the sea can rise suddenly and sweep away whole communities (Burroughs, 2003). Storm surges that hit the coast of Bangladesh move inland leading to flooding. In the northern Bay of Bengal, a unique combination of high tides, funneling coastal configuration, low flat coastal terrain and high population density have produced some of the highest mortality Figures associated with storm surges (Flierl and Robinson, 1972).

Storm surges are generated by two principal factors: pressure drop and wind stress. Atmospheric pressure drop below normal raises the water through "inverted barometer effect" (which is also called "sucking effect") by a nominal amount, *e.g.* about 1 cm per 1 Mb drop of pressure. Wind is the main force for the generation of storm surges. Wind exerts tangential as well as normal (downward) stresses on the water underneath. The tangential stress generates long water waves or storm waves *e.g.* storm surges. A surge that coincides with a high tide, for example, is much more destructive. The estuary can also have a funneling effect that accentuates flooding (Hussaini, 2005).

The destructive impact of storm surges will be greater when the surges are accompanied by strong winds and large onshore waves. Larger storm surges threaten greater future destruction, because they will increase the depth of inundation and will move further inland - threatening larger areas than in the past.

The last cyclonic disaster 'Aila, 2009' passed over 14 districts with wind speed of 70-90 km/hour and tidal surge was very high near about 2 to 3 meters above the normal astronomical tide (DMB, 2009). Many areas of the affected districts were inundated and houses, roads and embankments were damaged. According to the report of DMB (2009), 155 persons were reported dead, 10 persons were missing, 7108 persons were injured, about 801602 families were affected and almost 3606116 people were affected by cyclone 'Aila'. Further, more than 564315 houses were destroyed and 327406 acre of agricultural crop was damaged. Among the fourteen of the country's 64 districts, Satkhira being hardest hit with at least 25 deaths just after 'Aila'(IRIN, 2009).. According to local media reports, over 500 people are missing, many believed to be fishermen at sea when the cyclone struck. Shyamnagor and Assasuni upazilla were flooded adversely. According to Caritas Bangladesh (2009), a total of 88 km of ring embankments were damaged especially of polder no 5, 15 and 7a. About 1 lakh people were affected in those two upazilla.

'Aila' took a heavy toll on the coastal people's livelihoods. The main damage was done by the flooding of water breached through the damaged embankments all round the district. It was found that there is direct relationship between the damage of the embankment and breaching activities by the shrimp farmers near the particular embankment. According to Roy *et al.,(*2009), frequent breaching of the embankments to lift saline water in shrimp farm made the half-century old embankments quite weak and led it break down during the tidal surge inflicted by cyclone 'Aila'. Moreover, silting up of the river beds in region has also forced the tidal surge and usual river flow to put immense continuous pressure on the embankments to make them even weaker. Roy *et al.,* (2009) also suggested that it's not 'Aila' that solely responsible for the havoc in the coast of Bangladesh, rather it's the failure of the embankment to protect the coastal belt from storm surge that is responsible for the wreckage.

2.5 Coping Strategies

Population of the south coast adapt to a number of adaptations in their life and livelihood, considering the threat of multiple natural hazards. Considering salinity ingress, the south west coastal area would be severely affected than the rest. In the south west region, about 6 million people are deprived of safe non-saline drinking water (Ahmed, 2008). Since it is a slow process compared to other hazards, the population gets much time to adapt with the salinity hazard. They accept variety of approaches seriously for reducing their loss to cyclone hazards. From recent past cyclone (1997), the accurate and in time forecasting systems and in time publicity, mobilization and action were very effective to reduce the loss of life and damage of properties (IWM & CEGIS, 2007). According to Ahmed (2008), the environment of the cyclone shelters is also discouraging factors for the vulnerable population for not going to the shelter. Cyclone shelter of the south western district (*e.g.* Satkhira) protects only 5% of the total population (PDO-ICZMP, 2005a). Every section of the society tries to strengthen their houses prior to the monsoon and cyclonic storms. They raised the platform to protect the houses from unusual tidal surges (Ahmed, 2008).

Bangladesh already employs coastal embankment towards management of coastal flooding, particularly when it is caused by high tides and storm surges. Inadequate drainage infrastructure along an embankment can be counter-productive, and could interact with several aspects of climate change to produce a cascade of adverse consequences. The failure of regulators in polder no-24, located in the western coastal region, caused saline flooding for over a decade (Agrawala *et al.*, 2003). In 2007, one of such breaches in embankment was detected in Shyamnagor thana in Satkhira, It has been subsequently mended twice, yet the structure could not secure the land from being inundated by saline water (Ahmed, 2008). While coastal embankments have flow regulators (albeit poorly maintained), the coastal roads network generally lacks drainage infrastructure, a factor which believed to have contributed to flood of 2000 (Tutu, 2001). To reduce risk of the impact of climate change and sea level rise includes provision of sufficient protection against storm surge and flooding, a number of adaptation options were proposed by World Bank in 2001.

Issues	Physical Adaptation	Institutional Adaptation
Cyclone and storm surge	• Waning system development • Adequate and improve cyclone shelter • Modification of coastal embankment, landfills • Mangrove green belt development • Modification of valuable infrastructure	• Improve forecasting systems • Adopt land use development policy • Regular maintain of the embankment
Drainage congestion	• Increasing drainage capacity • Intervention of new regulators, tidal basin, and pumped drainage	• Guidelines to incorporate climate change in long term planning • Proper O&M arrangements • Developing design criteria for drainage capacity
Salinity	• Increasing local storage of surface and ground water • Desalinization plants and equipments • Diversion project • Resuscitation of river networks	• Proper O&M sluices and regulators • Effective management of ground water • Changing land use practices • Development water saving technique

Some of the adaptation options to cyclone and tidal flood have been identified during the study of IWM and CEGIS (2007) in the coastal zone of Bangladesh.

Present coping strategies during cyclone and coastal tidal flood are:

- Forestation on the mudflat outside the polder
- Raising embankments
- Stay at cyclone shelter or high buildings
- Reserve dry food
- Maintenance and drainage of *Khals*
- Take preparation by hearing early warning from TV, Radio, mike
- Protect fish farm boundary with net
- Sell the fishes and harvest the crops earlier
- Take the livestock to the safer place

For reducing the future impact due to climate change, a project entitled Reducing Vulnerability to Climate Change (RVCC), implemented in six southwestern districts of Bangladesh during 2002 till 2005, applied a few adaptation measures for the agriculture (Table-2.8).

Table 2.8: Household level strategic approaches for agricultural adaptation

Strategy	Measure
Increase food through agriculture	Drought tolerant crops/vegetables
	Floating gardens
	Low-cost irrigation
	Homestead gardening
	Saline tolerant non-rice crops
Increase income through alternative livelihoods	Embankment cropping
	Integrated farming systems
	Cage aquaculture
	Prawn fish poly-culture
	Shrimp fish poly-culture
	Cattle Goat and Pig rearing
	Poultry and Duck rearing
	Apiculture & honey processing
	Nursery & homestead afforestation
	Saline tolerant tree plantation
	Mele (reed) cultivation

Source: Ahmed (2006)

According to Ahmed (2010), the implemented strategies during RVCC to agriculture have been adopted by the community of the south-western districts. Such measures include a) change in verities of rice to enhance crop resilience, b) change in irrigation practices, c) changes in crop rotation and fertilizer application, d) promotion of integration approach, e) hanging vegetables and f) floating gardens.

In order to reduce vulnerability to natural disaster and improve resilience to climate change of the pro-poor community a number of initiatives have been taken by the government (WB, 2006). The Government of Bangladesh maintains a variety of social safety net programmes designed to address mainly transient food insecurity stemming from shocks. There are 30 specifically designed social safety net programs directly operated by the Government of Bangladesh (Ahmed, 2007). Some of the most prominent safety net programmes is found of the south west area include Vulnerable Group Feeding (VGF), Open Market Sales (OMS), Cash for Work (CFW), Food for Work (FFW) Vulnerable Group Development (VGD) and Gratuitous Relief (GR).

CHAPTER THREE
METHODOLOGY OF STUDY

3.0 Introduction

Impact of climate change on economy and livelihood has been determined through the analysis of a hazard and socio-economic vulnerabilities in a particular area. The steps of this study are shown in Figure-3.1. The research has been initiated when the cyclone ‘Aila’ passed over the south west coast of Bangladesh on 25^{th} May in 2009. A detail study has been conducted on the southwest coastal part of the country. This part is encircled by earthen embankment. Without proper management and enhancement of shrimp culture make the polders more vulnerable to breach with comparatively lower categories cyclonic event. This zone was highly damaged to the cyclone induced disaster ‘Aila’ in 2009. ‘Aila’ has been selected as a base year scenario in this study. This study explores the climate change influencing future storm surge disaster on a particular coast and subsequently estimates the additional impact on socio-economy and livelihood of that community. The process of information collection, data arrangement, analysis and future impact assessment are elaborated one by one as follows.

3.1 Steps of the Study

3.1.1 Literature Review

Sea level rise due to climate change is one of the main focusing issues especially for the coastal region of Bangladesh. Newspapers, seminar, reports and scientific papers are always agitated about this issue. For the study regarding climatic issue, a number of related literatures have been reviewed in particular for south west coast. It helped to develop ideas about the study of climate change influencing surge disaster and subsequently its impact on socio-economy and livelihoods to the coastal community.

3.1.2 Base Year Selection

At the beginning, a representative storm surge event has needed to select for comparative impact study. During ‘Aila’, storm surge intruded into the polder by breaching and flooded a vast region for several of months. Loss of life and properties at the time of cyclonic storm surge and aftermath sufferings of the inhabitants for long time noted ‘Aila’ as a severe disaster in the south west region. ‘Aila’ was considered as a base year storm surge event for future impact assessment in this research. It passed over the south west coastal polder of Bangladesh on 25th May in 2009. As a result, it severely affected the south west coastal polders which had been constructed in late sixties. This study has been conducted on Polder no-5 which was severely affected by 'Aila'. Storm surge played the major role for the high causalities of coastal community.

Cyclone 'Aila' was well-documented disaster that swept over Polder no-5. The impacts of this disaster on the polder community were dominated by storm surge rather than wind speed. So, in order to work with polder, climate change and storm surge event of the south west region, cyclone 'Aila' obviously is a good case study. It would generate scientific knowledge and this experience could be used in future disaster. Selection of 'Aila' as a base year would be a great opportunity for the research in real time field study. Reconnaissance survey for research has been carried out just after 'Aila'.

3.1.3 Study Area Selection

South west area is one of the highly risk prone areas of cyclone and storm surge due to its geographic location. This area is enclosed from the sea by polders. Polder no-5 has been selected for this research. The embankment was highly vulnerable due to shrimp culture and poor maintain. This polder includes Shyamnagor and parts of Kaligonj upazilla under Satkhira district. The reasons of selecting Polder no-5 as study area are as follows;

- Geographically Polder-5 is representative of the rest of the coastal area of the south west region.
- It is one of the most vulnerable polders to future sea level rise due to its land use pattern.
- The effect of recent disaster (Aila) is distinctly evident in this polder

3.1.4 Surge Height Determination

In this step, relevant data have been collected from different primary and secondary sources. Water level data was collected from Bangladesh Inland Water Transport Authority (BIWTA) 2009 publications and surge height information during 'Aila' was obtained form Bangladesh Meteorological Department (BMD) reports. It was full moon and high tide period when cyclone 'Aila' was crossing over the south west coast. So, the coincidence of both storm surge and high tide simultaneously accelerated the devastation to the polder. Secondary information has been verified during field survey, such as water mark on the trees and walls approximated the surge height level during ‘Aila’. Subsequently, the total surge height (TSH) of cyclone Aila was determined through the summation of tidal height (TH) and surge height (SH) at the same period (eq. 1).

$$TSH = TH + SH \quad \ldots\ldots\ldots\ldots (1)$$

The movement of surge waters over coastal land is very complex. It is extremely difficult to estimate the distance the surge water will move inland especially when the coast is protected by polder. The movement is governed by a number of factors. In the absence of any model for the Bay of Bengal, the Multipurpose Cyclone Shelter Programme (MCSP, 1992) produced an empirical formula following that given by Freeman and Mehaute (1964). The formula used was (eq. 2); where L is the maximum distance traveled by the surges, d is the depth of water approximately at the point where h is determined, s is the bed slope, and c is the friction factor.

$$L = \frac{4(d + 1.5h)^2}{3(d + h)(s + c/8)} \ldots\ldots\ldots\ldots\ldots (2)$$

But lack of available data on the study area and availability of time would make the study more difficult. This study focus mainly on the surge height related to coastal flooding rather than intrusion distance into the polder during cyclone. So this study has been done more generic away.

According to scientific justification, if same type of disaster (*e.g.* Aila) would be in future projected years (*e.g.* 2030, 2050 or 2100) climate change will intensify the surge level in various aspects. In this study SRES–A1B scenario in AR4 of IPCC (2007) has been considered especially for SLR. According to the equation (3) of Nicholls *et al.* (2008) the future storm surge height is estimated easily.

Current storm surge = S100

Future storm surge = S100 + SLR + (UPLIFT * 100 yr) / 1000 + SUB + S100 * x...(3)

S100 = 1-in-100-year surge height (m)

SLR = sea-level rise for SRES-A1B scenario (m)

UPLIFT = continental uplift/subsidence in mm/yr

SUB = Total human-induced subsidence

x = Storm enhancement factor

Sea level rise adjacent to the Polder-5 is assumed to be equal in this study. 1-in100 year return period of the storm surge is substituted by representative storm surge (*e.g.* 'Aila'). To find out future total storm surge height (FTSSH) of a cyclonic disaster with respect to 'Aila' event the equation of Nicholls *et al.* (2008) is slightly modified which is shown as follows (eq.4) and the result has been shown in the result and discussion chapter in Table-5.2.

FTSSH = RCSH+ SLR + (UPLIFT * 100 yr) / 1000 + SUB + RCSH * x…….. (4)

RCSH = Representative cyclone surge height (6.1m for 'Aila')

SLR = 0.14m, 0.32m and 0.48cm in 2030, 2050 and 2100

UPLIFT = Not accounted

SUB = 0.5 m (applies to deltas only)[1]

x = 0.1 or increase of 10%, applied only in coastal areas currently prone to cyclones[2]

3.1.5 Estimation of Inundated Area

Return period of a particular surge height (*e.g.* Aila) has been calculated by using Log normal distribution of the past 50 years (1960-2009). This Log normal distribution plot has been used to estimate the return periods of different surge heights in future. This distribution fits best to the data.

The best available spatially-disaggregated data (*e.g.* 30m, DEM) of Polder no-5 was collected for spatial analysis through GIS. GIS was used as an important tool to determine flood inundated area during breaching of the embankment or only overtopping of the embankment with respect to changing surge heights. In this study,

[1] A fixed uniform amount of potential subsidence of 0.5 m over the seventy years was applied across the coastal cities, as a scenario of major human-induced subsidence (Nicholls, 1995)

[2] An intensity increase of 10% is assumed, consistent with intensity projections (Knutson & Tuleya, 2004).

polder height, tidal height and land elevation of the study area has been assumed to be constant for the future. However, the flooded area has been accounted through DEM analysis for cyclone 'Aila', and estimated in the year of 2030, 2050 and 2100. During PRA application, the flood inundated area has been verified at the field level in case of 'Aila'.

3.1.6 Socio-economy Impact

To find out socio-economic impact of cyclone 'Aila', a long term regular field investigation has been carried out in the study area. Primary data has been collected by using Key Informant Interview (KII) and Participatory Research Appraisal (PRA) tools like resource and social mapping, pie chart, trend line analysis, GD and FGD. Those tools of PRA were used to identify the impact of the disaster 'Aila' in different economic sectors like crop production, shrimp production, captures fisheries, forests and infrastructure. The livelihoods of the population were affected in accordance with the depletion in different economic sectors. Actually, most of the population of the study area was impacted directly and indirectly by that disaster.

Some of the documented field data were also collected from local offices of govt. and non-govt. organizations like Upazilla Agricultural Extension Office, Fisheries Office, Land Office, Upazilla WAPDB and Shushilan, Muslim Aid, Caritas etc. By compiling the primary and secondary data, an impact has been estimated.

Past data about different productive sectors have been analyzed to predict the trend of future production especially in rice and fisheries sectors. But impact on livestock, forestry and infrastructure has been identified by the application of only PRA tools.

3.1.7 Resources Status

Future population has been estimated according to the trend of A1B-SRES in AR4 of IPCC. Assumptions in the A1B scenario include a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. In terms of energy technology, the A1B scenario assumes a balance across all sources, where balanced is defined as not relying too heavily on one particular energy source. This study tried to identify the loss of assets especially land resources which were important for their livelihoods. Loss of present capitals and future opportunities force them to change their livelihood after the disaster. Loss of livelihood is quantified through perceptional study which is very much related to the destruction of land resources in the polder. So, this study has considered this relationship to draw future livelihood situation. It has identified the changing of occupation due to 'Aila' event through the using of pie chart diagram. Two FGDs were carried out with only women participants of the affected community. Some of the important social issues like cultural attitude, literacy, living status, warning system and demographic condition were considered for future livelihood impact study.

3.1.8 Livelihood Study

Changes in livelihood of the study area have been estimated in accordance with ICZMP livelihood projection. By comparing the future loss with the present 'Aila', it has been conceptualized about what extent the changing climate will increase the vulnerability in the polder. All of the estimated loss in economy and change of livelihoods for the future disaster have been presented in percentage.

3.2 Applied PRA Tools

Primary data were collected through KII and PRA tools.

3.2.1 Reconnaissance Survey

During 'Aila', the most of the damages was caused by storm surge rather than wind. Devastation due to 'Aila' has been estimated like injury and loss of life, damage to the infrastructure, shrimp and agricultural farm. The misery of the polder communities were magnified during coastal flooding just after storm surge. Reconnaissance surveys have been carried out in mid June, 2009 for collection information about this disaster. Some of the group discussion (GD) and key informants interview (KII) have been carried out at the time of reconnaissance survey.

3.2.2 Transect Walk

Three transect walks (TW) have been carried out with a team consisting of local inhabitants in the study area for detail observation about impact. First transect walk has been conducted at Noabeki village just after a focus group discussion. Second and third transect walks have been conducted on Burigoaliny and Pankhali in February 2010 before the social and resource mapping. During TW, they helped to identify resources, impacted bodies, land use pattern and social situation of the study area.

These TWs facilitated the research to overview and validate the raw information. In addition, TWs helped to build up rapport with the local people.

3.2.3 Group Discussion

Most of the group discussions (GD) were informally held at the field (Table-3.1). A GD was conducted at the initial steps of the study. The affected populations were living in different places of the study area without considering the socio-economic status. So, classification in social caste, race, gender, religion, economy, livelihoods became insignificant at the time of GD. Group discussions were mainly location dependent where the participants (10-15) were gathered to continue the session. In every GD, at least one third women participation was tried to be insured.

Table 3.1: Schedule of group discussion (GD)

Date	Place	Participants	No. of Participants
14-06-2009	Noabeki	Directly affected population	15
25-10-2009	Iswaripur	Indirectly affected population	10
26-10-2009	Pankhali	Directly affected population	12

3.2.4 Focus Group Discussion

Every focus group discussion (FGD) has been conducted through preplanned arrangement. Most of the FGDs were conducted quite sometime after the cyclone ‘Aila’. The target groups were selected on the basis of the following criteria:

- Geographically identical with respect to habitat, land elevation, land use pattern and distance from the embankment.
- Livelihoods and change of livelihoods almost similar.
- Comparable in social status, gender, caste, religion and culture of the community.
- Economic and political classes were also considered.

FGDs were conducted with approximately 9-15 homogenous people engaged in a particular place on scheduled time. Most of the FGDs were held for one and half hour in average at a common place like institutional ground, homestead or fallow ground. Detail information about the FGDs has been given in Table-3.2 where, the places, number and target group are mentioned. Discussion with the focused group like farmers, fishers, women, labors etc at different time and locality helped to account present impact and future economy and livelihood dimension for such a disaster.

Table 3.2: Schedule of focus group discussion (FGD)

Date	Place	Target Group	No of Participants
01-10-2009	Noabeki	Fisher	6 M, 6F
01-10-2009	Noabeki	Day labor	11 M, 4 F
22-07-2010	Burigoaliny	Farmer	9M
23-07-2010	Burigoaliny	Women	7 F
22-07-2010	Burigoaliny	Small business men	10 M
21-07-2010	Nakipur	Farmer	12 M
24-07-2010	Nakipur	Women	13 F
25-07-2010	Nakipur	Fisher	7 M, 5F

Note: M-male and F-female

3.2.5 Social and Resource Mapping

This tool was used to get information about resources situation in the study area. Both natural and man-made infrastructures were considered during social and resource mapping (SRM). At first, the objectives of the study were explained to the villagers. Subsequently, different types of resources, livelihoods, institutions and its functions were interpreted for their consideration and mind setup. The resources were identified through discussion with the community and shared the ideas with them. Participants including women helped to draw the social and resource map. At the beginning, it was needed to initiate by preliminary sketching on the paper and subsequently the villagers automatically engaged to draw the social and resource map by them. Two SRM were completed at Burigoaliny and Pankhali in February, 2010. Those mapping exercises were conducted near the highly affected and moderately affected areas. Both social and resource mapping were done at the same time on the same sheet of paper in order to manage the time.

3.2.6 Seasonal Calendar

Seasonal calendar was used to extract information about seasonal livelihood activities of the participants. Seasonal calendar has been developed through the participation of different livelihood groups at Nakipur. At first, a paper sheet was provided to the participants that contained a table showing livelihood in row and season in column. Subsequently, they marked on the table according to their livelihood with seasonal rotation.

3.2.7 Pie Diagram

To know about the changing occupational pattern due to storm surge disaster was the main objective for drawing pie diagram. Two pie diagrams were sketched by the participants at the field. They indicated not only the qualitative but also quantitative information regarding their livelihoods. They provided available information before the cyclone ‘Aila’ and made important indication about future mode of occupation pattern.

3.2.8 Timeline Analysis

Timeline analysis (TA) was used to reveal historical records about the impact of storm surge disaster in Polder no-5. It helped to study sequential development activities in fisheries and agricultural sectors and about changing in land use pattern and livelihoods of the study area. This study was carried out only with the older inhabitants in a particular location. The changes of socio-economic and cultural activities were also identified in this process. For timeline analysis, 10 years interval from 1980 to 2010 was selected for the study. It was conducted especially during the end of field visit at Nakipur village. Future scenarios were also estimated by the participants during TA session.

3.2.9 Key Informant Interview

Key Informant Interview (KII) was used as an important tool to gather appropriate information. It helped to verify and evaluate the field survey data. KII was conducted with selected persons in different time and places from the beginning to end of the field research. The participants of KII have been mentioned in Table-3.3.

Table 3.3: Participants for Key Informant Interview (KII)

Serial No	Designation
1	Upazilla Agricultural Officer
2	Upazilla Fisheries Officer
3	BWDB Thana Survey Officer
4	LGED Upazilla Assistant Engineer
5	School Teacher, Porakathla Primary School
6	Chairman, Burigoaliny union Parisad
7	Member, Gate Operating Committee, Pankhali
8	Chairman, Farmer Association, Nakipur
9	Villagers, Donor Agencies, Others

3.3 Secondary Data Collection

A number of secondary data have been obtained for this study. The data providing agencies and the types of data or information are summarized in Table-3.4.

Table 3.4: Secondary data and sources

Agencies	Document
1. Bangladesh Water Development Board (BWDB)	Books, Reports, Papers, DEM data, Projects report, Journals, Maps, 'Aila' impact report, Field aggregated data etc.
2. Bangladesh Meteorological Department (BMD)	
3. CEGIS, CGC, IWM, Practical Action and WARPO	
4. Upazilla Fisheries Office	
5. Upazilla Agriculture Office	
6. Thana LGED Office	
7. Local NGO's	
8. Report of International Donor Agencies	
9. Institute of Water and Flood Management, BUET	

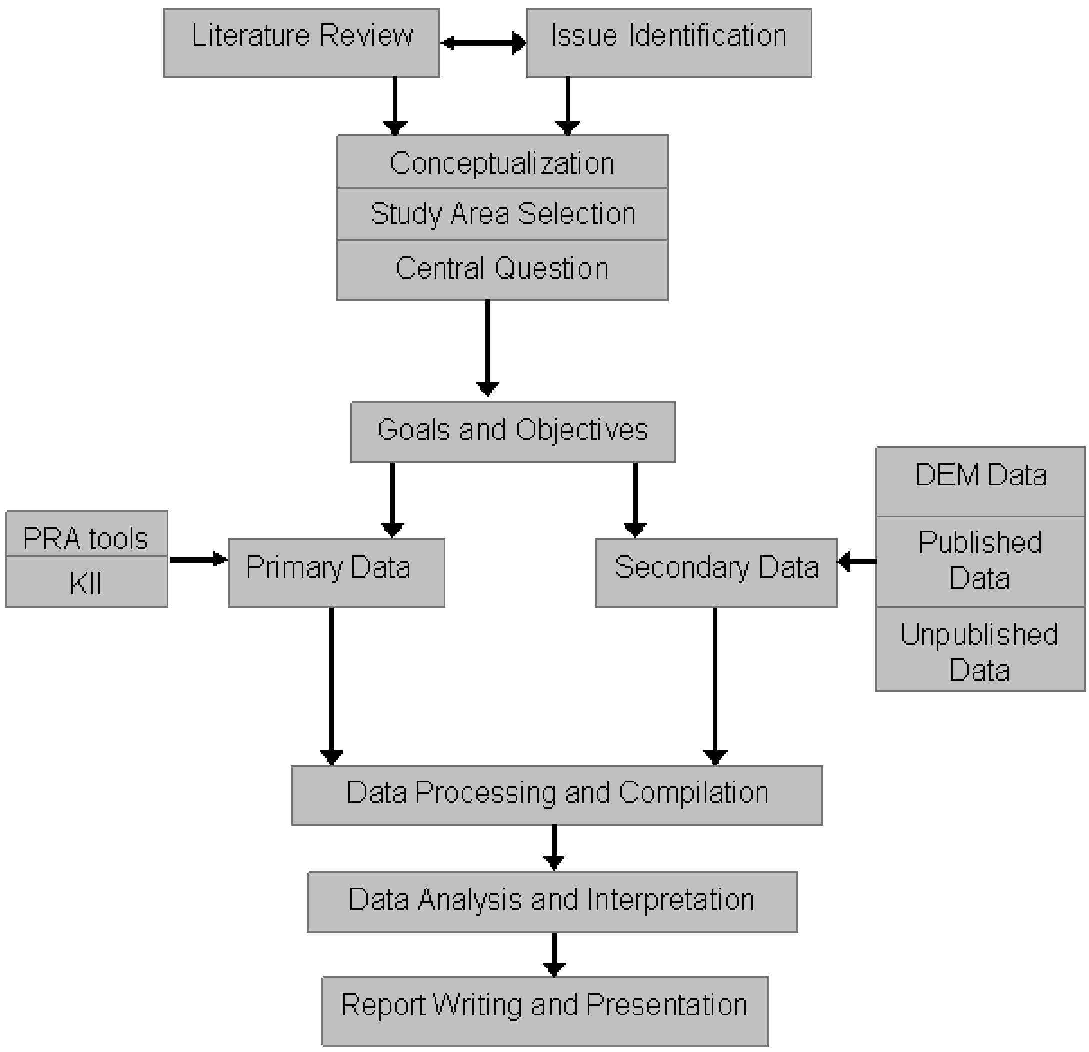


Figure 3.1: Conceptual flow chart of the study

CHAPTER FOUR
STUDY AREA

4.1 Location

Polder number-5 (Figure- 4.1a&b) is located on the southwestern part of Bangladesh. It is bounded by Polder no-3 on the north, Polder no-4 on the north east, Polder no-7(a) on the east and Polder no-15 on the south east part. Rest of the areas, particularly southern part is bounded by Sundarban and west part is bordered by West Bengal state of India. The main rivers are Kalindi, Kakshiali, Kholpetua, Arpangachia, Malancha, Hariabhanga and Chunar.

Figure 4.1 a: Satellite image of the Polder-5

4.2 History

The Coastal Embankment Project (CEP) was carried out in mid 60s targeting to maximize the agricultural return. However, the concept of CEP dates back to the 17th century. Small dikes or levees around individual land parcels are separated by numerous tidal creeks and inlets to limit saline water overflow that has been practiced since the 17th century by Zamindars (Big Landlords).

This Polder includes Dhumghat which was the capital of Raja Pratapaditya. He ruled over the greater south west of Bengal. During his reign this area was protected from the sea by Sundarban and connected with the sea by a number of rivers. Later it was renamed as Iswaripur. An ancient port was built by Basanta Roy, uncle of Raja Pratapaditya in 1593 at Jahajghata Port (Khanpur).

With the abolition of the Zamindari system in 1947, construction of embankments by local efforts practically ceased and the condition of existing embankments deteriorated due to lack of maintenance. At last construction and development of polder started in 1961 in the coastal areas. Polder no- 5 was constructed in 1964 with an area of 55089 hectare.

Only single crop (*e.g.* B. Amon) was cultivated before 60s in this area. After construction of the Polder, the agricultural practice was changed. The farmers cultivated double paddy crops inside the polder for the first time. They got winter crops from their agricultural land. Subsequently, shrimp culture was initiated during 1980s. During 1990s shrimp cultivation reached its peak covering 50% of the total cultivable area. To facilitate shrimp cultivation fish farmers cut Polder at different places to intrude saline water. Such practice raised conflict with paddy farmer and also weakened the embankment. This shrimp sector was severely affected due to attack of virus after 2000. Lack of demand at the foreign markets and effect of diseases simultaneously reduced shrimp cultivation during last couple of years in this area. As a result, farmers were moving to paddy culture, white fish culture, crab culture, shrimp with white fishes or paddy cum fish culture in this area. Now maximum agricultural land is used in integrated way.

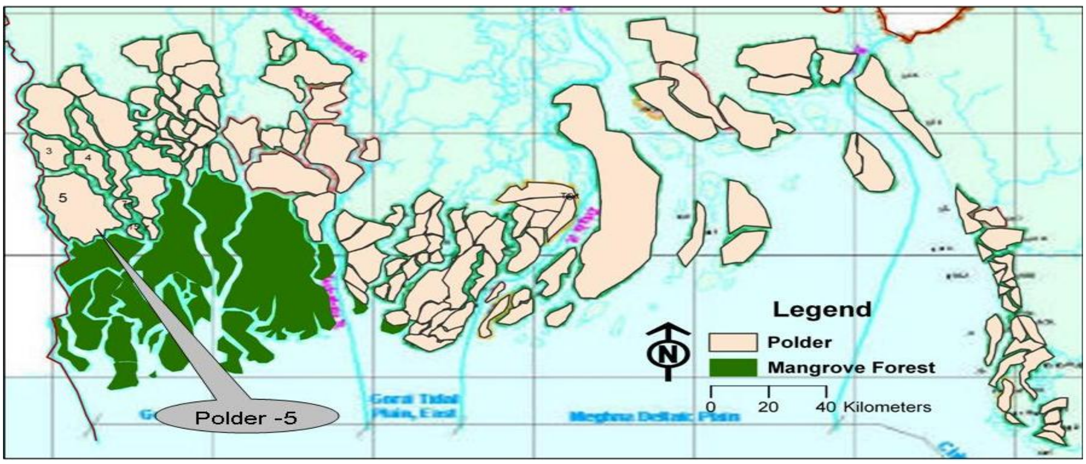


Figure 4.1b: Geographic location of the coastal Polders

4.3 Administrative Units

Shyamnagor is the largest upazilla of Bangladesh with an area of 1968.24 km². Maximum lands of this upazilla are included in Polder no-5. Kaligonj upazilla is located on the north of Shyamnagor upazilla with an area of 333.79 km². Small part of Kaligonj upazilla is also included in Polder no–5 (Figure-4.2).

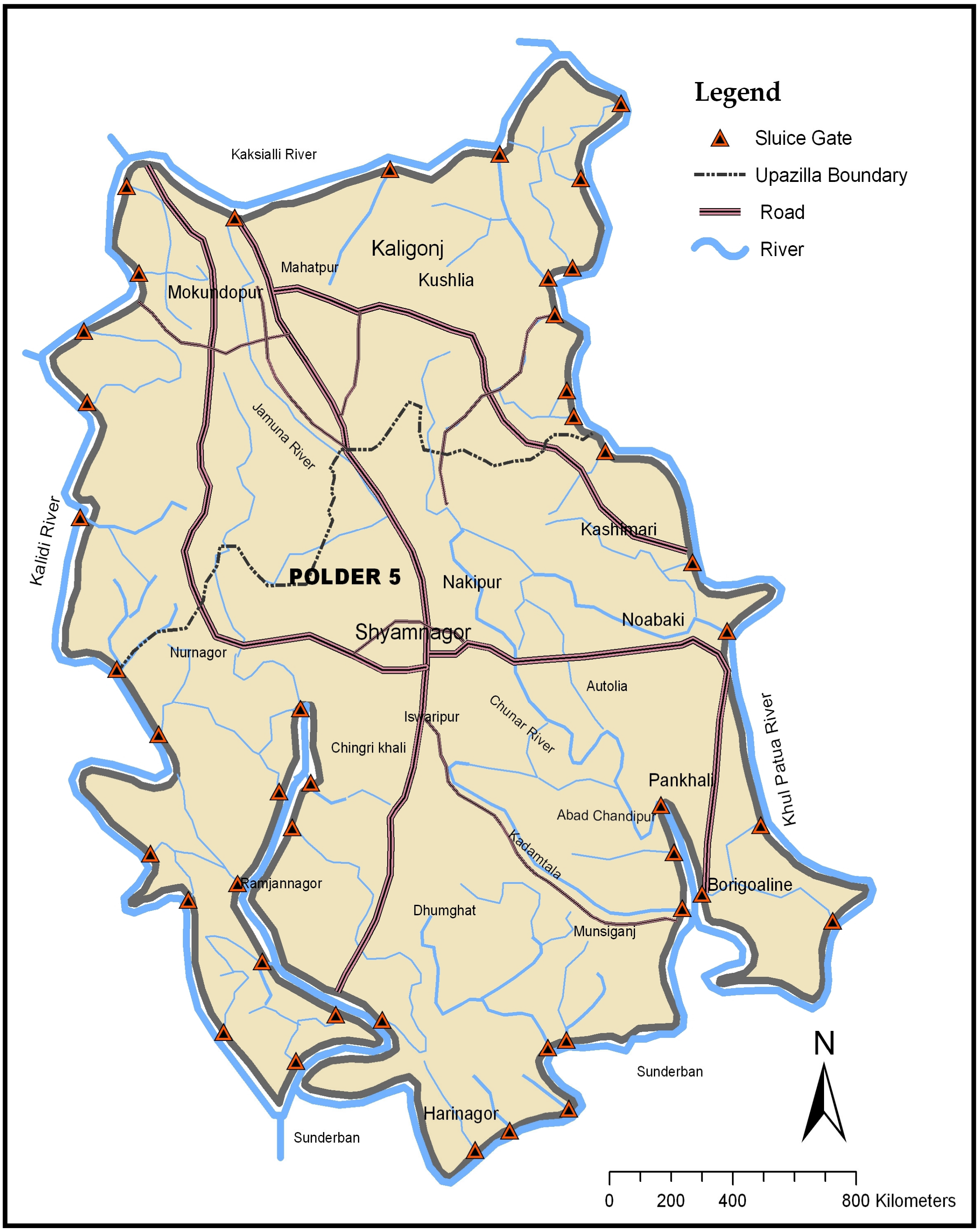


Figure 4.2: Administrative units in Polder-5

4.4 General Information of Polder no-5

4.4.1 Population

The estimated population in the polder is 272,047 where male is 50.46% and female is 49.54%. In Shyamnagor upazilla 74.14% of the total population is Muslim, 25.40 % is Hindu, 0.06% is Christian and only 0.01% is Buddhist. Rest of the population (0.39%) is included in ethnic or indigenous group called Munda (Buno). Around 700 families are found adjacent to the side of Sundarban (PDO- ICZMP, 2005).

4.4.2 Literacy and Occupations

The average literacy rate is 28.1% where male is 38% and female is 17.4% in the study area. Shyamnagar upazilla is dominated by agricultural practice. About 33% of the total population is directly involved in rice cultivation and fish culture including shrimp culture, 25.81% is agricultural wage laborer, 6.21% is forest dependent, 2.34% is involved in fishing, 10.11% is entangled in trade and commerce, 3.38% is engaged in service sectors and finally 12.11% is dependent on transport and communication services (PDO-ICZMP, 2005a).

4.4.3 Land Use Pattern

Total cultivable land in the Polder is about 38552 hectare where fallow land is 6257.79 hectare. The agricultural land is occupied by single crop 55.8%, double crop 23.06% and negligible triple crop. Among the peasants, 19% are landless, 30% are small, 28% are marginal, 16.5% are intermediate and 6.5% rich and the cultivable land per head is 0.13 hectare (PDO-ICZMP, 2005a).

Paddy, potato, linseed, sesame, pumpkin, mustard seed and vegetables are the main crops in this polder. Exporting of shrimp is one of the important earning sources of the inhabitants in this polder. Fishes, crab and fry are also exported from the study area.

4.4.4 Infrastructure

The Polder includes one upazilla health complex and nine family planning centers. Electricity is provided to less than half of the total areas. Most of the houses are built with mud, wood and straw or leaves where few are brick built. Roads in the Polder consist of 67km pucca, 35km semi pucca, 811km mud road. Waterways is 73 nautical mile.

4.5 Climate of the Study Area

A subtropical monsoon climate with a moderate rainfall is prevailing over the study area. There are four main seasons which are pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and dry winter season (December-February). The pre monsoon is characterized by southerly winds, high temperatures and high evapo-transpiration and by occasional thunderstorms and cyclonic storm surge. The monsoon brings heavy rainfall, high humidity and cloud cover. The post-monsoon is hot and humid, with occasional thunderstorms, cyclones and storm surges. Finally, the dry winter season is characterized by cool, dry and sunny weather. Average climatic data indicates that the monsoon occurs from May, averaging 238mm rainfall to October, averaging 137mm rainfall where the peak is in June and averaging 419 mm rainfall. Rainfall is quite rare during the dry season in the study area. The annual average rainfall is 1692mm of the south west area. According to Khulna meteorological station in 2010, the relative humidity is high, ranging from 70% in March to 91% in July and the mean monthly air temperature range from 15^{0}C to 36^{0}C. The major natural hazards in the study area are cyclones, storm surge, saline water intrusion, drainage congestion and drought. All these limitations effect agriculture activities and degrade the surface water quality, causing distress to livestock and humans.

4.6 Hydrology

The study area is intersected by many rivers and canals, the larger are termed as *nodi* and the smaller are *khals*. Khulpatua and Kalindi river are flowing to the east and west side of the polder. Kaksialli river which is flowing along the north side of the polder connects both of those rivers (Figure-4.2). Every river carries high amount of sediments. There are a number of sluice gates on the polder for proper hydrological function of the polder. Sluice gate drains out inland rain water to reduce water logging inside the polder. Currently most internal canals in the polder areas are silted up and have been obstructed by shrimp farm dykes. As a result, poor drainage and waterlogged conditions occur in the polder. Before polder construction, many creeks and rivers were interconnected with each others. But after polder construction, they are shrinking and reducing day by day. Now, insignificant tidal effect is found in small rivers and creeks and has become stagnant water bodies. So, the ecosystem and biodiversity were severely transformed after the polder construction. Most of the population depends on surface water for their drinking, domestic and irrigation purposes. Some peoples use ground water for drinking purposes despite salinity, iron and arsenic contamination.

4.7 Damage Due to 'Aila'

On May 25, 2009 (at 03:30 pm) tropical storm 'Aila' hit the Bangladesh coast. Wind speed was more than 70-90 km per hour and tidal surge was very high near about 2 to 3 meters above the highest level of astronomical tide. Cyclone 'Aila' had been crossing over the polder for 7-8 hours. Continuous surge hitting the polder broke the embankment at 32 points. People were unaware about the strength of 'Aila' and were unprepared to leave their own home. Saline water intruded violently and washed away every thing. People lost their children, family members, livelihood means, property, belongings, and stored grains.

Population of the surge-affected areas took immediate shelter on the embankments, cyclone shelter, schools and trees. Subsequently, they left their house and resided on the polders or migrated to other places. Some of the organizations like Government and Non-government organizations supported the affected population during 'Aila' to at-present. The organizations are trying to rescue and save life of the affected people by supplying basic needs. They are attempting to improve livelihood opportunity of the affected people to sustain their life. But in most of the cases, those areas are flooded again and again because of repeated polder failure after it is repaired. After all, they were living in the area with a lot of difficulties (Figure-4.3).

Most of the population has returned to their home with the recession of floodwater. They are trying to cope with this disaster situation in different ways as soon as possible. For example, changing their livelihood to fisheries and wage labors, raising the height of the house and changing the construction materials, harvesting rainwater, changing their food habits etc.

a. Breached embankment

b. Flood inside the Polder

c. Sufferings of the people

d. Collection of drinking water

Figure 4.3: Photographs of the study area after ‘Aila’

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1 Sea Level Rise

The current global average temperature is likely higher than at least the last 2000 years (Jones and Mann, 2004). Increasing temperature leads to raises of the sea level. The effects of SLR to the coast of Bangladesh are permanent inundation, drainage congestion in the polders, storm surge inundation and salinity intrusion. As a result, a wide range of impacts on socio-economy and natural systems is anticipated on the coastal zone of Bangladesh. Different organizations have projected sea level rise in future. Their prediction depends on the past trend analysis and future change of environment and socio-economic dimension.

On the basis of future technical and socio-economic dimension, SRES scenarios in the 4AR of IPCC (2007) are used for regional climate forecasting. SAARC Meteorological Research Centre (SMRC) and National Adaptation Programme of Action (NAPA) estimate SLR depending on IPCC projection. However, A1B scenario (Figure-5.1) of the AR4 of IPCC (2007) has been considered in this study.

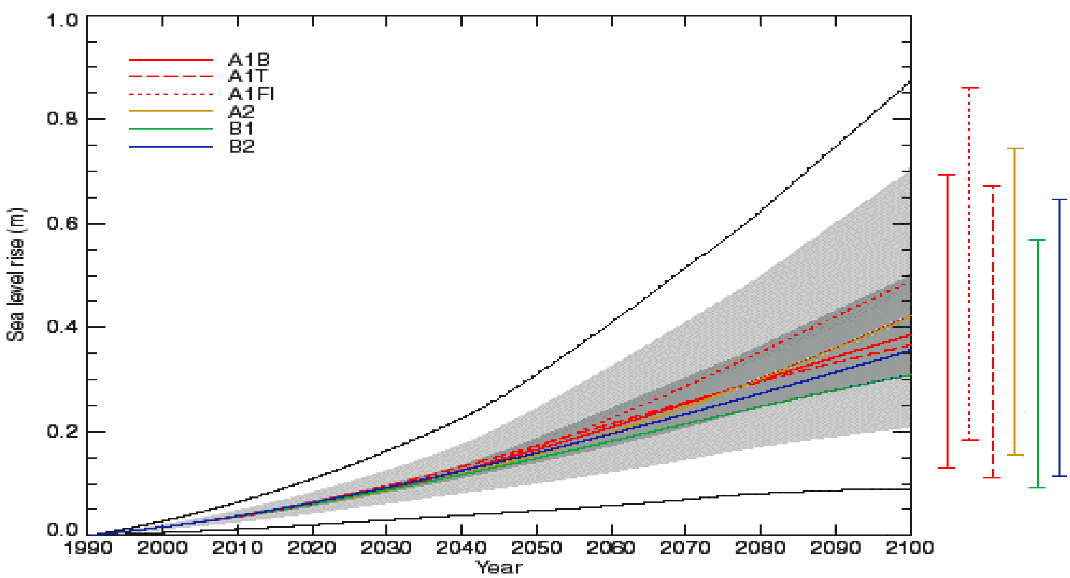


Figure 5.1: Sea level rise projection in AR 4 (IPCC 2007)

The projected SLR is shown in Table-5.1 for different years. SMRC and NAPA estimate rising of sea level until 2100. A1B scenario in FAR shows quite identical rises till 2050. After the year 2050 the rate of SLR will be reduced to 48 cm by the year 2100.

Table 5.1: Sea level rise at the coast

Year	Sea level rise (cm)			
	TAR IPCC (2001)	SMRC	NAPA scenario	A1B Scenario in 4AR, IPCC (2007)
2030	14	18	14	14
2050	32	30	32	32
2100	88	60	88	48

Source: IPCC, 2001; SMRC 2000; NAPA, 2005; IPCC, 2007

5.2 Storm Surge Height Prediction

From the literature and field investigation through reconnaissance survey it was found that during 'Aila', storm surge lifted about 2-3m above the highest level of astronomical tide. The maximum wind velocity of 'Aila' was about 90 km per hour while it was passing over the polder. So it can be identified as category one[1] level cyclone considering wind velocity. After group discussion and KII, it was found that cyclonic surge coincided with high tide and created a deadly disaster to the polder areas.

Through literature review of the coastal embankment projects (CEP) and KII with the officers of BWDB, it was confirmed that the polder height was 4.27m PWD that encircled the low inland. Surge of 'Aila' intruded from the sea through mouth of the river and propagated to the polder within a short time. The villagers near the breaching point informed that river water swelled up rapidly and reached in close proximity to the embankment level at the beginning of 'Aila'. One or two hit of the surge along with rigorous wind speed destroyed the polder within a short time. Polder-5 was breached at least at 32 points at that time. The height of the surge or duration of the cyclonic event and seawater intrusion period were the determining factors of devastation of the polder. Lack of information or awareness and preparation of the community were the major reasons for their loss of life and properties according to the information of the respondents.

[1] Saffir-Simpson Hurricane Scale, named for Herb Saffir and Robert Simpson, who developed it, Category 1 where Winds 74-95 mph

Different studies estimate that the present surge height will increase in future (IPCC, 2001; Agrawala *et al.*, 2003; Dasgupta, *et al.,* 2009). If same type of disaster (*e.g.* 'Aila') occurs in future, the surge height will be increased which is shown in Table-5.2. Future surge height is calculated through the equation (4) which is espressed detail in methodology.

Table 5.2: Projected surge height (m)

Year	Polder height m(PWD)	Spring tide level in PWD	Relative surge height (Without representative surge) (m)	Future total surge height (FTSSH) m PWD
2009	4.27	3.35	2.7	6.1
2030	4.27	3.35	3.6	6.9
2050	4.27	3.35	3.9	7.2
2100	4.27	3.35	4.1	7.5

During 'Aila', the total surge height was 6.1m PWD. According to the equation, future surge heights for a storm surge disaster is determined through the summation of additional intensified surge height, representative surge height, subsidence and sea level rise. Surge height of 'Aila' has been used as a representative surge event for the future projection. Homogenous 10% intensification of surge to the representative level and sea level rise will amplify the total surge to 6.9m in 2030. The same event will cause increase up to 7.5m by the year 2100.

5.3 Surge Event Projection

According to the chronological records (Appendix-A), storm surge disaster is a regular phenomenon in the coast of Bangladesh. Table-5.3 shows the approximate percentage of storm surge occurrences in various regions of the globe where Bangladesh is the most affected country. Storm surges generated by tropical cyclones are most common in the Bay of Bengal and the Gulf of Mexico.

Table 5.3: Approximate percentage of storm surge occurrences

Region	Percentage
Bangladesh	40
Asia (excluding Bangladesh)	20
North America	20
Europe	10
Africa and South America	5
Australia and New Zealand	5

Source: Murty and El-Sabh (1992)

Cyclone and storm surge related detail documents are available only for the last 50 years (*e.g.* 1960-2009) for the coast of Bangladesh. Scarcity of information regarding the past surge event creates difficulties for return period analysis of the storm surges to the south west coast. Therefore, return period analysis has been carried out counting the entire significant cyclonic surges that impact all over the coast of Bangladesh. Recently south west coast is frequently affected by cyclone. Among the three coastal segments, Khulna zone is the most vulnerable in terms of cyclone landfall (Islam 2009).

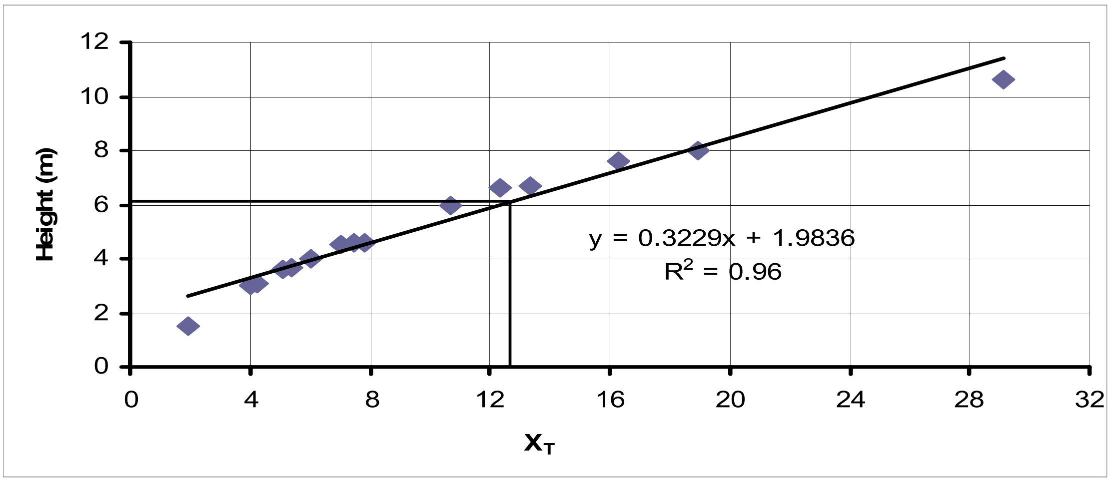


Figure 5.2: Return period analysis of last 19 maximum surges (Log normal distribution)

Taking 19 maximum surge levels from 1960 – 2009 in the coast of Bangladesh, a return period analysis of the surge height is done which is shown on the Figure-5.2. Return period of 12.5 years is found for the storm surge of 6.1m of 'Aila'. In case of future storm surge, this height will increase up to 6.9m in 2030, 7.2m in 2050 and 7.5m in 2100. The return periods of these levels of storm surges are shown in Figure-5.3. It is seen that the return period these storm surges are 15.2 year, 16.15 year and 17.1 year respectively. So it can be said that similar (Aila-like) storm surge event will occur more frequently.

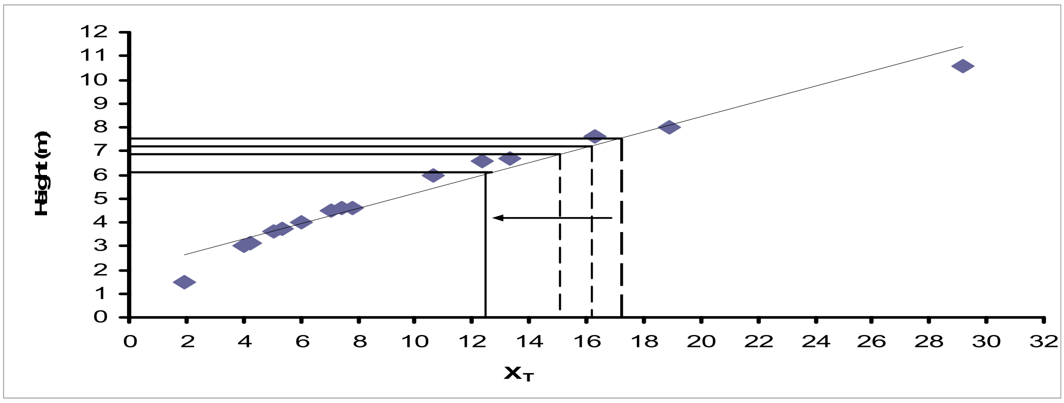


Figure 5.3: Storm surge height and return period relationship in different years

5.4 Role of the Polder in Storm Surge Protection

During KII and GD with the respondents, it has been informed that seawater over topped at different locations of the south-western part of the embankment. It breached mostly at the south-eastern part of the polder. Ingress of surge water flooded a vast region of the study area. Storm water destroyed existing crops, shrimp farm, vegetation, livestock etc.

At the time of FGD with the fisher and the agricultural farmers, it has been shared that both of them were not satisfied at the period of constructing polder during mid 60s considering their livelihood security. Subsequently, they had to change their livelihood from fisher to paddy farmer or had to move to another place to sustain their original livelihood. Nevertheless, the major goal of CEP (*e.g.* increase of agricultural production) seemed to be achieved at the early stage of this project when paddy farmers used to get more production from their agricultural land. At that time, low lying areas were used for culturing white fish *e.g.* fresh water fishes, native species etc. After mid 80s, most of the marshy land were tended to convert into fish culture especially shrimp culture. Afterward, the land use of this area shifted from paddy cultivation to shrimp farming.

Before ‘Aila’, most of the affected areas were dominated by shrimp culture. Settlements and forests were scattered over water and were interconnected by narrow road network. Embankments were used as their main roads and the banks of shrimp farm were used as internal linking road for their communication.

The result of DEM analysis through GIS is quite interesting to understand the changes of the inundated area due to storm surge flood. Changing of the surge height directly affects the flood coverage of the study area. The function of the polder for protecting in land has been given in Figure-5.4. From the figure, it is estimated that if the polder was not constructed, around 1500 hectare of land would be affected by regular tidal flood. Most of the low-lying riverside areas would be the major affected region for this regular flood (Figure-5.4a).

The highest level of astronomical tide has been recorded up to 3.35m PWD that is easily protected by the polders. It protects well at the level of 4.27 m PWD storm surge. Therefore, the polder is effective in defense for minimal storm surges lower than 4.27m PWD in different years. The embankment is protecting at least 4080 hectare (7.5%) of land (Figure-5.4 b) from those storm surges that are not more than 4.27 m PWD. All the estimation is predicted through DEM data analysis.

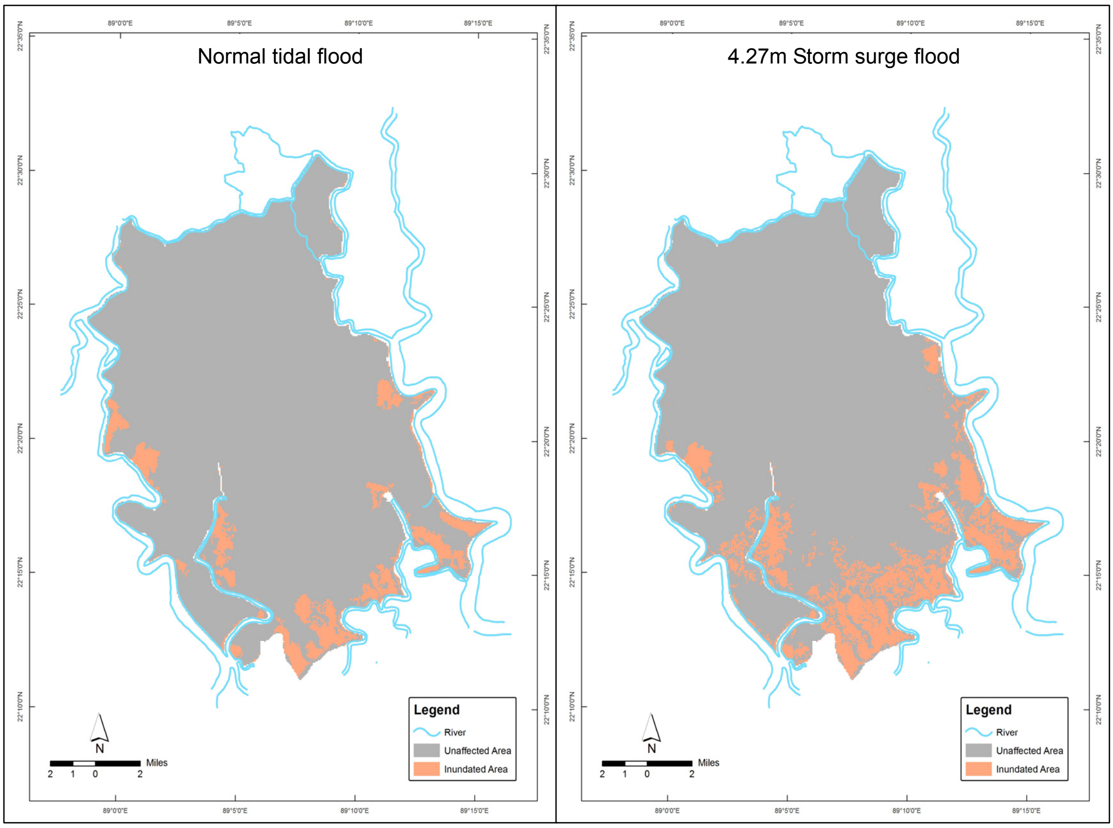


Figure 5.4: Area protected by polder from (a) tidal flood (b) storm surge flood equal to height of the polder (4.27m)

The villagers have shared that the constructed polder used to protect their land and habitats up to certain level. Usually, it protects those who live in the low lying and river side areas. A number of destitute and marginal families used to live at different low-lying areas inside the polder which has been reclaimed due to construction of the polder. Most of the population lives adjacent to the embankment because it can be used as the main communication road, as well as the inhabitants take the maximum opportunity of river related activities.

5.5 Storm Surge Flooding in Different Years

During cyclone 'Aila', the storm surge height was 6.1m PWD. Storm surge coincided with astronomical high tide and swept away the polder only within first one and half hour. According to the field observation, the processes of water movement were dependent on the following factors in the study area:

- Height of storm surge including tidal level and sea level rise
- Duration of storm surge hazards
- Slope, drag factors and land use pattern of the hazardous area

Most of the east side of the polder was damaged due to breach the embankment and most of the south side was affected due to overtopping. DEM analysis and field verification are used to prepare an appropriate storm surge inundation map for the 'Aila' in 2009. According to the study, about 22.7% (12.5 thousand hectare) of land has been inundated (Figure-5.5a) by the cyclone 'Aila'.

The villagers accused the farming practice of shrimp inside the polder. Shrimp farming practice is directly responsible for the damage of the embankments. Shrimp farmers improperly cut the polder at irregular points and used to off take saline water from the river for their shrimp farm. Lack of management by BWDB and local authorities, made the embankment weak and vulnerable. In future, when the surge height will increase, the present polder will never be able to protect from those similar disaster. Therefore, the coastal flood will inundate more areas in future, which are shown in the Figure-5.5.

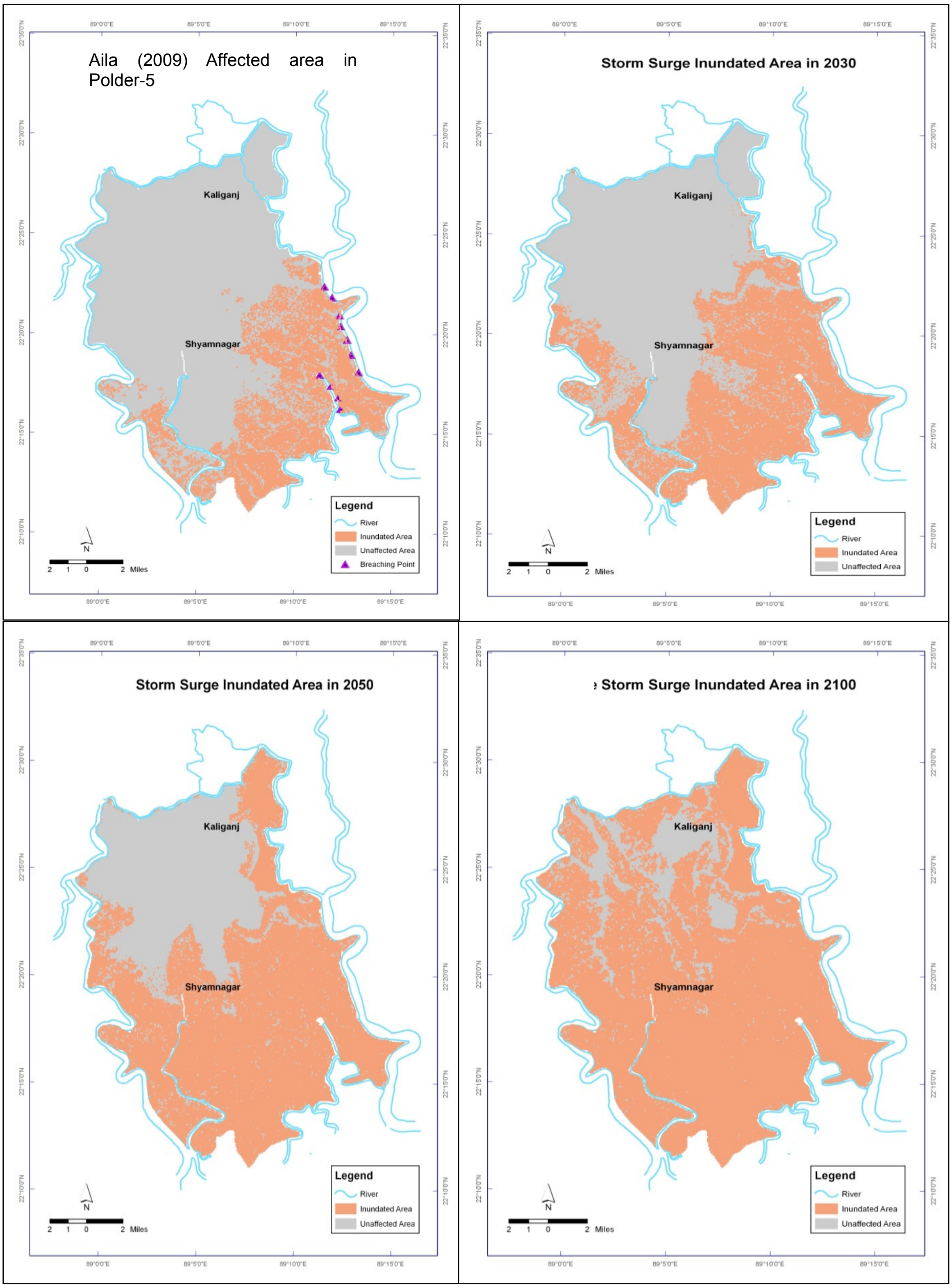


Figure 5.5: Estimated coastal flooded area concurrently breaching and overtopping due to projected storm surge

Some of the shrimp farms and agricultural land were protected by different infrastructures during the 'Aila'. But in future especially in 2030, those areas will be inundated by storm surge coastal flooding. In 2030, storm surge will inundate about 41.4% (*e.g.* 22.8 thousand hectare) land of the total polder. In 2050, about 64.2% (*e.g.* 35.4 thousand hectare) land will be affected by same kind of disasters. Finally, in the year 2100 only 14.3% (*e.g.* 7.9 thousand hectare) of terrestrial land of the polder will be free from flood (Figure-5.6).

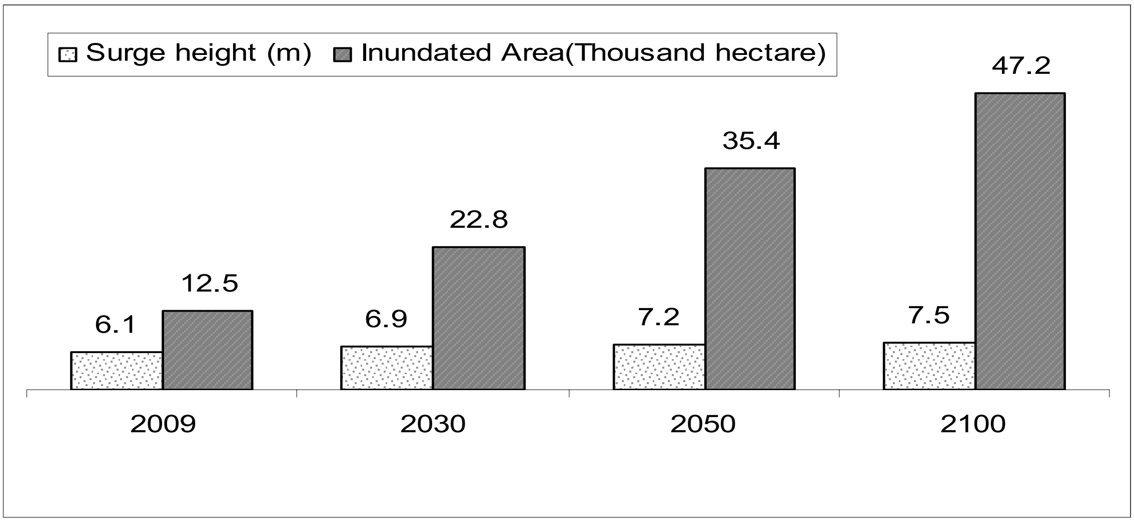


Figure 5.6: Storm surge inundated area in present and future

All of the above discussions and prediction are based on the intrusion of sea water. Intruded sea water causes flood in the Polder-5. During 'Aila', the south-east part of the polder was breached within half an hour. According to the respondents, the rate of water intrusion was nearly 2.5 m/s which flooded rapidly inside the polder. Storm surge with 6.1m height traveled over the flooded water around 3 hours and it affected more frequently to the adjacent area of the polder. If the polder were not breached at that time of 'Aila', the suffering would reduce significantly. Only overtopping water would not make a highly disaster situation aftermath of this event (*e.g.* 'Aila') to the south-west area. In future, the volume of overtopping water of storm surge will increase along with the increasing surge height. Therefore, only the overtopping water in 2030 will inundate 14.2% (7.8 thousand hectare) of the low lying south-east region of the polder. The increasing surge height will be overtopped the coastal embankment and flooded about 26% (14.3 thousand hectare) in 2050 and 57.1% in 2100 (Figure-5.7).

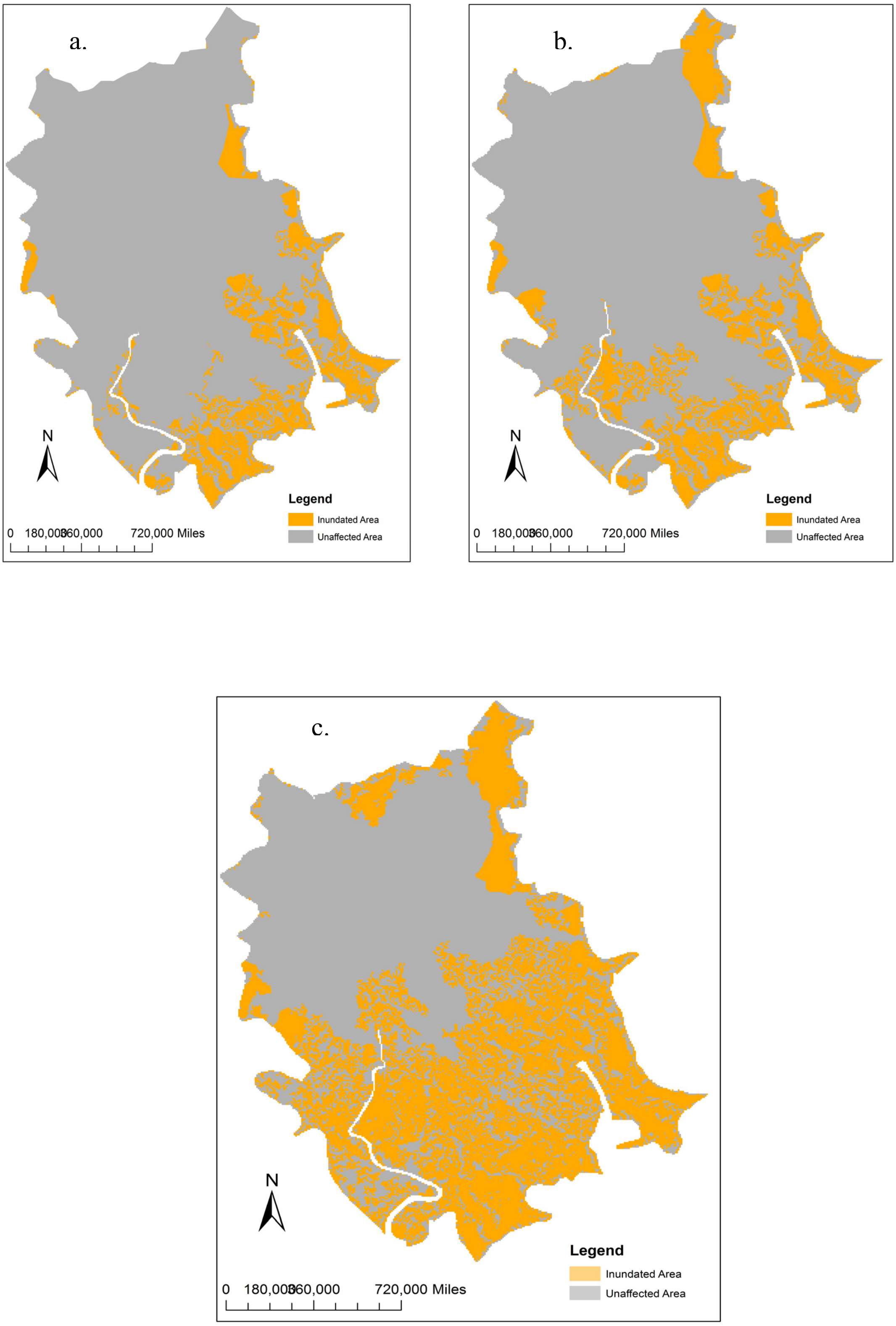


Figure 5.7: Storm surge inundation due to only overtopping in different years (*e.g.* a. for 2030, b. for 2050 and c. for 2100)

5.6 Impact on Water Resources

The villagers eagerly identified different water sources during the social and resource mapping. They mentioned that water quality has been severely deteriorated by the cyclone 'Aila' of the study area. Storm surge destroyed all of the fresh water resources of the affected areas. Huge volume of saline water intruded in to the polder at the time of 'Aila' and after the 'Aila' event. Cyclone 'Aila' significantly damaged not only the surface water resources but also the ground water resources. Saline water affected all of the areas. Pond, shrimp farm (*e.g.* gher) and tube wells were submerged fully or partially under floodwater.

The inhabitants were suffering much for the water. During the field survey, water related issues have been categorized on the basis of water uses and user concern. They have shared some temporary solution regarding water related issues during participatory discussion with the villagers including women (Table-5.4).

Table 5.4: Water related issues and temporary solution

Use of water	Dimension of problems	Temporary solution
Drinking	Severe scarcity	Supply water, Rain water
Domestic	Lack of fresh water	Use of saline water, Rain water
Irrigation	Saline water intrusion	Embankment reconstruction, Rain water
Shrimp culture	Flash out, Infrastructure destruction	Embankment reconstruction, White fish farming

From the field investigations it is found that about one-fourth land of the polder has been affected by salinity. It not only destroys the water bodies but also changes the total water ecosystem of the affected areas. Sometimes the inhabitants urged that it was too difficult for them to tolerate such saline weather prevailing almost all over the polder.

Before Aila, people used to drink, tube well water pond sand filter (PSF) water and surface water rarely. Especially in rainy seasons a lower number of communities used to harvest rain water in their house. They can not but cope with the slightly saline ground water for their drinking purposes. However, after Aila, saline water intrusion and continuous inundation have contaminated almost all sources of fresh water of the study area. Water has been more saline and high turbid. People have become highly dependent on supply water and rainwater. Women spend on average 4-5 hours for collecting water in a single day. Girls still have been walking 2-3km to reach the nearest safe water collection point. People are bound to drink un-safe water. They are forced to spend their limited financial resources either to travel for safe drinking or to purchase it.

Intruded water is trapped inside the inland that can not be removed for drainage congestion. As a result, saline water logging situation creates a big problem to the inhabitants. They can neither utilize the saline water nor drain it out. In most of the cases they are waiting for saline water to dry out from their land. This processes further increase the salinity of the inundated soil. However, they are trying to adapt this situation by changing their living status, behavior and livelihoods.

During FGD and KII, it has been informed that in future such kind of disaster will create more devastation to the water sectors. Drinking water supply is the key challenge to make it available for every person of the affected community. Till today they have been drinking around 5 ppm saline water. Nevertheless, they are very much anxious about the situation of drinking water in future. The community anticipates that near future (2030) they will be dependent on filtering surface water and harvesting rainwater. But in the long run (2050) they will have to accept water pricing. At that time, improvement of water supply system will be necessary for reducing drinking water scarcity in the polder. According to their statement, for the future generation (*e.g.* in 2100), population will be wiped out from this area only for the scarcity of drinking water.

During study, it has been shared by the farmers that most of the times they practice rain-fed rice cultivation of the study area. They store fresh water in their local water bodies for the use during the dry season. 'Aila' has destroyed all of the local fresh water bodies and their connectivity. So, salinity is one of the major obstacles for agricultural practices in the study area at present and in future. Discussion with the paddy farmers and subsequently through the pie chart analysis, it is found that the increasing of inundation area will pull down fresh water resources, which will be annihilated in 2100. Domestic water will be proportionally degraded with the expansion of flooded area. However, salinity intrusion and surge height intensification will lower the living status of the future generation in the polder-5.

5.7 Impact on Agriculture

For agriculture impact assessment consecutive FGDs with the farmers and KII with the agriculture officer have been conducted at different locations. Before ‘Aila’, about 38,552 hectares of cultivable land were used to grow paddy, vegetables and paddy cum fish culture in the polder. Most of the lands of the study area were used to grow single crops. Double crops were only cultivated in the northwest and north central parts of the polder. The farmers were growing paddy *e.g.* T. amon and hybrid rice inside the polder.

Their rice production depends on different types of positive and negative factors. In future, those factors would decide the production level of the study area. Most of the positive and negative factors (Table-5.5) of rice production have been identified during field survey. Through the trend analysis (Figure-5.8), it is evident that rice production is showing slightly upward trend. The production of rice was 78718 metric ton during the previous year of ‘Aila’. But after ‘Aila’, this production has been reduced to 37856 metric ton. Therefore, cyclone ‘Aila’ is responsible for the loss of 38.4 % rice from the average production in the polder.

Table 5.5: Negative and positive factors for rice production

Negative Factors	Positive Factors
Salinity intrusion	Paddy cum fish culture
Land use change	Invention of HYV and STV crops
Population pressure	Demanding food consumption
High price of Shrimp	Security in price and storage of rice
Low cost of shrimp farming	Transportation facility
Socio political effect	Rearing livestock
Irregular rain fall pattern	Outbreak of virus diseases to shrimp farm
Opportunity for migration	Irrigation and Govt. subsidy

The affected people of the study area estimated that it would take next 3 - 4 years for washing out salinity from the inundated land to regain its productive capacity. According to Ahmed (2008), people cannot get high yield from *Amon* cultivation because of salinity. The villagers said, ‘once the land is contaminated by saline water, it is very difficult to grow paddy for the next years’. Therefore, the increasing of salinity reduces rice production and makes opportunity for the shrimp farmer.

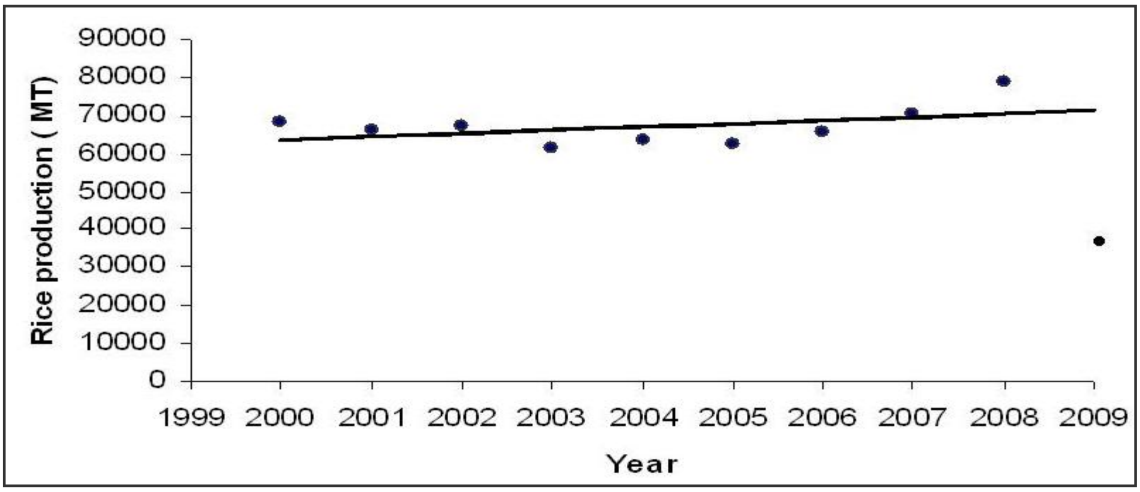


Figure 5.8: Autonomous trend of rice production from 2000 – 2009 (excluding of the production in 2009)

From the FGDs and past data analysis it is estimated that if there were no significant disaster in future, the rice production would be 79425 MT in 2030 (Table-5.6). Because of increasing inundation area, storm surge disaster at that time (*e.g.* 2030) may damage 64% of rice production compare to 'Aila' 2009. In this away, if this storm surge event would occur in 2050, the rice production would be destroyed by 88.7%. Finally, the disaster of coastal flooding due to storm surge will ruin almost whole agricultural production in 2100.

Table 5.6: Estimated rice production and loss due to storm surges

Year	Loss of rice production (MT)	Estimated Average Production (MT)	Loss of production%
2009	27856	72520	38.4
2030	50809	79425	64.0
2050	78885	88920	88.7
2100	105184	105450	99.7

5.8 Impact on Fisheries

About two fifth of the polder areas are occupied by fisheries sectors. Cyclone 'Aila' destroyed the whole fish farm of the affected areas. It destroyed around 4880 hectares of shrimp farm instantly. Eight fishers were lost at that event of the study area. According to the report of upazilla fishery office, in the polder around 90 crore taka in total has been damaged in the fisheries sector by 'Aila'. It destroyed almost 82% of fish production in the polder. This loss was only accounted for culture fisheries. But the capture fisheries suddenly reached the peak just after ‘Aila’. The fishers were fishing on the open water during flood. After ‘Aila’ fishing was only the sustaining occupation for their livelihoods. Therefore, most of the unemployed people were turning their livelihood as a fisherman, boatman or fish related business after the ‘Aila’ event.

Fishery is the most promising sector of the study area that helps to recover at least some of the losses. Salinity intrusion, tidal effects, low land, polder and high demand of shrimp in foreign markets would accelerate to flourish shrimp farm in future. From FGDs, it has been found that most of the regions are gradually converting from paddy cultivation to fish farm. They are farming not only shrimp but also crab, carp fishes, brackish water fishes. If the factors like a) reduction of virus diseases to the shrimp, b) exporting facility, c) good demand of shrimp in the market and d) government support are in favor, fisheries sector would be the main economic driving force for this area in future. Unfortunately, shrimp farm is increasing the vulnerability of the polder. It increases both physical and socio-political vulnerability of the study area.

Timeline analysis in the field has been used to obtain the background information about farming situation of the study area. After conducting FGD with the fishermen, a trend line analysis has been conducted which is shown on the Table-5.7 regarding historical record of fisheries. Fish species are classified into four classes as well as shrimp to know about the situation of fishes of the preceding decades. The period of 1980 to 2010 has been selected for trend line analysis where 10 years interval has been taken for understanding the changes in fisheries production with decadal differences. Group of the fishes are classified according to their habitat and they are identified by their local name. For example, estuary fishes- Hilsa, Bhangon, Pungus, Paisha, Bhetki, Baile, etc., carp fish- Catla, Rui, Merigal, Grass carp, etc., native fishes- Shingi, Magur, Koi, Boal, Taki, etc., and sea fishes – Rupchanda, Loitta, Tapashi, Shapla pata, etc. Fishermen have shared a comparison study about the abundance of fishes from past to present of the study area which is summarized in the Table-5.7. They have anticipated about the mode of fishing for the succeeding decades on the basis of their past experience.

Table 5.7: Availability of fishes from timeline analysis

Year	Estuary Fish	Carp Fish	Native fish	Sea fish	Shrimp
1980	High	Moderate	High	High	Low
1990	Moderate	Moderate	High	Moderate	High
2000	Low	Low	Low	Moderate	Moderate
2010	Low	Low	Low	Low	Moderate

The destruction of ‘Aila’ was not same for the culture and capture fisheries. Culture fisheries were totally destroyed. It damaged about 82% of fish production with respect to past year. But during FGD with the perennial fisher, it has been found that their income was increased at least three times after ‘Aila’. Actually, the culture fishes were moved out from the farms to the flooded water. As a result, the increasing of capture fisheries might reduce the total loss in this sector. Finally, the total loss has been estimated as 50% of the total production.

According to compilation of FGD, KII result and secondary information, a matrix has been developed that express the future fishing status and loss due to storm surge considering climate change (Table-5.8).

Table 5.8: Fish (including shrimp) production and loss in particular years

Livelihood dependents different types of fishes		2009		2030		2050		2100	
		Production	Loss	Production	Loss	Production	Loss	Production	Loss
Capture	Sea fishes	+++		++		+		+	
	River, open water	++	- -	++	- -	+	- - -	-	-
	Native fishes	++	-	+	-	+	- -		
Culture	Shrimp	+++	- - -	+++	- - -	+++	- - -	++	- - -
	Carp fish	+++	- -	++	- -	++	- - -	+	- - -
	Brackish water fishes	++	-	++	- -	+++	- -	+++	- -

Note: ‘+’ increase and ‘–’ decrease

At present, carp and native fishes become rare in the market of the study area. Capture fishes and carp fishes are going to be reduced day by day. In future 2030, capture fisheries will be shrinking at a faster rate than culture fisheries and it will be reduced to a threatening stage. It can be estimated that native species will also be wiped out for the next century in that particular area. Population pressure, polder construction, over extraction, dried up river and salinity intrusion is responsible to form such a critical situation for capture fishes in the study area. According to Ahmed (2008), increasing number of low pressure system due to climate change means that for an increasing number of days per annum the sea will be rough and stormy (accompanied with high tides) along the shore – a change in the coastal environment which will prevent fishermen to sail for fishing. So, they will eagerly move to culture fisheries including shrimp culture which will further increase the vulnerability of the study polder. The cumulative fish production will be damaged by almost 62% in 2030 for the storm surge disaster. After time trend analysis, matrix explanation and KII in the study area, it is estimated that almost 70% of fish production will be lost in 2050. However, storm surge in 2100 will cause significant damage (85%) to the fisheries sectors of this southwest polder.

Usually, higher salinity may instigate to culture saline water fishes or shrimp inside the polder. In future, favorable environment and sociopolitical opportunity will help to flourish shrimp (*e.g.* Tiger prawn) and brackish water fishes like Paisha, Telapia, Tengra, Bhetki etc in the polder. But field investigation has shown interesting information about the culture of brackish water fishes. It will be increasing rapidly compared to shrimp for the future. Because, virus attack and lower exporting facilities reduce the economic return from shrimp culture.

5.9 Impact on Livestock

Livestock is quite few in the study area because of abundance of fish farms. Prior to 'Aila', people used to have poultry and rear different livestock at household level. Almost 90% of the livestock were lost during cyclone 'Aila' in the affected areas. After 'Aila', remaining livestock were sold immediately at reduced price due to lack of fresh water, fodder and space for them. Saline water eradicated grass or bushes inside the polder. Now affected families are rearing only duck rather than other livestock like goat, cattle, sheep etc.

In last five years, poultry farming has been found as one of the emerging sectors in urban areas like Shyamnagor town. From discussion with the villagers, it is found that present disaster has caused loss of 33% livestock of the study area. They are very much anxious about rearing livestock in future. Only some families of the unaffected areas are rearing cattle, goats and sheep. Shrimp culture reduces the grazing land that ultimately decreases the livestock in the polder day by day. In 2030 the livestock will be half of the present stocks and in 2050 it will turn at least one fourth of the present. They remarked that only poultry farming would be the key livestock for the next century in this area.

After consultation with the villagers it is anticipated that autonomous reduction of the livestock and storm surge flooding will cause around two third (66%) loss of the present livestock in 2030 in the polder. This loss will be increased up to 90% for such a storm surge disaster in 2050. Population of the study area may not able to keep livestock for the future storm surge in 2100.

5.10 Impact on Forestry

The largest mangrove forest Sundarban is on the southern part of this polder. Most of the banks of the river side are dominated by mangrove forests that are eradicating day by day due to human demand. From the FGDs and seasonal calendar, it is found that people cultivate vegetables and fruits in their homestead garden, bank of fish farms and both side of the polder. The respondents informed that vegetation and paddy cultivation is going to be limited. The cultivable land and forest areas are converted to shrimp farms. The inhabitants want more benefit by cutting of the mangrove forest for shrimp culture, agriculture, settlement or commercial activities. They only plant those trees that produce fruits and wood in place of mangroves. During ‘Aila’, most of the planted fresh water trees died. Areas were looking like a desert at the time of transect walk. Higher salinity, population pressure and shrimp farm will tend to evacuate the polder from vegetation and forest coverage in up coming decades. Forest coverage will reduce significantly in the future disaster.

5.11 Damage to Critical Infrastructure

Surge of cyclone ‘Aila’ destroyed the embankment of the study area severely. Ingress water with high velocity damaged the interior infrastructure of the study area. It flooded about 22% area of the polder. During disaster period, flood water was obstructed by road network and other infrastructure and forest also. According to the estimation of upazilla fishery office, cyclone ‘Aila’ destroyed around 20 crore taka of fisheries related infrastructure. The estimated damage of cyclone ‘Aila’ has been shown in Table-5.9.

Saline water is responsible for weakening the cementing materials of the infrastructure. Building materials of different structure will be deteriorated with the increase of salinity. Thus, this sort of disaster will destroy the entire infrastructure of the affected areas in 2030. Road network may be the most vulnerable sectors for the disaster in 2030 when maximum shrimp farms and low-lying areas will be flooded.

Table 5.9: Infrastructure damage by 'Aila' (Caritas Bangladesh, 2009; DMB, 2009)

Polder	5 (Shyamnagar, Parts of Kaligonj Upazilla)
Affected Area	12519 hectare
Affected Household	Fully-67968, Partially- 20175
Affected Roads (Km)	99 Km
Affected School, Collage	50
Embankment	32 points

After 'Aila', government and NGO's are trying to improve the situation through risk reduction structure, warning system development, health facilitation and subsidies. They are trying to develop the adaptation process for the community which helps them to cope with future disasters. They are trying to improve nonstructural measures rather than physical development for reducing losses in future. However, it is anticipated that at the end of this century, such kind of disaster along with climatic phenomenon will annihilate total development of this exposed polder.

5.12 Population Distribution

Population density of the study area is 494 per km^2. At present, the rate of population growth is 1.32% (BBS 2010). The total population was 272047 in the study area before 'Aila'. This population (272047) in the polder no-5 will be increased to 362224 in 2030 and 38135 in 2050 by taking consideration of A1B scenario of FAR. According to SRES-A1B scenario of IPCC (2007), the population of the earth will decline after the mid century.

But, this statement seems to be paradox for developing countries like Bangladesh especially for the coastal region (Figure-5.9). A1B scenario infer a convergence world among inter or intra regions. That will imply the extensive social and cultural interaction worldwide and typically globalization. Therefore, migration is the key process for the reduction of the population in 2100 in the polder.

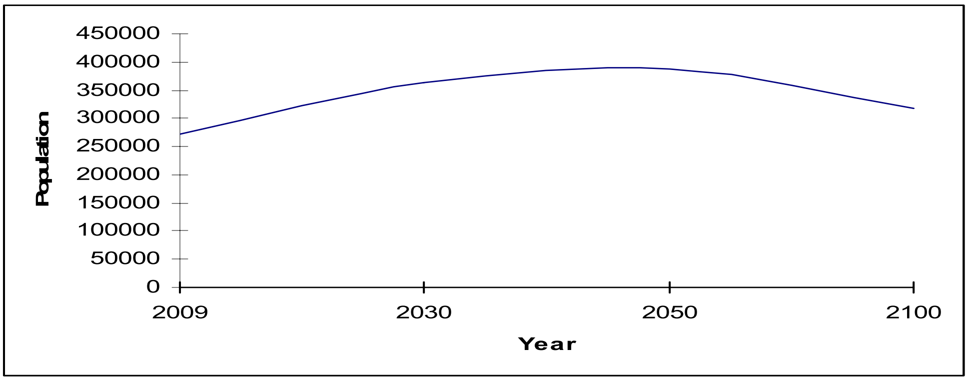


Figure 5.9: Projected population of the polder-5 in different year

During disaster period, the living and livelihood assets of the flooded population have been destroyed. Devastation of their habitats pushed them to move to other places. It is found that one third of the total population migrated temporarily during the flood period. They migrated to intra region *e.g.* neighboring villages; inter region *e.g.* urban areas, such as Satkhira, Khulna, hilly regions (Bandarbon and Khagrachori) and neighboring countries. Apparently, 14% of the population has migrated from the affected areas because of the disaster 'Aila' (Halder and Rahman, 2010). In future, the rate of migration will increase and they will disperse not only intra-nation but also international as climate refugees.

5.13 Livelihood Status

Population of the study area are engaged in agriculture 32.93%, agricultural labor 25.81%, wage laborer 6.21%, forestry 2.34%, fishing 5.5%, transport 1.61%, commerce 10.11%, service 3.38% and others 12.11% (ICZMP 2005). Their livelihoods do not strictly differentiate in one occupation. Population of the study area shows multiple working skills with changing of the seasons. Livelihood seasonal calendar and pie chart have been used to seek the information regarding their occupation pattern in the study area.

Most of the people depend on different types of occupations through out the year. They take seasonal opportunities and provide their livelihood. The marginal population, farmers, day labors, small business men, land owners and services men also change their livelihoods. During field study, different homogenous group expressed their view in multiple livelihoods and seasonal business. It is actually a process of work force mass transformation from one occupation to another occupation with shifting time. During November to March almost 45% of the population migrates temporarily out side the Satkhira district and they work as day labor in the brickfields or rickshaw puller in the town. About 35% of the male population has no fixed occupation where as 75% of the female populations engage in household work. Their livelihood involvement and the volume of workforce in different sectors are identified with changing season in the study area which is shown in the Figure-5.10.

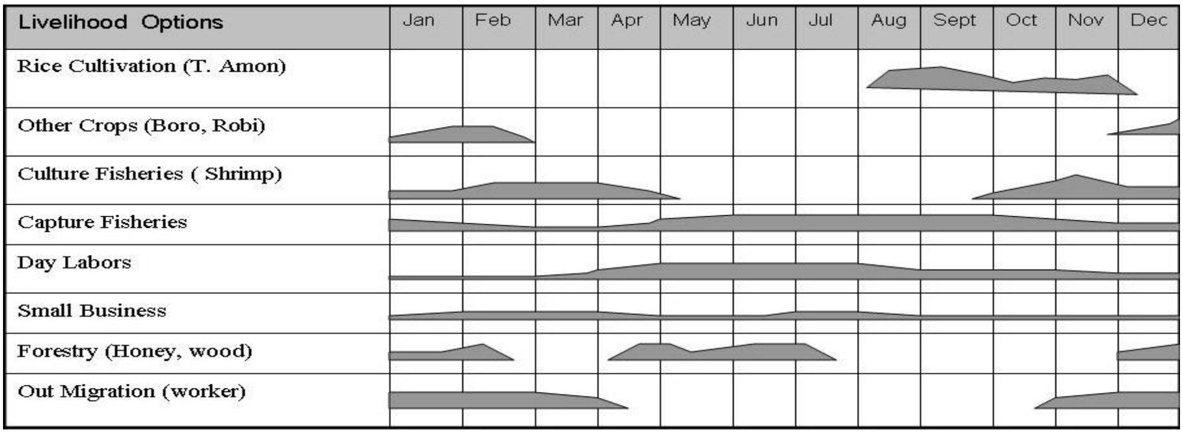


Figure 5.10: Livelihoods seasonal calendar

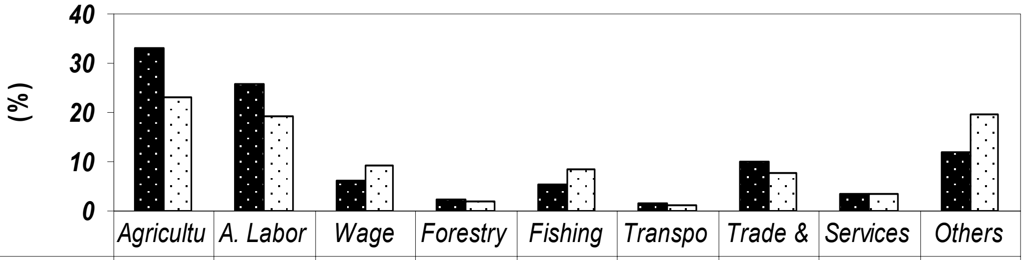
From the livelihood seasonal calendar, involvement of the inhabitants in different sectors is clearly identified. This Figure also estimates the volume of population engaged in different sectors with changing season. During interval period of any specific occupation the employee join in other seasonal occupation to sustain their livelihood. Rice cultivation is dominated by T. amon. Vegetation and Boro are also planted in the study area. Small business and fishing are continued round the year with changing its labors engagement. Seasonal collection of wood and honey from the forest is also conducted by the community. A large number of people move to the other parts of the country as seasonal labor. They return in wet seasons and work as agricultural labor or day labor in the study area. Some of the women are employed in the garments factories at the cities.

5.14 Impact on Livelihood

Livelihood resources are identified by the villagers through FGDs. After the group discussions they pointed out the livelihood assets that were damaged severely due to storm surge disaster. They pointed out their loss of natural, physical and financial resources on the social and resource map prepared by them. Especially, the loss of social and human assets was revealed after the catastrophic ‘Aila’. The livelihood framework prepared by DFID (1999) identifies five core categories of asset upon which livelihoods are built. As a result they had to change their livelihoods for deterioration of their own resources. The loss of different assets is estimated on the basis of the land destruction. Storm surge inundated a vast region of the study area which is eventually affecting their livelihood capitals.

They mentioned that the natural capitals of the study area such as water, soil, forest and land were drastically destroyed during ‘Aila’. Usable water, productivity of soil and availability of land will be the major threatening issues for future disaster. It also includes physical resources *e.g.* private and public assets of the study area. (a) Houses mostly made of mud, straw or leave (*e.g.* golpata) (b) schools, (c) clubs, (d) different institutional buildings and (e) roads were highly damaged by ‘Aila’. According to local people's prediction, almost 60% of the physical assets were damaged in this storm surge flooding. It also affects the financial resources like markets, farms, commercial region, small mills and factories. 'Aila' has a direct or indirect impact on all of the economic sectors of the affected areas. Most of the affected people have still been dependent on the open water fishing. However, this storm surge flood has changed their livelihoods.

Communication, social network, social relationship, culture and social festival were very much affected by disaster. Last disaster blocked the cultural activities, educational system, clubs or social organization activities. Social crime, gender inequity, political discrimination and uncertainty broke down the social confidence of the affected population. At the time of disaster, a number of people were injured and few were lost in the study area. The main sufferings have begun when there was scarcity of fresh water, food and nutrition, sanitation facility which destroyed the human skill and capacity of work. Especially, after the disaster, health and sanitation have been the most important issues to be faced. The change of livelihood is quantified on the basis of perception considering all of the impacted sectors which are shown in the Figure-5.11.



	Agricultu	A. Labor	Wage	Forestry	Fishing	Transpo	Trade &	Services	Others
Before 'Aila'	32.9	25.8	6.2	2.3	5.5	1.6	10.11	3.4	12.1
After 'Aila'	23	19.35	9.3	2	8.5	1.2	7.6	3.3	19.6

Figure 5.11: Change in livelihood due to 'Aila'

5.15 Future Change in Livelihood

Almost 272,047 people lived in the polder no-5. Before 'Aila', they were involved in different types of occupation. After 'Aila' this situation especially their occupation has been severely hampered. Most of the people suffered for their basic needs. Their livelihoods opportunities were totally disrupted. As a result the affected population migrated to other regions. In case of future disaster, the livelihood resources will be affected in various ways. The resources dependent occupation will also be disturbed in future. Therefore, Storm surge inundation of the land in future is responsible for the changing their livelihoods. Table-5.10 shows the impact on livelihood in future storm surge events.

Table 5.10: Change in livelihood for future storm surge disaster with respect to base year

Sectors	Livelihood in 2030 (%)	Livelihood in 2050 (%)	Livelihood in 2100 (%)
Total Population (A1B)	362224	3881635	318295
Agriculture (Shrimp &Rice farmer)	19.28	11.78	Significantly Change
Agricultural Labor	15.12	9.24	
Wage Labor	11.85	14.9	
Forestry (Maouli, Baoli)	1.35	0.08	
Fishing	10.9	13.9	
Transportation	0.9	0.6	
Trade & Commerce	5.9	3.62	
Services	3.3	3.1	
Others (Seasonal migration)	25.23	32.5	

The population of the study area will be increased to 362224 by 2030. The storm surge in 2030 will inundate at least 41.4% of the polder. So, the loss of land will be translated into different economic sectors of the study area. As a result, the livelihood will also be changed from different sectors on the basis of increasing flooded area. It will reduce their livelihood opportunities with respect to base year (*e.g.* 'Aila') situation.

In 2009, most of the population was involved in agriculture (*e.g.* rice and shrimp culture). They used to grow single crops, double crops or integrated paddy cum fish in their land that were heavily damaged by 'Aila'. In agricultural sectors *e.g.* paddy and shrimp farmers will constitute 19.28% in 2030 and 11.78% in 2050 because of storm surge disasters. Agricultural labors will decline due to reducing farming opportunity. Future disaster will make agricultural labor 15.12% in 2030 and 9.24% in 2050. Wage labor and fishing activities will be the only options of switching their livelihood in future disasters. Wage labor will be increased to 11.85% in 2030, 14.9% in 2050 and fisher will be 10.9% in 2030, 13.9% in 2050. Rest of the livelihood opportunities inside the polder will also be reduced with the changes of disaster magnitude in future. They will seasonally migrate for work from this area. About 25.23% in 2030 and 32.5% in 2050 of the population of the study area will seasonally migrate from this polder. The livelihood of the Polder-5 population will significantly change in 2100 due to multiple socio-economic along with technical issues.

5.16 Adaptation Measures

Most of the population faced this storm surge flood situation for the first time in their life. They had no idea about what was to be done during storm surge disaster. They were going through the worse disaster situation and tried to cope with the disaster. Different types of adaptation options have been found in the study area after the 'Aila' event which is shown on the Table- 5.11.

Table 5.11: Some of the adaptation measures found after 'Aila'

1.	Changing their livelihoods to fisher, wage labor and migrating seasonal worker
2.	Repairing the embankment
3.	Better operation and maintenance of the polder
4.	Increase the height of the new houses, roads and other institutions

5.	Low investment in farming, housing etc.
6.	Rain water harvesting in every house
7.	Fencing of the shrimp farm by net over the bank
8.	Inundated agricultural land converted into fish or shrimp farms
9.	Shifting to duck rearing from cattle and goat raising
10.	Development of small handicraft industry by the women
11.	Moving to higher land from near embankment places
12.	Re-excavation of the *khals* and canals for proper drainage
13.	Committee formation for the operation of the regulators

CHAPTER SIX
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Almost 45 years have passed since the Polder no-5 was constructed. Since then, no major renovation work has been taken in this polder. Cyclone 'Aila' caused significant damage to polder no-5. Present surge height (*e.g.* 6.1m of 'Aila') will increase to 6.9m in 2030, 7.2m in 2050 and 7.5m in 2100 due to climatic influence. Therefore, the inundated land will also increase from 22.7% in 2009 (Aila) to 41.4% in 2030, 64.2% in 2050 and 85.7% in 2100 with intensified storm surge. In case of only overtopping, the storm surge will inundated about 14.2% in 2030, 26% in 2050 and 57.1% in 2100 of the polder.

Return period analysis shows that 'Aila' event has an average return period of 12.5 years, whereas storm surge height of 7.5m (2100 scenario) has a return period of 17.5 years. So, similar storm surge events will occur more frequently.

Present disaster reduced 38.4% of rice production from the annual average production. In 2030, this type of disaster (*e.g.* Aila) will damage around 64% of rice production. In 2050, the damage will increase to 88.7% and finally in 2100, it will overwhelm the total paddy cultivation in the Polder no-5.

Storm surge causes devastating flood in the study area. Only fisheries may flourish in future. However, research findings show that the fish production including shrimp will be declining in future. From the impact study of 'Aila' it is found that about 50% fish production has been lost in 2009. Cyclone 'Aila' destroyed around 20 crore taka of fisheries related infrastructure. About 62% in 2030, 70% in 2050 and 85% in 2100 will be the estimated total loss in fisheries sector for that particular year storm surge event.

'Aila' destroyed at least 33% livestock of the study area. Loss of livestock will increase to 66% in 2030 and around 90% in 2050. Livestock will be rarely found after the storm surge disaster in 2100. Storm surge will change the land use pattern inside the polder. Now, forest areas are already under pressure by settlement, shrimp culture, paddy cultivation etc. Therefore, forest areas will reduce along with increasing future storm surge.

Considering SRES-A1B scenario, the population (*e.g*. 272047 before 'Aila') of the polder will reach to 362224 in 2030, 388135 in 2050 and 318285 in 2100. Most of the population of the polder is involved in multiple seasonal occupations. They are involved in different economic sectors like agriculture, fisheries, trade and business, forestry, labor, services and seasonal work. 'Aila' destroyed those economic sectors on which their livelihoods depend.

'Aila' reduced livelihood related to agriculture including shrimp framing from 32.9% to 23%. Future disaster will reduce the livelihood in agriculture sector to 19.28% in 2030 and 11.78% in 2050. Storm surge flood 'Aila' also reduced the agricultural labor from 25.8% to 19.35% in the study area. In case of future disaster, agricultural labor will be 15.12% in 2030 and 9.24% in 2050. But wage labor will increase as like 'Aila' event. After 'Aila' wage labor increased from 6.2% to 9.3% in the study area. Retaining the trend, the wage labor will be 11.85% in 2030 and 14.9% in 2050. Livelihood opportunity in forestry, transportation, trade and commerce sectors will reduce. Only, fishing opportunity will show slightly increase just after the flooding but it which will no longer extend in the long run. Migration for work was the major livelihood option during 'Aila'. After 'Aila', seasonal migration increased from 12.1% to 19.6%. For the future storm surge disaster, seasonal migration will increase to 25.23% in 2030 and 32.5% in 2050.

6.2 Recommendation

Based on this study, the following recommendations are made;

- Further impact study can be carried out considering other SRES-scenarios of IPCC (2007)
- Effect of sea level rise into the inland water bodies can be estimated precisely in future.
- Future study can be carried out for finding the optimal adaptation options to reduce the impact on economy and livelihood.
- Proper operation and maintenance of the existing polder are needed to reduce the vulnerability of the study area.

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APPENDIX A

IMPORTANT DATA

Table A 1: Chronological history of the cyclone/ storm surge at the coast of Bangladesh

Year	Coastal Zone	Wind Speed (km/hr)	Storm Surge (m)
1822	Central	---	-
1876	Central, Eastern	---	12.2
1897	Eastern	---	-
1960	Central, Eastern	193	6.1
1961	Western	161	3.1
1963	Eastern	202	6
1965	Central	184	3.7
1966	Eastern	139	6.7
1970	Central	222	10.6
1974	Chittagong	161	5.1
1983	Chittagong	135	1.5
1985	Eastern, Central	154	4.6
1988	Western	162	4.5
1991	Eastern, Central	235	7.6
1995	Central	110	3.6
1997	Eastern, Central	150	4.6
1997	Eastern, Center	150	3
1998	Eastern	186	3
2007	Western	250	8
2009	Western	95	6

Source: Quadir and Iqbal (2008) and IFNet (2009)

Table A 2: Typical storm surge characteristics for cyclones in Bangladesh

Wind Velocity (km/hr)	Storm Surge Height (m)	Limit to inundation (km) From the coast
85	1.5	1
115	2.5	1
135	3	1.5
165	3.5	2
195	4.8	4
225	6	4.5
235	6.5	5
260	7.8	5.5

Source: MCSP (1993)

Table A 3: Rice production in polder no-5 (Calculated)

Year of production	Rice Production (Mt)
2000	68187
2001	66174
2002	67238
2003	61235
2004	63290
2005	62427
2006	65515
2007	70234
2008	78718
2009	37856

Source: Upazilla Agriculture Office (2010)

Table A4: Population projection of the Polder-5

Year	Population
2009	272047
2030	362224
2050	388135
2100	318285

APPENDIX B

APPLICATION OF PRA TOOLS

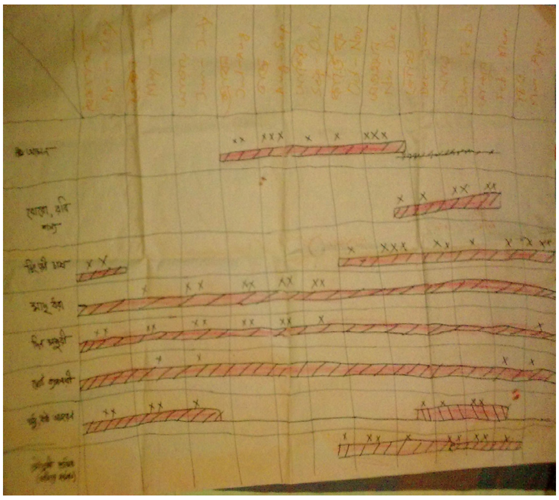

Figure B1: Livelihood seasonal calender

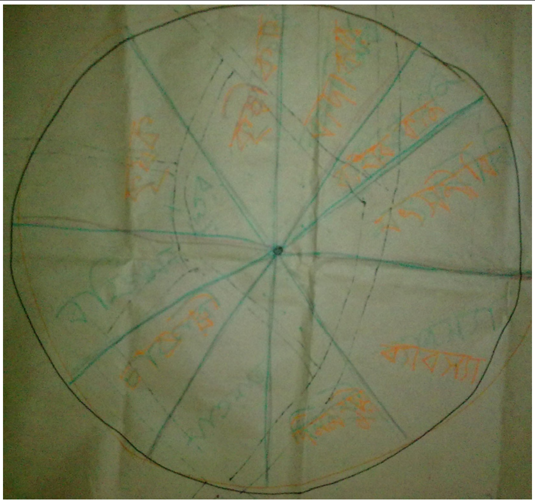

Figure B2: Pie chart diagram

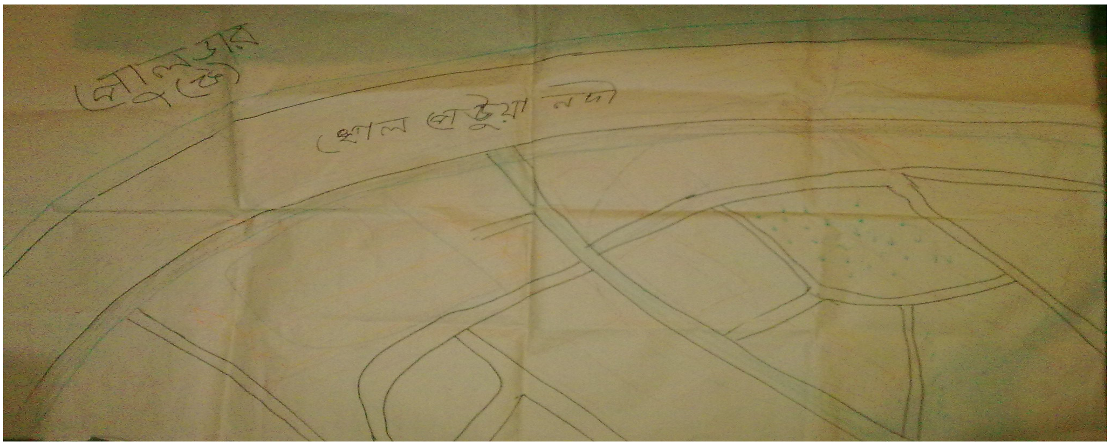

Figure B3: Social and resource mapping

APPENDIX C

PHOTOGRAPS

Photograph C 1: Flood due to ‘Aila’

Photograph C 2: Flood water inside polder

Photograph C 3: Part of the Polder-5

Photograph C 4: Agricultural land

Photograph C 5: Destruction of the habitat

Photograph C 6: Livestock situation

	
Photograph C 7: Livelihood of the fisher	Photograph C 8: Women activities
	
Photograph C 9: Livelihood as wage labor	Photograph C10: Food for work
	
Photograph C11: FGD at Nobaki	Photograph C12: Breaching point

Note: Photographs have been captured from 14th June, 2009 to 25th July, 2011.