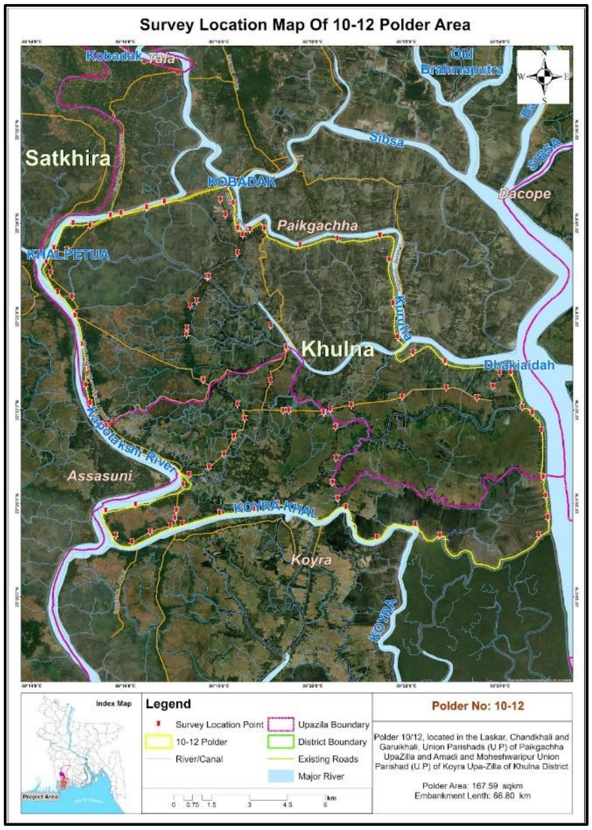
MSc. in Climate Change and Development (CCD)

Department of Environmental Science and Management

INDEPENDENT UNIVERSITY, BANGLADESH






CCD 522 THESIS

CLIMATE CHANGE VULNERABILITY AND RESILIENCE OF PEOPLE LIVING IN THE POLDERS AREA OF KHULNA DIVISION AND ASSESSMENT OF EFFECTIVENESS OF LOCALLY LED ADAPTATION (LLA)

Submitted By

Md. Shahadat Hossain

Student ID 2130850

Independent University, Bangladesh

Department of Environmental Science & Management

NOVEMBER 2022

ABSTRACT

Bangladesh is likely to be one of the most vulnerable countries in the world to climate change due to geographical location and geomorphological conditions. Bangladesh experiences extremely disastrous situations like cyclones, floods, saline water intrusion, waterlogging, heavy rainfall, river erosion, storm surge, etc. that occur frequently in the coastal part of Bangladesh. This result in huge loss of lives damages properties and degrades the integrity of the environmental components. Bangladesh's physical and cultural characteristics as well as the livelihoods of its people are defined by the GBM delta, which is endowed with an abundance of natural resources. The dynamically evolving coastal landscape of Bangladesh is controlled by the underlying geology and topography of the delta and the dynamic interaction between the influx of water and sediment, the coastal processes such as tides and wave action, and episodic events such as cyclones and monsoons. In Khulna Division, there are several polders. We have selected 04 polders for our study named: 7/1,7/2, 10-12, and 13-14/2. The flood damage information was collected from several household-level surveys which were caused by various Cyclonic events in these regions by using KOBO Toolbox. Then the data was used to prepare various flood damage curves to show the quantity of loss & damage of these polders people due to various Cyclonic events in the last 20 years. In parallel, the Locally Led Adaptation (LLA) practices were collected along the selected polders boundary by using FGD where a discussion was arranged with people to know the damages and how they are using their knowledge for making the decisions themselves. The focus is on the Local people Engagement of these polders in planning, implementation, and monitoring to manage the risks and challenges faced by the people due to climate change by predicting flood inundation in the upcoming years according to the report of IPCC. The inundation rate has been analyzed using ArcGIS. After that a fuzzy model was developed through MATLAB to predict the damage rate for 2100 due to sea level rise. Also, a detailed assessment was done about the gaps for the implementation of Locally Led Adaptation (LLA) among polders people and a way forward to develop them to prepare against the cyclones & floods due to Climate Change and Sea Level Rise (SLR).

Key Words: *Khulna, Polder, community-based adaptation (CBA), FGD, KOBO, Drone, FDC, LLA, Geographic Information System (GIS), Fuzzy Inference System (FIS)*

TABLE OF CONTENTS

ABBREVIATIONS

BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
CBA	Community Based Adaptation Practice
CEIP	Coastal Embankment Improvement Project
CEP	Coastal Embankment Project
DAE	Department of Agricultural Extension
DDM	Department of Disaster Management
DEM	Digital Elevation Model
DoE	Department of Environment
DPHE	Department of Public Health Engineering
FGD	Focus Group Discussion
FIS	Fuzzy Inference System
GBM	Ganges-Brahmaputra-Meghna
GIS	Geographic Information System
GoB	Government of Bangladesh
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
KII	Knowledge Informant Interviews
LLA	Locally Led Adaptation
RCP	Representative Concentration Pathways
U.P.	Union Parishad
USGS	United States Geological Survey
VGP	Vulnerable Group People
WARPO	Water Resources Planning Organization
WB	World Bank

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND AND CURRENT STATE OF THE PROBLEM

Bangladesh is considered one of the most disaster-prone and climate-vulnerable countries globally. The coastal zone is influenced by river system fluctuations and coastal processes such as tidal propagation, salinity intrusion, cyclone events and climate change impacts. The 19 districts of Bangladesh that are adjacent to the Bay of Bengal make up the country's coastline region. The Bengal Delta is the largest delta in the world. It drains through the three main river systems: the Ganges, Brahmaputra and Meghna from the Himalayan Mountain. There are 710 km of coastline on the Bay of Bengal. The flat topography of Bangladesh makes the country highly vulnerable to coastal and river flooding due to its location in the lower part of the GBM basin. The flat delta is exposed to high tides, saline intrusion, regular cyclones from the Bay of Bengal. Effective management of this immense natural resource is a challenge now. Nearly 38.5 million people live in the coastal area (BBS, 2011). One third of the coastal region people live below the poverty line. These people are vulnerable to issues like lack of food, income, clean water, and health. The districts of Shariatpur, Chandpur and Barisal situated in the tidal floodplain of the Ganges-Brahmaputra-Meghna delta, are in the fourth quartile, i.e. highest category, the most vulnerable areas. Around 870-1400 inhabitants are living per kilometer. These people are exposed most to inundation hazards. The delta's mouth is the most vulnerable to cyclonic flooding. (Bernard *et al.*, 2021). Inundation of such area could cause major socio-economic loss. According to a study by Huq *et al*. (1995), 11% of the country's population lives in the area threatened by 1m rise in sea level. Bangladesh's current situation is not well off to adapt such sea level rise. The costs of coastal protection would be fundamental. The most vulnerable part of Bangladesh, the Khulna district, lies in the country's southwestern coast. The hilly areas of Bangladesh are mostly in northwestern part of the country. Usually, flash floods occur in these areas. Apart from the hilly areas, most of the country is less than 10m above sea level. If proper measures are not taken, sea level rise could displace millions of people in the long run (Agrawala *et al.*, 2003).

1.2 IMPORTANCE AND SIGNIFICANCE OF THE STUDY

Sea level rise has a tremendous socio-economic and environmental cost which is anticipated to lead long run macroeconomic shock in Bangladesh. The country is growing at about 6% rate per year in last decade. The adverse effect of sea level rise will hamper the growth potential of the economy (Uzzaman and M.A., 2014). The country started introducing large-scale flood control infrastructures like coastal polders (e.g., earthen embankment parallel to the riverbank), sluices, regulators and drainage interventions after the major floods in 1954 and 1955. Designs of all those structures have followed a traditional return-period-based approach. Coastal areas in Bangladesh are Polarized to protect the hinterland from tidal and storm surge flooding. Bangladesh introduced the coastal polder system during 1960s. The Coastal Embankment Project (CEP) was initiated by the then Government of Pakistan in the 1960s to protect coastal zone areas subjected to inundation by high tides and saline water. The crest level of the Polder was fixed at the maximum average high tide level (recorded from 1960 to 1968) plus a freeboard of 1.5 m. The coastal embankment system of Bangladesh was designed initially without attention to storm surges. Subsequently, storm surges have caused significant damage to the polders and threatened their integrity. In addition to breaching due to cyclones, siltation of peripheral rivers surrounding the embankments has caused failures of the drainage systems, creating waterlogging inside the Polders. This has led to large-scale environmental, social, and economic degradation. Poor maintenance and inadequate management of the Polders have also caused internal drainage congestion and heavy internal siltation. Soil fertility and agriculture production are declining in the water-logged areas. Other areas suffer from increased salinity due to seawater intrusion into the Polders.

The Bangladesh Government's progress in reducing the vulnerabilities of the coastal zone communities includes the construction of 139 polders and has been outstanding during the last 60 years. For the past 45-50 years, polders have significantly reduced the vulnerability to natural disasters and have created economic opportunities for the coastal communities, ensuring enhanced agricultural production. Nevertheless, throughout the last years, the effectiveness of the polders in protecting the land and people within the polders, in many cases, has been compromised by damages caused by severe cyclones, shifting coastal and riverbank lines, deterioration due to frequent storm surges. The prevailing vulnerability of the coastal zone to direct and indirect coastal threats highlights the urgency to rehabilitate the damaged infrastructure as well as improve their resistance to climate change threats. In recent times, a strategic shift, which includes consideration of storm surge hazards, has been initiated by the Government of Bangladesh (GoB) in rehabilitating the polder system.

1.3 RESEARCH OBJECTIVES

The broad objective of this study is to assess the flood damage in coastal area and to prepare local people to fight against the cyclones & floods due to Climate Change. The specific objectives of the study are as follows:

- To find out the major damages from the survey
- To determine the inundation rate using GIS
- To give a prediction of inundation according to RCP 8.5
- To plot and analyze flood damage curve.

1.4 STUDY AREA

The Coastal Embankment Improvement Project (CEIP) Phase 2 is the continuation of CEIP Phase 1. The CEIP-1, implemented by the Bangladesh Water Development Board (BWDB) and funded by the World Bank (WB), safeguards the Coastal Zone of Bangladesh against flooding due to storm surges and cyclones, combats erosion and enhances the coastal resilience. The project locations/polder locations will be in the same districts as of CEIP-1—Patuakhali, Borguna, Satkhira and Khulna. 15 polders selected for CEIP-2 are Polder 4, 5, 7/1, 7/2, 10-12, 13-14/2, 39/ 1A, 39/ 1B, 41/5. 41/7, 45, 47/1, 50-51, 54, 55/2D. Total gross protected area in the polders is 185,026 ha with 977 km of embankment. Total population in the polders is around 1.25 million. In our study, we have worked with four polders - 7/1, 7/2, 10-12, 13-14.2. Polder 7/1 is located in 10 No. Pratapnagar Union under the Assasuni Upazila and 11 No. Paddapokur union under Shyamnagar Upazila of Satkhira District. Map shows the base map of the Polder.

Figure 1-1: Houses near Koyra Union at Khulna District

Polder 7/2 is in Pratabnagar, Anulia, Baradal and Khaira Union under the Assasuni Upazila of Satkhira District. Figure 1-1 shows the base map of the Polder. Construction of the Polder 10-12 was started in 1962-63 and completed in 1968-69. The Polder-10-12 is in the Laskar, Chandkhali and Garuikhali, Union Parishads (U.P) of Paikegacha Upa-Zilla and Amadi and Moheshwaripur Union Parishad (U.P) of Koyra Upa-Zilla of Khulna District in the South-Western area of Bangladesh. The polder is bounded by Koyra river in the South, Kapatakshi river in West, Shibsha in the East and Karulia river in the North side. The Polder-13-14/2 is in the Bagli, Maheshwaripur, Maharajpur, Koyra, and Uttar Bedkashi Union Parishads (U/P) of Koyra Upa-Zilla of Khulna District in the South-Western area of Bangladesh. The polder is bounded by Kapataksho river in the West and part of South side, koyra river in the North and part of the East side, and Shagbaria river on the part of East and South side.

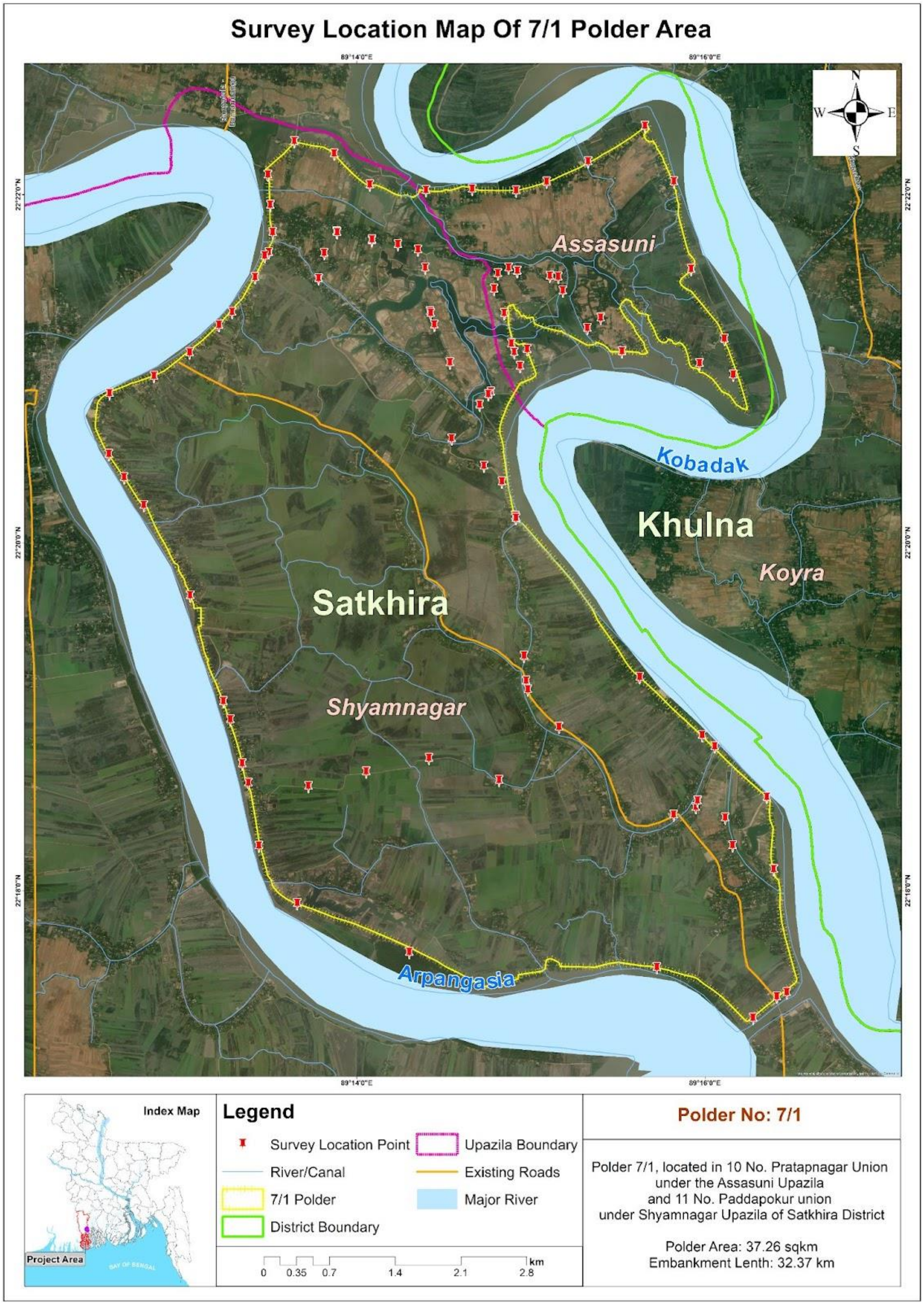


Figure 1-2: Location Map of Polder 7/1

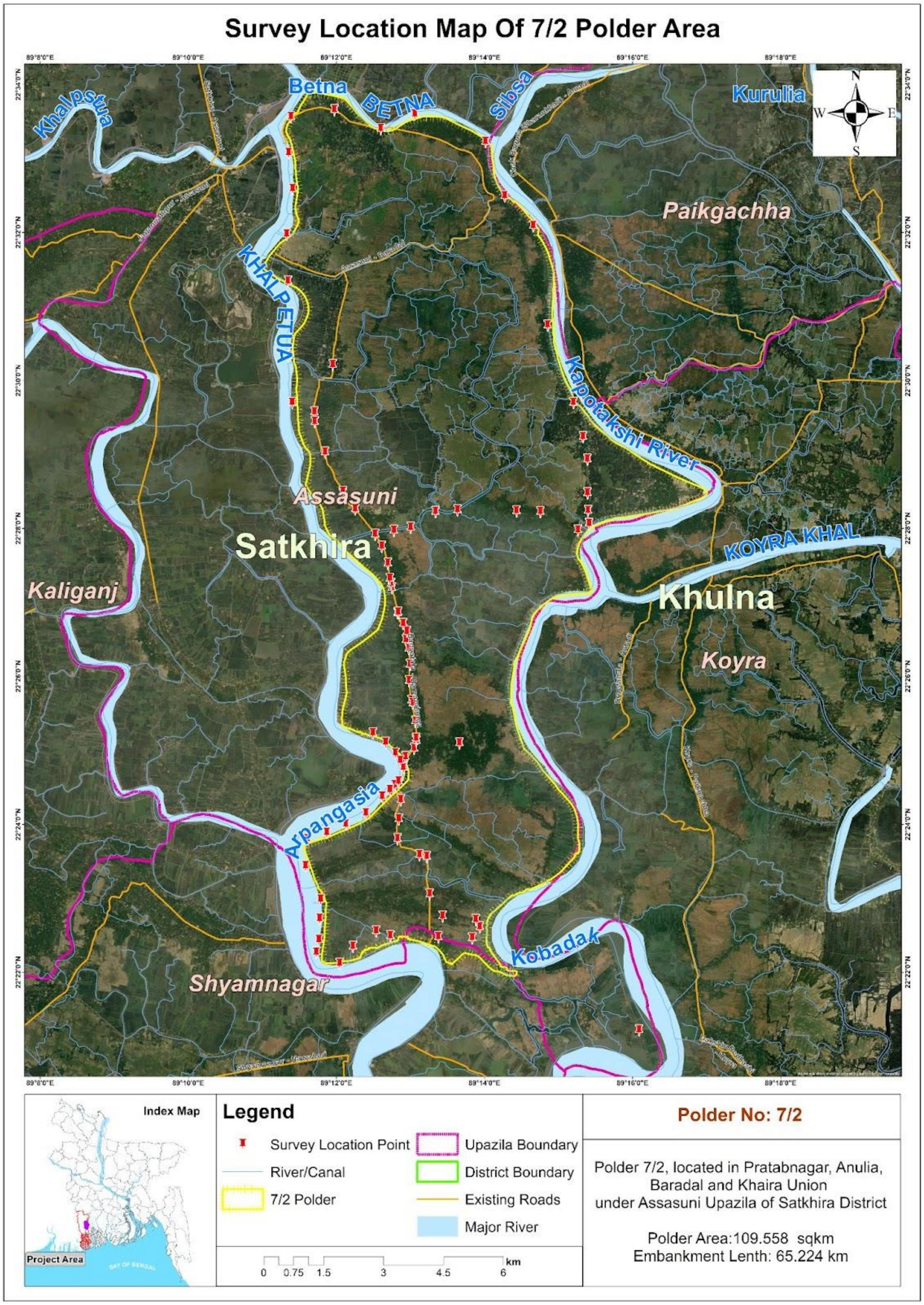


Figure 1-3: Location Map of Polder 7/2

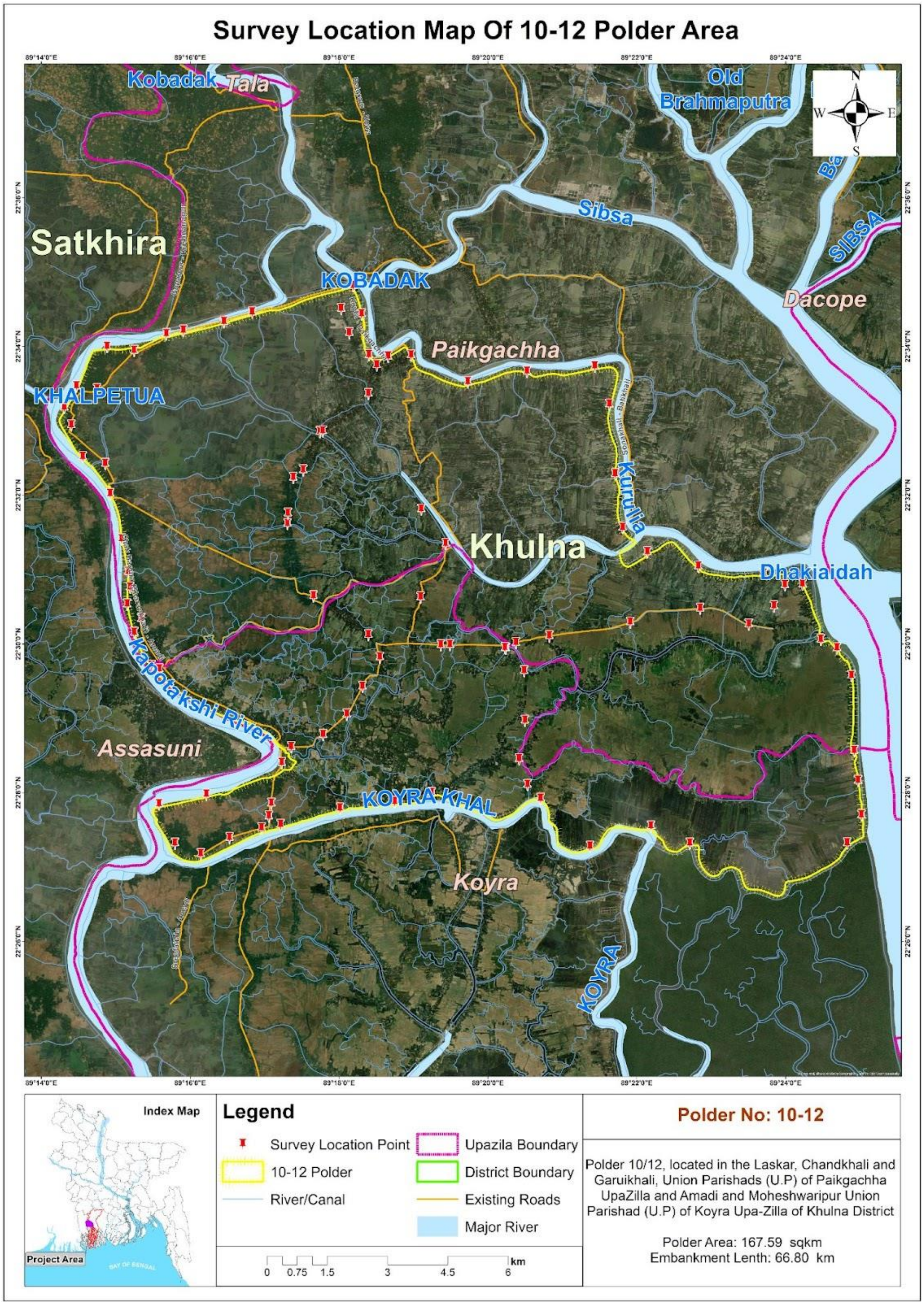


Figure 1-4: Location Map of Polder 10-12

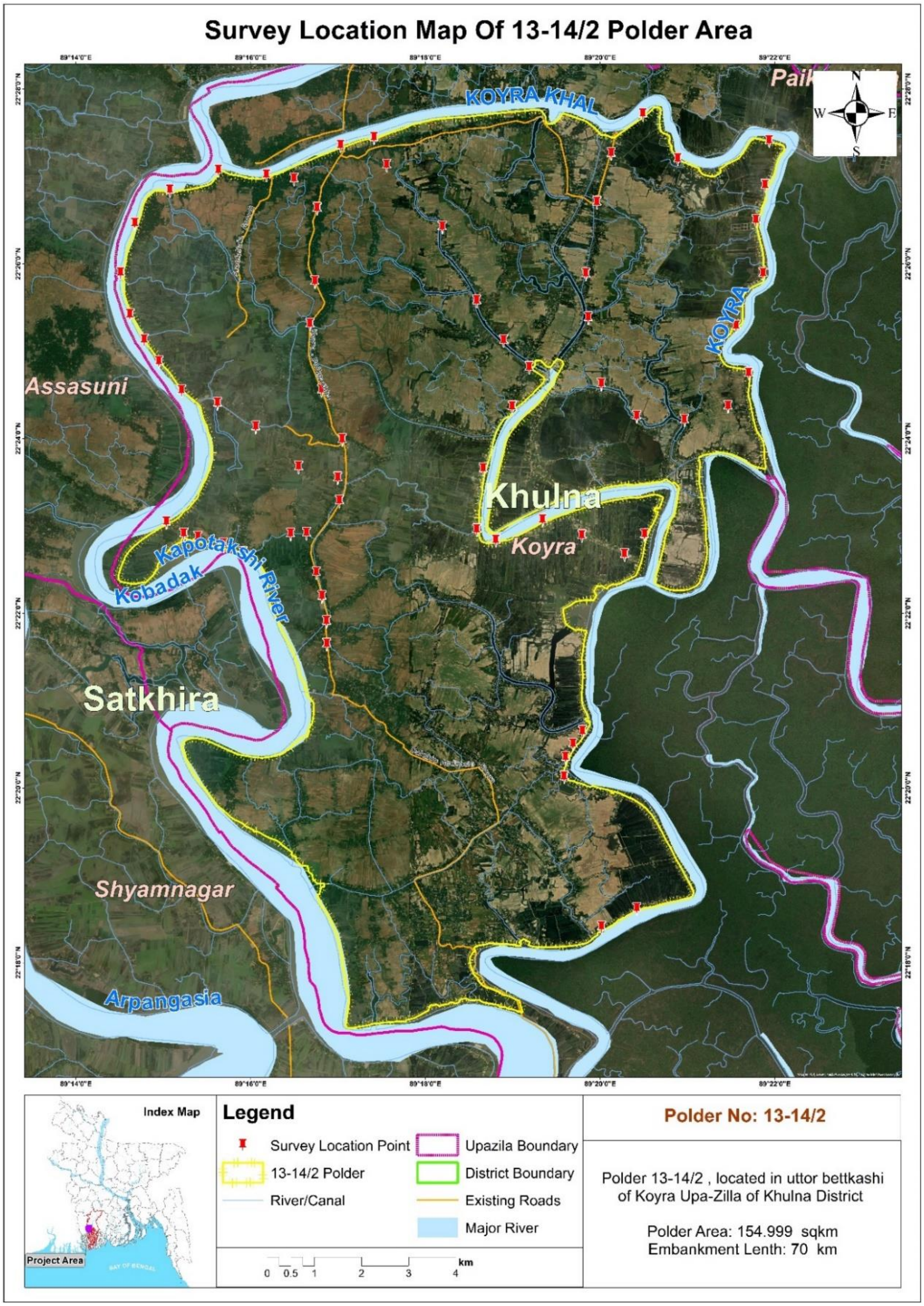


Figure 1-5: Location Map of Polder 13-14/2

Figure 1-6: Shanta Hat on Polder 10-12 in Khulna District

Figure 1-7: Koyra Polder 13-14/2 near Sundarban

1.5 THESIS ORGANIZATION

Chapter 1 is the introduction of the study. It contains background and current state of the problem, importance and significance of this study, research objectives, study area and thesis organization.

Chapter 2 provides the literature review. Previously many studies have been conducted on flood damage, its management. We have reviewed previous studies and briefly described their findings.

Chapter 3 presents the methodology for this study. It contains details about data collection, Inundation Rate Analysis through GIS, Flood Damage Curve Analysis.

Chapter 4 presents data analysis and results. This part explains the finding of our study and how it can be helpful for the flood damaged people in the coastal area.

Chapter 5 represents the concept and details of fuzzy logic. This chapter is basically for uncertainty analysis. A flood damage prediction has been represented in this chapter according to RCP 8.5 which is suggested by IPCC

Chapter 6 presents the conclusion & recommendations of this study. Our motive is to help people to recover from the damage flood has caused to them. This study gives prediction on inundation for polders mentioned above. Provides suggestions and recommendations for future work on relevant studies or for the extension of it.

CHAPTER 2: LITERATURE REVIEW

2.1 PREVIOUS STUDIES OF FLOOD AND ITS CLASSIFICATION

Bangladesh is in the low-lying delta and around 80% of the country is classified as floodplain. Around 18% of the landmass is inundated and 75% of the country is below sea level. Here the tropical monsoon climate is influenced by the Himalayan Mountains in the north and northeast, and the Bay of Bengal in the south (Rahman *et al.*, 2014).People living in this country, frequently face natural and man-made disasters - flooding, groundwater pollution, droughts, cyclones, riverbank erosion, air pollution, wetland loss, tornadoes, earthquakes and coastal erosion. The coastal morphology makes it more vulnerable to sea level rise, salt intrusion, thus influences flooding. It also occurs when high tide, storm surge and wave conditions cross coastal defences. Backwater effect of tides prevents efficient drainage flood water causing floods in the low-lying coastal areas (Karim *et al*., 2008). The risk of coastal flooding is increasing momentarily. As a result, people living in such area are in great menace. The threats to local communities include coastal storms, cyclones, landslides etc. These affect the shape of coastlines,contributes to coastal erosion resulting in more frequent flooding. Moreover, 90% of our country is only about 10 meters above sea level. There are high chances that permanent flooding will occur since it is predicted that the Indian Ocean will rise due to global warming. From 1970 to 2009, flooding is one of the major diasters in the subcontinent where 35% of the natural disasters have occured in Bangladesh (Abbas *et al*., 2016). According to a study by Rahman *et al*. (2017), the flood of 1988 has been the worst in nature, and it took around two thousand lives.

Table 2-1: List of proposed facilities according to FAP-8A Study

Year	Death
1987	1657
1988	1708
1998	918
2004	747
2007	800

Flood is a natural annual event in Bangladesh. But it can be of different types. When the water flow exceeds the holding capacity of any catchment area during rainy season, it inundates the whole area. This can be called annual flood. When annual flood inundates upto 20% of the land area, it is considered blessing for the crops. On the contrary, when such flood inundates upto 35%

of the land area, it is considered destructive as it brings dilemma to the people's lives and economy. However, flood can be categorized into three types- monsoon flood, flash flood and tidal/coastal flood.

Table 2-2: Categories of Flood and its Characteristics

Categories of Flood	Characteristics
Monsoon Flood	It is caused by torrential rainfall during monsoon season. It increases and decreases slowly. It inundates the entire area causing damage to properties.
Flash Flood	It is the result of heavy rainfall in low-lying areas. Water increases and decreases rapidly. Generally, occurs in the hilly areas.
Tidal Flood/Coastal Flood	It is caused by sea level rise, sinking land at coastal areas. It is usually of short duration, height is 3m to 6m, blocks inland flood drainage.

In a study by Baten *et al.* (2018), the main reason for flooding is extreme rainfall due to the monsoon belt with the Himalayas in the North Bangladesh. Figure shows different type of flood with their frequency. Around 54% riverine flood has occurred from 1972 to 2017. Other types of flood have also occurred frequently. In Bangladesh, 80% rainfall occurs from May to September and 90% of the water is carried by the GMB basin.

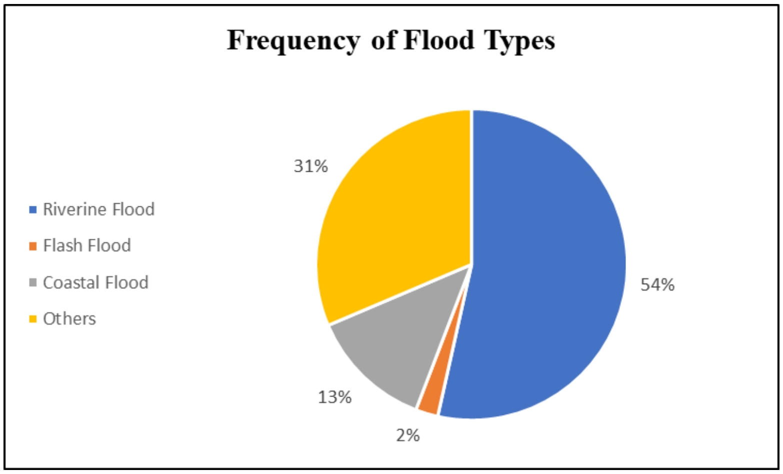


Figure 2-1: Frequency of Flood in Bangladesh based on their Types (EM-DAT/CRED)

2.2 PREVIOUS STUDIES OF FLOOD DAMAGE

Flood damage contributes to one third of the economic losses inflicted by natural calamities worldwide (Neumayer *et al*.,2014). It brings great misery to the local people causing damage to their lives and property. The amount of damage of a specific flood depends on the vulnerability of the affected socio-economic and ecological system (Cutter *et al*.,1996). Every year, around 18% of the whole country is flooded, taking over more than thousand lives, destroying million homes.

Table 2-3: Impacts of Natural Disasters on Bangladesh since 1972 (EM-DAT)

Disaster Type	Total Deaths	Total Affected
Flood	42279	304256323
Storm	174288	63445949
Epidemic	10188	3042429
Landslide	263	136470
Extreme Temperature	2440	414200
Earthquake	45	19395
Drought	18	25002000
Total	229521	396316766

It damages the power transmission; thus, no affected people must pass days without electricity. Many people lose access to safe water. As a result, transmission of diseases such as diarrhoea, cholera, typhoid fever, and leptospirosis. Locals suffer without proper treatment and medicine relief.

Table shows that flood has caused the maximum fatalities among all the disasters. Even in the year 2022, 102 poeple died from drowning, snake bites and lighting in the flood hit areas according to a report of the Health Emergency Operation Centre and Control Room. Again, the timeline of the fatalities was between May 17,202 and June 28, 2022. Flood damage is dependant on different parameters- depth, velocity and duration flooding (Khan *et al*., 2012). Severity of the damage also depend on these parameters. Flood risk is a function of vulnerability and hazard where the term vulnerability indicates susceptibility and coping capacity. Thus, the intensity of flooding is highly inflicted by land-use practice. Agricultural land covers around 59% of the land and other water bodies cover about 9%. Over the last two decades, Bangladesh has been through devastating floods. It is still at very risk. Table shows the severity of the flood damage in the last 20 years according to a study by Hasan *et al*. (2018).

Table 2-4: Hazards and Damages of major floods occurring in Bangladesh in last 20 years

Year / Damage		1998	2000	2002	2004	2007	2011	2012	2015
No. of Victims	District	52	9	36	39	46	11	17	48
	Upazila	366	40	209	265	263	64	58	222
	Family	5711962	81144	1949940	7468128	2851559	348621	888336	165054
	People	30916351	3244576	7606837	36337944	13343802	923465	1386060	816988
Crops damaged (Acre)	Fully	1423320	14262	438016	1605958	890898	77486	38987	40445
	Partially	1808401	438016	437050	1038176	1335382	254968	125089	60531
No. of House Damage	Fully	980571	437050	309775	894954	81817	243191	14101	218275
	Partially	2446395	309775	564527	3389101	961420	370587	58418	598818
No. of Dead People		918	37	26	747	970	180	41	76
No. of Dead Livestock,Cattles & Goats		26564	1643	25237	15143	1459	1501	8716	4946
No. of Damage Institution	Fully	1718	41	302	1295	563	445	239	292
	Partially	45896	8874	15690	45528	27125	6621	1210	2968
Road Damage	Fully	15927	409	3720	14271	3705	2233	171	1635
	Partially	45896	8874	15690	45528	27125	6621	1210	10922
Bridge & Culvert Damage		6890	1234	9406	5478	360	157	123	1573
Embankment Damage		4528	118	4734	3158	88	1743	125	448

Figure 2-2: Flood Affected Area

Profile of vulnerable communities has been prepared by the participants of the consultation meetings themselves through a self-assessment exercise. The assessment is based on the year-round income and the inhabitants' food consumption within three categories. On average, about 41% of the households are in the 'extremely poor' category, 33% are moderately poor, 17 % are middle-income, and the rest, 09 % are rich. These households have been identified in the consultation meetings as the poor households of the Polder area. Considering the standard food consumption (three meals a day), the extremely poor group usually took two meals a day in the lean period since they could not afford three full meals.

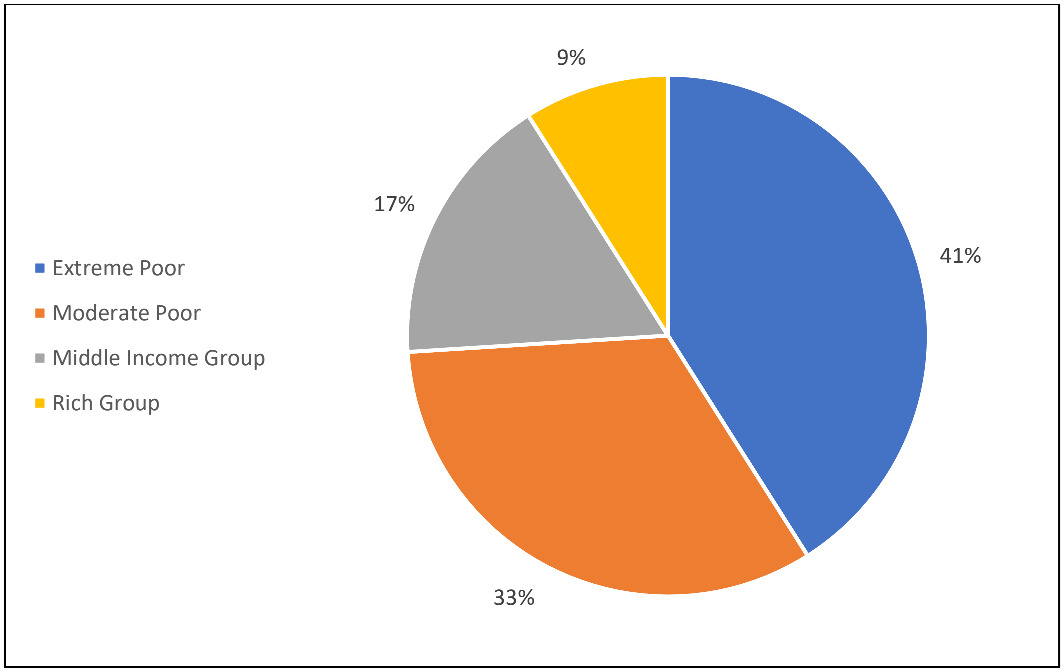
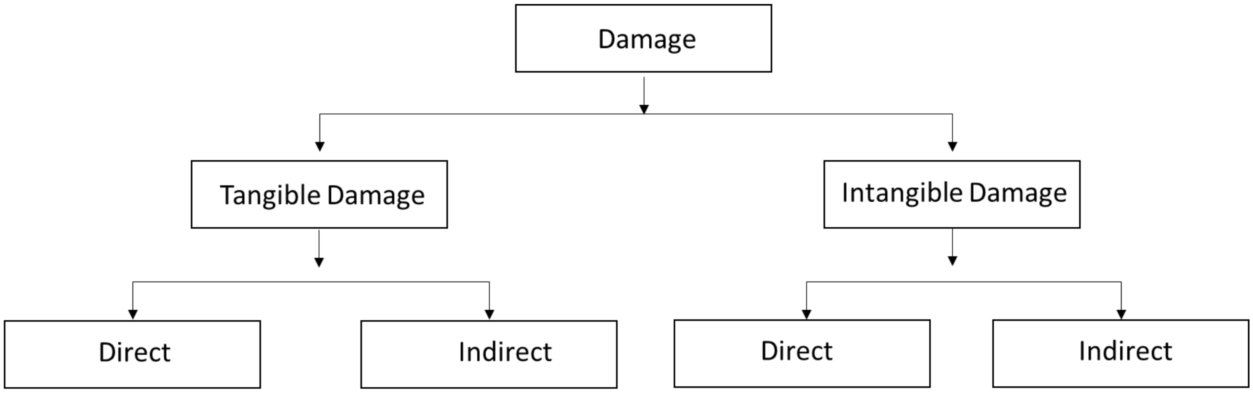


Figure 2-3: Poverty Situation (Source: KMC's Socioeconomic Survey, April 2022)

The major social safety nets and poverty reduction programs initiated in the area include the Vulnerable Group Development (VGD), Food/Taka for Work (F/TFW), Food for Education/Cash for Education, Old Age Allowance, Freedom Fighter Allowance, and Integrated Poverty Reduction Program. According to local people, these programs have created food security as well as social safety nets among the targeted poor households and vulnerable communities to some extent.

Every year in Bangladesh, flood causes social and economic damage to the local people. High tide floods take several lives, impacts on infrastructure, causes deterioration of roads, rails etc. from exposure to saltwater. Thus, proper flood damage assessment is essential. Many researchers, government and non-governmental organizations are emphasizing on flood damage assessment. Flood damage can be primarily classified into the following categories.



Tangible damage can be defined as damage that has monetary value i.e. damage to lifelines, buildings, properties. It can be determined quantitatively in economic terms. Intangible damage means non-economic damage such as trauma, sufferings, inconvenience of social life. Both tangible and intangible damage are of two types - direct damage and indirect damage. Tangible direct damage indicates the damage of building and contents, vehicles etc. Intangible direct damage means mortality and injuries, environmental losses. Tangible indirect damage includes infrastructure disruption and business disruption. Intangible indirect damage indicates psychological trauma, loss of trust in authorities. Moreover, many researchers have categorized flood damages into primary and secondary damages. Primary damage has a direct connection with flood while secondary damage is the one casual step removed from the flood. Flood damage categories should cover as much of the damage as possibly can occur. For example, while assessing of urban flood damage, one must include all the sub-categories such as residential, commercial, and industrial building. Again, it is not necessary to include agricultural damage while assessing urban flood damage. In a study, Dutta *et al*. (2001) determined the categories and subcategories of damage as shown below.

Table 2-5: Categories and Sub-Categories of damage

Major Categories	Sub-Categories
Urban Damage (residential and non-residential buildings)	• Structure Damage • Content/stock damage • Outside property damage • Emergency and clean cost
Rural Damage	• Damage to crops and vegetables • Damage to farm infrastructure
Infrastructure Damage	• System damage • Interruption loss

According to a study by Mushar *et al*. (2019), tangible damage is mostly assessed in most studies for its data is easily accessible. There is no specific method for flood damage analysis. Previously, many studies have been conducted on flood damage assessment. International Union for Conversation of Nature (IUCN) assessed impairment of different factors of damage such as health, water, sanitation etc. caused by the 1998 flood (Khan *et al*., 2012).

2.3 FLOOD MANAGEMENT AND COMMUNITY BASED ADAPTION (CBA)

CBA (Community Based Adaption) emphasizes on the involvement of the vulnerable people, their needs and analyzes different parameters of vulnerability such as social, political, and economic parameters. According to a study by Hill *et al*. (2020), communities at the coast may both beneft from shoreline protection and socio-economic opportunities inspite of coastal hazards and sea-level rise.It will reduce relative vulnerability. Studies show that polders have reduced fluvial and tidal floods in coastal Bangladesh. Weather forecast, warnings and shelters have mostly contributed in lessening fatalities (Haque *et al.* 2018). The local people were introduced to the flood hazards, how to prevent them, how to overcome them in broader perspective. Our team discussed the following things-

- Creating awareness on community-level flood and drought management.
- Provision of medical supplies and food for emergency.
- Understanding flood forecasts and take precautions accordingly
- Identifying risks to communities
- Networking, monitoring, and reporting
- Training to facilitate effective evacuation
- Resource mobilization.
- Management of information for future reference.

The work on this study will develop a prediction on inundation in the coastal areas of Bangladesh. This will help the stakeholders in their planning and decision making for flood management. Community based adaption and measures taken on the prediction will steer the policymakers away from traditional flood management practices, towards more real time and effective decision making which should improve the overall flood management framework.

2.4 OVERVIEW OF THE POLDERS

The polder 7/1 (34.21KM) is in Satkhira District's Shyamnagar and Assasuni Upazila. Satkhira Operation and Maintenance (O&M) Division of BWDB oversees the administrative and management of the water control structures in the Polder. The Polder is divided into two Union Parishads (UPs), Padma Pukur in Shyamnagar upazila and Pratap Nagar in Assasuni upazila. The polder is surrounded by Kobadak river to the east and Kholpetua river to the west. The polder covers a gross area of 3887 ha of which net cultivable area is 2700 ha. Figure show the current situation of the polder.

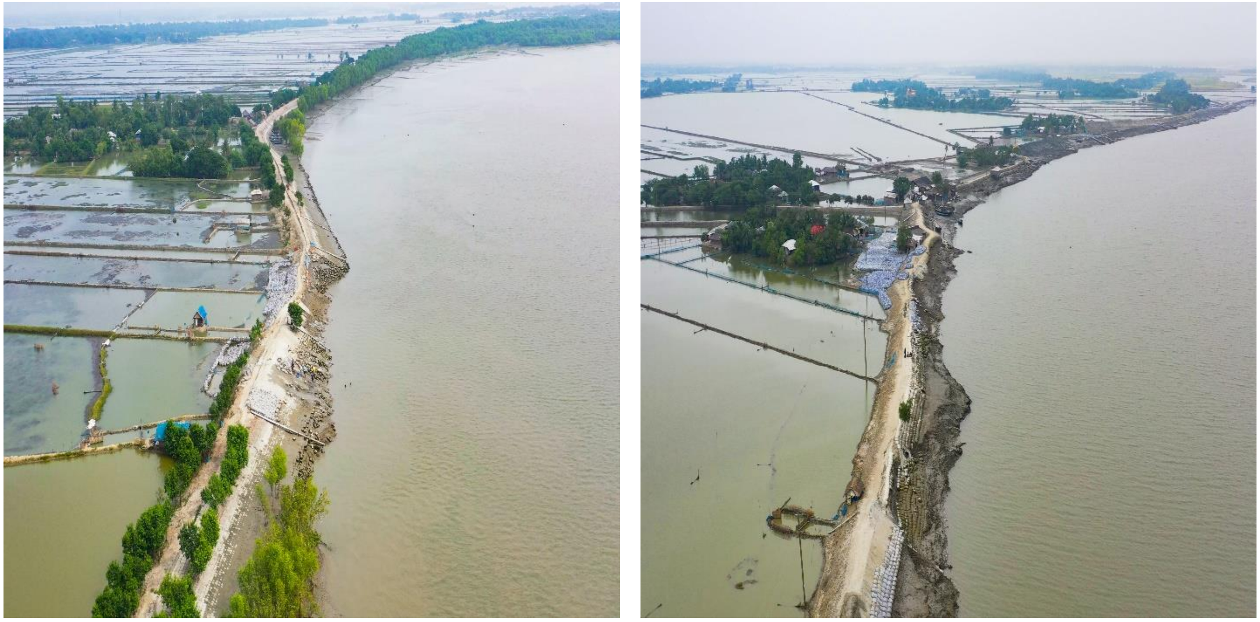


Figure 2-4: Damaged Polder 7/1 (Drone Survey View)

The polder 7/2 (66.002 KM) is located in Satkhira District's Assasuni Upazila. Satkhira Operation and Maintenance (O&M) Division of BWDB is in charge of the administrative and management of the water control structures in the Polder. The Polder is divided into four Union Parishads (UPs), Padma Pukur in Shyamnagar upazila and Pratap Nagar in Assasuni upazila. The polder is surrounded by Kobadak river to the east and Kholpetua river to the west. The polder covers a gross area of 10953 ha of which net cultivable area is 3375 ha. Photos 4.1 show the current situation of the polder.

Figure 2-5: Damaged Polder 7/2 (Drone Survey View)

Construction of the Polder 10-12 was started in 1962-63 and completed in 1968-69. The Polder-10-12 is in the Laskar, Chandkhali and Garuikhali, Union Parishads (U.P) of Paikgachha Upa-Zilla and Amadi and Moheshwaripur Union Parishad (U.P) of Koyra Upa-Zilla of Khulna District in the South-Western area of Bangladesh. The polder is bounded by Koyra river in the South, Kapatakshi river in West, Shibsha in the East and Karulia river in the North side. The entire length of embankment of the Polder-10-12 is classified as Interior Dyke having side slopes C/S: 2:1 and R/S: 3:1. For drain out the excess rain water from the polder area, 15 nos. drainage sluices (DS) was constructed.

Figure 2-6: Existing Condition of Polder 10_1

The Polder-13-14/2 is in the Bagli, Maheshwaripur, Maharajpur, Koyra, and Uttar Bedkashi Union Parishads (U/P) of Koyra Upa-Zilla of Khulna District in the South-Western area of Bangladesh. The polder is bounded by Kapataksho river in the West and part of South side, koyra river in the North and part of the East side, and Shagbaria river on the part of East and South side.

Figure 2-7: Existing Polder Roads of Polder 13_14/2

The Polder was scheduled to be built as part of the Coastal Embankment Project (CEP) in 1960. The Polder's construction began in 1966-67 and was completed in 1971-72. The polder was built to boost agricultural production by sheltering agricultural lands from saline intrusion induced by inundation from nearby rivers' high tides. Because the polder is so close to the Bay of Bengal, its embankment is vulnerable to sea cyclone surges, intense wind and cyclone wave attacks, river erosion, and other natural disasters. With climate change, the chances of this natural calamity occurring have increased. The polder's embankment was seriously damaged and breached at various locations with the landfall of hurricanes "SIDR" in 2007, "Ayla" in 2009, and "Amphan" in 2020. Some of the polder's hydraulic infrastructure were destroyed or washed away as a result of surge water overtopping during Cyclone landfall, while others were damaged or washed out due to their age and long-term use.

Existing Water Management Infrastructures

The existing water management infrastructures of different polders are represented in the following table and figure.

Figure 2-8: Existing conditions of the sluice gates in 7/1 polder

Table 2-6: Existing water management infrastructures (sluice gates) in 7/1 polder (Source: CEIP-2)

Location	Type of Structure	No of Vents
Su-Vadrakathi	Drainage Sluice	1
Paddapukur	Drainage Sluice	1
Kamalkathi-1	Drainage Sluice	1
Kamalkathi-2	Irrigation Inlet	1
Chandipur-1	Irrigation Inlet	1
Chandipur-2	Irrigation Inlet	2
Jhapa	Irrigation Inlet	1
Patakhali	Irrigation Inlet	1
West Patakhali	Irrigation Inlet	1

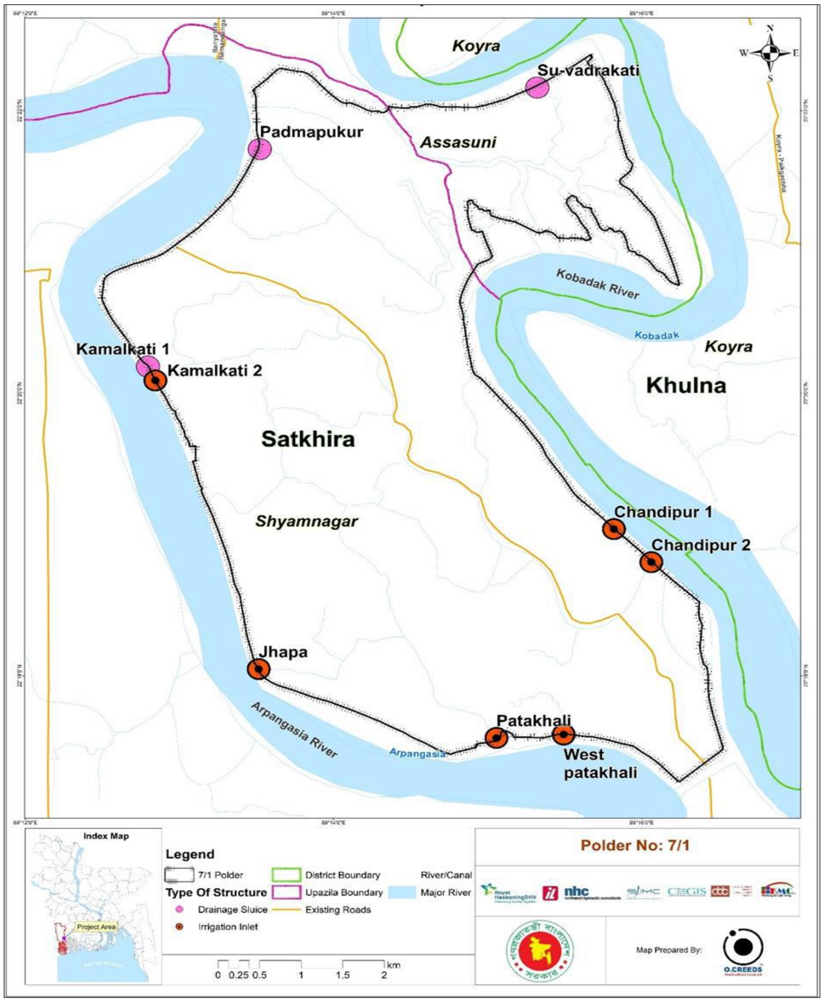


Figure 2-9: Existing conditions of the sluice gates in 7/1 polder (Source CEIP II by BWDB)

Table 2-7: Existing water management infrastructures (sluice gates) in 7/2 polder
(Source: CEIP-2, BWDB)

Location	Type of Structure	No of Vents
Su-Vadrakathi	Drainage Sluice	1
Paddapukur	Drainage Sluice	1
Kamalkathi-1	Drainage Sluice	1
Kamalkathi-2	Irrigation Inlet	1
Chandipur-1	Irrigation Inlet	1
Chandipur-2	Irrigation Inlet	2
Jhapa	Irrigation Inlet	1
Patakhali	Irrigation Inlet	1
West Patakhali	Irrigation Inlet	1


Figure 2-10: Existing conditions of the sluice gates in 7/2 polder

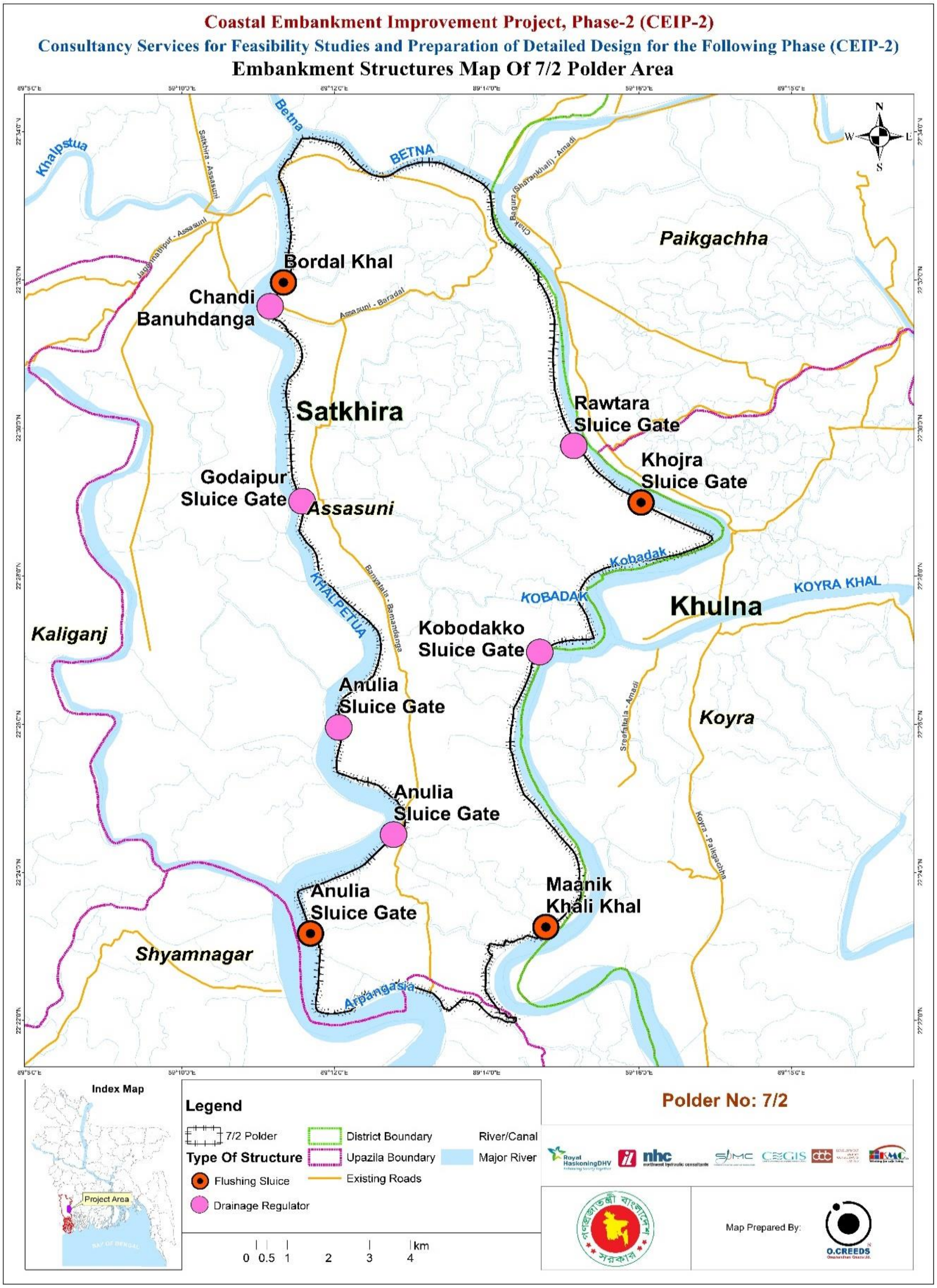


Figure 2-11: Existing locations of the sluice gates in 7/2 polder (Source CEIP II by BWDB)

Figure 2-12: Existing conditions of the sluice gates in 10/12 polder

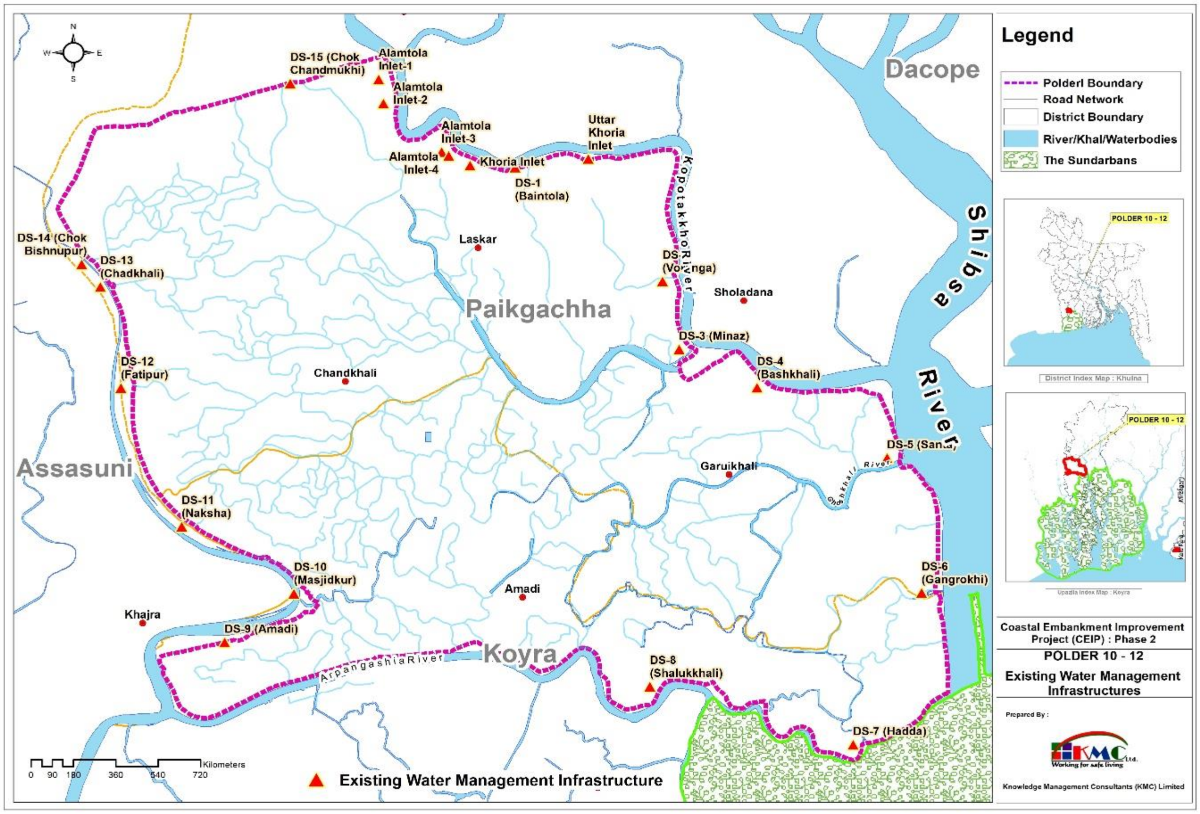


Figure 2-13: Existing locations of the sluice gates in 13/14.2 polder *(Source CEIP II by BWDB)*

Figure 2-14: Existing conditions of the sluice gates in 13/14.2 polder

The embankment of polder 7/1 is being harmed by river erosion. environment on the embankment, but both were extensively damaged. About 0.370 km of embankment washed out between km. 0.00 and km. 0.60, and the ring bundhs that were built are insufficient to protect against high tide during cyclones or monsoons.

To ensure the equitable management, effective use and sustainable management of water resources Infrastructure for water management appear to be physical interventions, which are essential components of intervention activity. In Polder 7/2, there are some common water management infrastructures present, such as lateral embankments, drainage sluices, drainage canals, and others.

All the rivers flowing around the Polder-10-12 is very close to the embankment's toe of the polder. Due to the riverbank erosion and damage done by the wave of the rivers, the embankment and drainage structures of the polder have become in extremely vulnerable condition. Improper and unsuitable use of them also increase their vulnerability. Due to inadequate allocation of maintenance budget, it cannot be repaired/reconstructed by BWDB as required. Total 66.80 km. of embankment of the polder is needed major repair/rehabilitation. There are 15 nos. drainage sluices, all of them are exist but they are badly damaged. The existing drainage sluices have been damaged badly due to their long age and as their locations are close to the sea (Bay of Bengal).

In case of 13/14.2 polder, there are 15 drainage sluices in the polder that are used to control water flow. Out of which 2 nos. of recently built, good condition sluices were made. The remaining 13 drainage sluices have some wear and tear. They are damaged and old enough that they are not operating correctly. The sluices' loose apron on the C/S and R/S is either destroyed or washed away. The RCC works are broken, their surface is ruined, and they can no longer be repaired.

Figure 2-15: Existing locations of the sluice gates in 13/14.2 polder *(Source CEIP II by BWDB)*

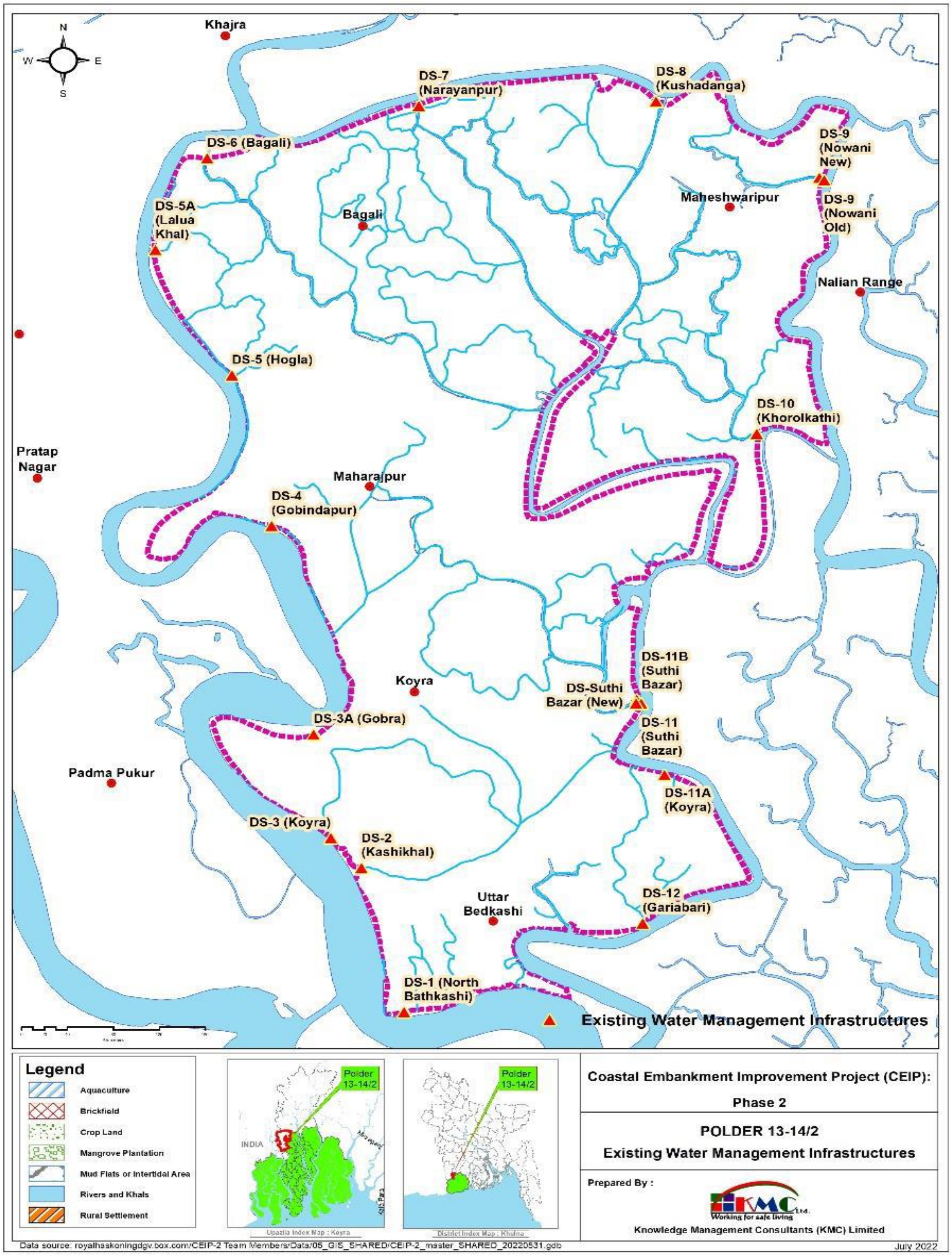


Figure 2-16: Existing locations of the sluice gates in 13/14.2 polder *(Source CEIP II by BWDB)*

Water Resources

The water resource system is the source of water supply and is essential for the environment's preservation of aquatic habitats, the assimilation and dilution of wastes, the attenuation and control of floods, drainage, and recharging into the aquifer.

The Kapotakkho River in the east and the Kholpetua River in the west are hydrologically connected to both Polder 7/1 and 7/2. These two nearby rivers run from north to south. The tidal influence of the rivers has an impact on the polder's floods and drainage system. The primary river in the project region is the Kapotakkho, which is 238 km long and has a width that ranges from 19 to 105 m. It is a meandering river that continuously empties. Its over 60 km long embankment is for flood management and protection. An offshoot of the Kapotakkho River, the Kholpetua River is over 66 km long and also meanders. This river also discharges continuously. The highest water level observed in the river is 4.0 meter and low water level is 2.5 meter. During the FGDs, the local people mentioned that the flow of both Kapotakkho and Kholpetua is high enough.

Figure 2-17: Kapotakkho (locally known as Kobodak) river at Polder 7/1

The Kopotakkho River, which runs to its north and west, completely encircles the Polder 10/12 region. The area is encircled on the south by Koyra Khal. The Koyra khal is bordered by Sundarban, the largest mangrove forest, which is found at the eastern end of the Polder 10/12. A number of khals, including Kumkhali Khal, Garuikhali Khal, Dhemshkhali Khal, Kathaltola Khal, Ganrai Khal, and Khoriya Khal, are present in the Polder region. All of these khals are linked by the Polder's peripheral canals.

The polder 13/14-2 is bounded by Kapatakkho River on the West and part of the South side, Koyra River on the North and part of the East side, and Sakbaria River on the part of East and South side. These auxiliary rivers and khals sustain a number of khals that are located within the polder. Shutir Khal, Koyra Khal, Khorlkathi Khal, etc. are a few of the khals. The polder's internal water courses make the flow and circulation inside the polder easier. At low tide, tidal water moves out through the nearby waterways and into the Bay of Bengal. In the wet season, these khals are utilized to drain the excess water out of the polder to prevent any water logging within the polder.

During the dry season, the khals are typically shut off by the sluice gates to prevent the introduction of saltwater.

Figure 2-18: Kapotakkho (locally known as Kobodak) river anear Polder 10/12

Figure 2-19: Kopotakkho river (Left) and Koyra Khal (Right) at Polder 13-14/2

2.5 FLOOD DAMAGE & INUNDATION ASSESSMENT BY GEOGRAPHIC INFORMATION SYSTEM (GIS)

There are various case studies have been done before. The elements that are needed for flood analysis are elevation, slope, drainage density, inundation depth, etc. According to Ali et al 2018, inundation is considered as the main parameter for flood assessment. Flood is a very common occurrence in coastal region. The polders in that areas are highly vulnerable to flood. Most of their embankments are not in good condition. According to Meraz et al, flood inundation analysis has been made through GIS and Flood frequency analysis. 14 polders' conditions are identified due to flood. The inundation rate has been analyzed based different flood levels. Normal distribution, Gumbel Method and EV-I method were used to predict the flood inundation level. The according to this predicted inundation level, the inundated area has been identified. The following table represents their inundation analysis of the study area.

Table 2-8: Percentage of Flood Inundation Rate (Source: Meraz et al 2022)

Polders	Inundation Depth (0 - 0.3)	Inundation Depth (0.3 - 0.9)	Inundation Depth (0.9 - 1.8)	Inundation Depth (1.8 - 3.6)
27/1	0.28	0.72	6.41	92.58
33	0.93	1.05	5.95	91.86
31-up	0.98	1.15	3.40	93.79
26	0.01	1.65	48.57	49.77
23	0.64	1.60	9.87	87.83
10/12	1.28	1.78	10.46	86.30
32	0.94	1.99	23.56	73.41
29	0.29	0.74	71.27	27.70
31-down	0.87	1.54	38.75	58.81
4	2.84	5.48	24.16	67.52
5	2.48	4.71	26.86	65.70
7/2	3.05	5.46	31.34	60.15
1	9.10	11.66	19.15	58.91
3	6.39	9.61	28.79	53.23
15	2.06	4.38	61.39	32.17
16	37.40	13.34	43.90	5.37

It has been observed that a catastrophic event happens around every ten years. Aila (2009) and super typhoon Amphan (2020), which have all inundated the coastal region and caused devastation for the local population, are like the 1998 flood in this regard. The polders represent a specific kind of false assumption of security. Every time a severe calamity strikes our coastal region, as has been documented previously (2004, 2007, 2009, and so on), polders crumble, causing flooding and agony for the populace (Meraz et al 2022).

2.6 FLOOD ASSESSMENT BY FUZZY LOGIC TOOL

Fuzzy is one of the best tools for uncertainties analysis. Uncertainty of outcome is a regular occurrence in domains connected to hydrology and water resources. Therefore, applying fuzzy inference systems to investigate the uncertainties is strongly advised. Bogardi (et al. 2003) stated that "hydrology entails uncertainty due to factors like climate, insufficient data, and imprecise modeling capabilities". The coast of Bangladesh is acknowledged as one of the hotspots for several coastal hazards, including coastal flooding, sea level rise, an increase in the frequency of tropical cyclones, etc. (Mullick et al 2019). According to (Mullick et al 2019), index based coastal vulnerability has been analyzed using fuzzy logic. The normalizing of highlighted components using three fuzzy membership functions—fuzzy-large, fuzzy-small, and fuzzy-linear—in geospatial analysis proved an effective method for handling the uncertainty of large-scale vulnerability research.

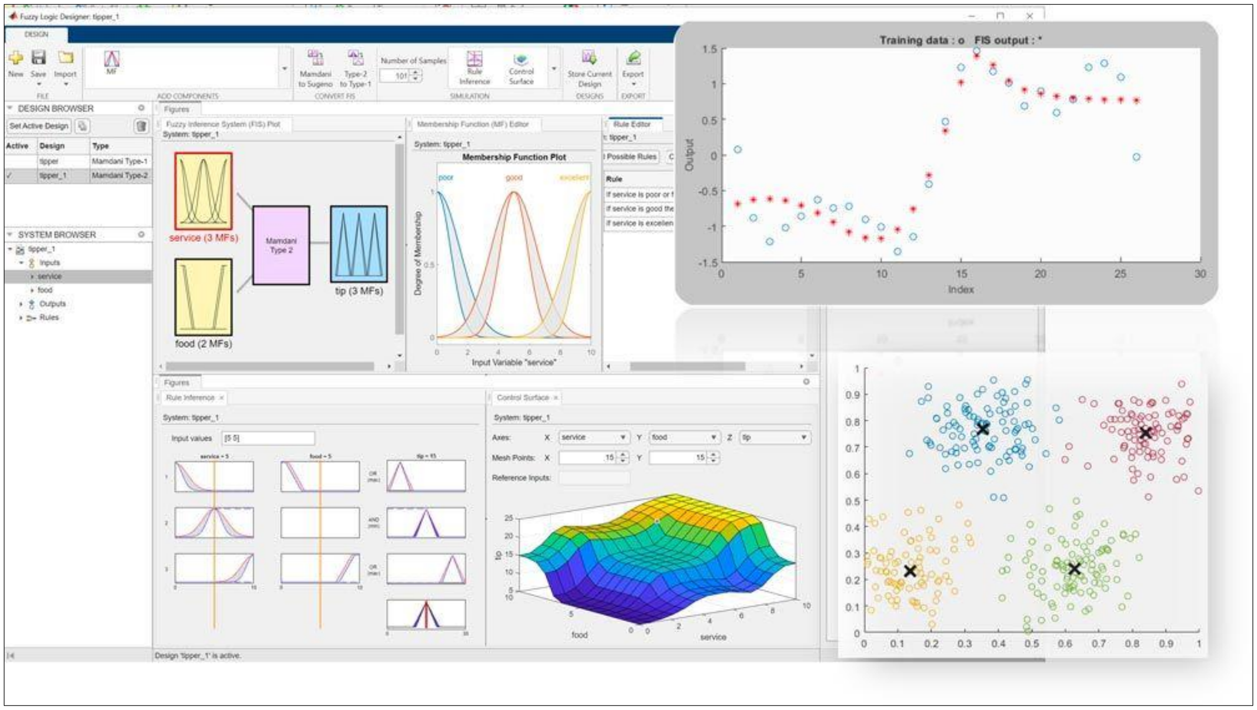


Figure 2-20: Fuzzy Logic Toolbox™ provides MATLAB functions, apps, and a Simulink block for analyzing, designing, and simulating fuzzy logic systems.

CHAPTER 3: METHODOLOGY

There are some steps have been developed to analyze the flood damage curve. Al these steps have been discussed in detail in this chapter. The steps and flow chart of the overall methodology are given below.

- Qualitative & Quantitative Survey
- Data Collection through Surveys
- Inundation Rate Analysis using Geographic Information System (GIS)
- Flood Damage Curve Analysis

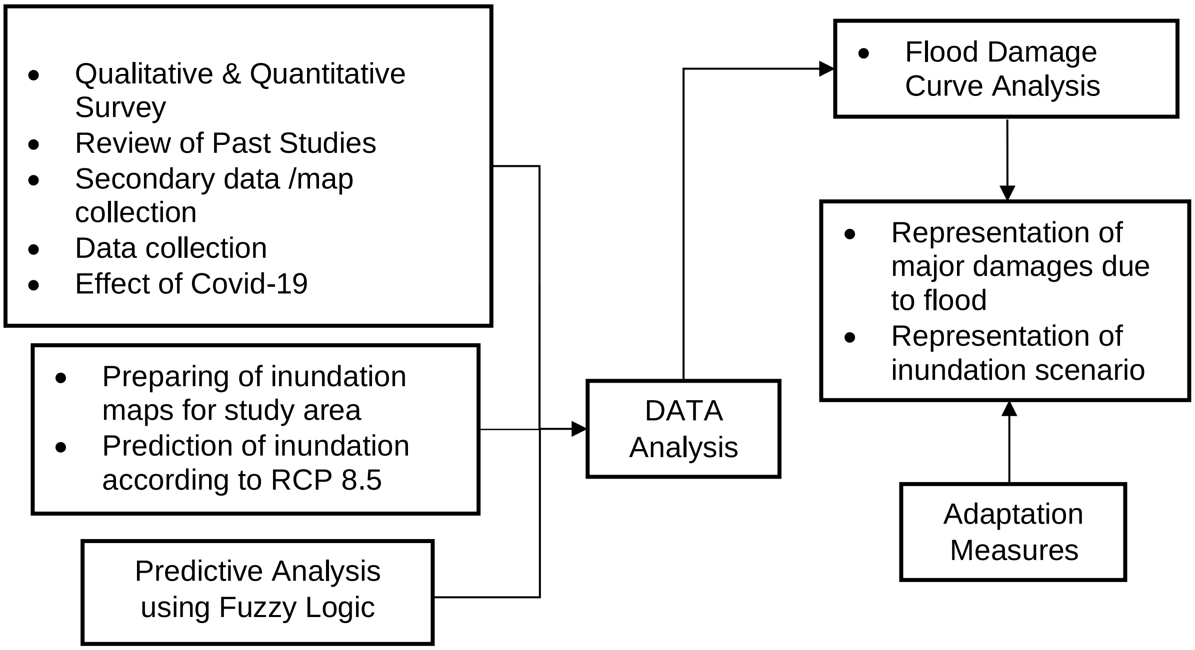


Figure 3-1: Flow Diagram of Methodology

3.1 QUANTITATIVE & QUALITATIVE SURVEY

As mentioned earlier the establishment of an adequate flood loss estimation model involves many issues due to the nature of the flood damages. Some of the most important issues in flood loss estimation are obtaining detailed flood parameters such as flow velocity, depth, and duration at any given location, proper classification of damage categories, and establishment of relationships between flood parameters and damage for different damage categories. The relationship between flood parameters and flood damage can be represented by stage–damage function, which is developed based on historical flood damage information, questionnaire survey, laboratory experiences, etc. Due to the multi-disciplinary nature of the study, the tools and techniques used in this study would vary differentially. The study has been made use of both qualitative and quantitative techniques. The quantitative part will be anchored in survey method following sampling techniques. A questionnaire will develop based on literature review, analysis of the project proposal and logical framework and consultation with study team. The questionnaire will include structured questions, guiding notes and code sheets to collect quantitative data from the randomly selected respondents.

Qualitative method has been applied for the purpose of validation and cross check and reinforcing quantitative data. Checklists will develop in close consultation with Anwar Group of Industries team to apply different qualitative techniques, i.e. Focus Group Discussion (FGD) and Key Informant Interview (KII). All the required tools and techniques were developed at the earlier stage of the assignment.

3.1.1. Focus Group Survey (FGD):

A focus group discussion (FGD) is a qualitative research strategy for gathering data in which a pre-selected group of participants engages in in-depth discussion about a particular topic or issue under the guidance of a trained, external moderator. The method is predicated on the idea that group processes engaged in a FGD assist in identifying and clarifying shared knowledge among groups and communities, which would otherwise be challenging to ascertain through a series of individual interviews. During these 'open' discussion rounds, an FDG enables the researcher to elicit both the participants' common story and their disparities in terms of experiences, attitudes, and worldviews.

Figure 3-2: Discussions with local fishermen on the Koyra Polder 13-14/2 near Sundarban

Figure 3-3: Discussions with local salesmen on the Koyra Polder 13-14/2 near Sundarban

3.1.2. Knowledge Informant Information (KII):

Key informant interviews are qualitative in-depth discussions with individuals who are knowledgeable about the local community. Key informant interviews serve the objective of gathering data from a wide range of persons who have firsthand knowledge of the community, such as community leaders, professionals, or residents. These local specialists can shed light on the nature of problems and make recommendations for remedies thanks to their specific experience and understanding.

There are two common techniques of conducting key informant interview:
• Telephone Interviews
• Face-to-Face Interviews

In this case study, face to face interviews has been conducted to complete the survey. Site visit has been conducted to understand the sanitation scenario and waste disposal of the proposed area. There are some tools which is used at the time of conducting survey. The tools are checklists, map layout, GPS/GNS (KOBO Toolbox)

Figure 3-4: Discussions with local van drivers on the Koyra Polder 13-14/2 near Sundarban

Figure 3-5: Discussions with local farmers on the Koyra Polder 13-14/2 near Sundarban

3.1.3. KOBO Toolbox Survey & Techniques:

KOBO Toolbox can be called as Open Data Kit. Open Data Kit is a suite of tools that allows data collection using mobile devices and data submission to an online server, even without an Internet connection or mobile carrier service at the time of data collection. One can collect data remotely without an Internet connection or cell carrier access. Gather text, numeric data, media and more with a mobile device. Then, host collected data online using Google's powerful hosting platform, Google App Engine, and visualize your data as a map using Google Fusion Tables and Google Earth.

The developed tools and techniques have grounded in the study area for pre-testing. Focus group discussion and household survey have been conducted by the study team to receive the response of the respondents. Then the questionnaire and checklists were cross-checked considering the field test outputs. Finally, a sharing meeting with Anwar Group officials were conducted to finalize all the tools and techniques developed for this baseline situation analysis. There are multiple Advantages of using KOBO TOOLBOX in collecting field data.

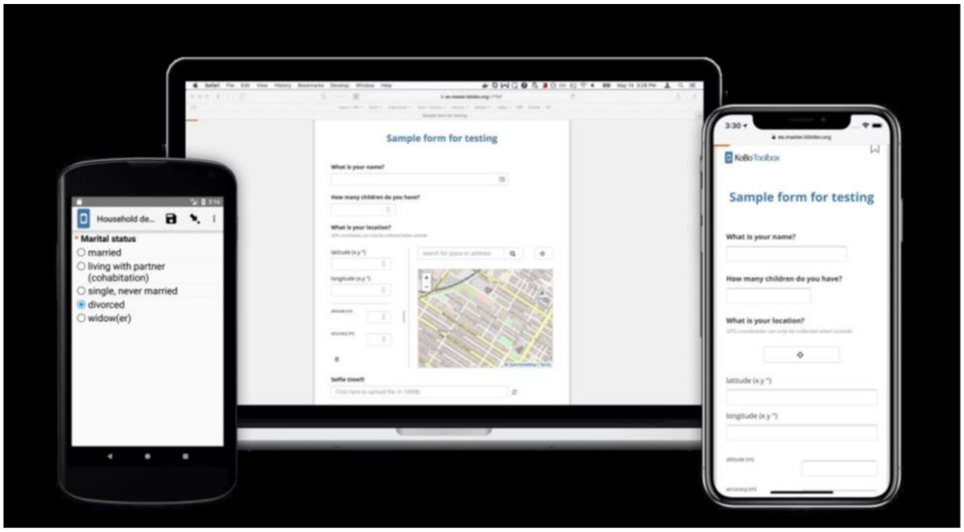


Figure 3-6: Data Collection by KOBO Toolbox

The advantages are

- Better Implementation
- Better Analysis
- Better Reporting
- Increased Transparency
- Improved Accountability
- Increased Timeliness
- More time can be spent analyzing the data and making useful information products because less time is spent on collecting data.

Figure 3-7: Data Collection by KOBO Toolbox at polder househols

3.2 DATA COLLECTION

A thorough research project requires adequate data to be conducted. To undertake study on urban drainage, information on the following topics is generally required. Technical information on a variety of topics, such as:

- Annual average flood level
- Meteorological data
- Groundwater condition
- Agricultural information
- Socio-economic information

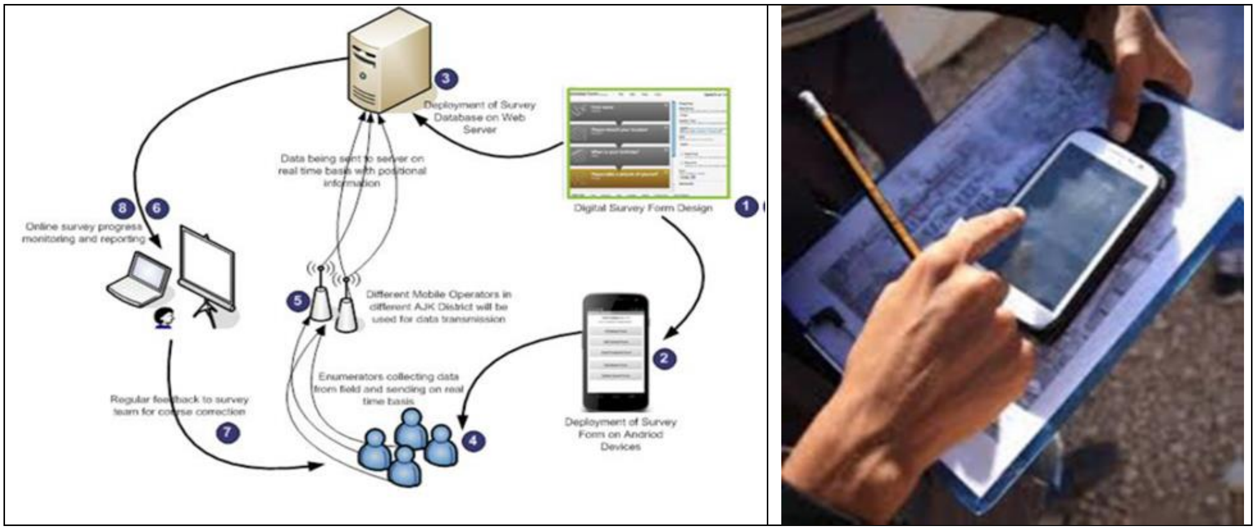


Figure 3-8: Data Collection by KOBO Toolbox and database maintanenece

3.2.1. Primary Data

Table 3-1: Collected Data from Primary Field Survey

General Social Data	Total Asset Values	Damages to Disasters
• Village Name • Upazilla Name • Union Name • District Name • Name of the Respondent • Age • Income Source • Total Monthly Income	• Lands • Ponds • Household Assets • Poultry • Cattle • Other	• Flood Duration • Flood Depth • Household Damage • Cost of Household Repair & Maintenance • Total Crop Damage • Total Pond Area Damage • Total Fish Damage • Total Cattle Damage • Cost of Drinking Pure Water

Using the KOBO Toolbox, I gathered data on the flood damage resulting from several household-level surveys that were triggered by different cyclonic episodes in these locations. The information will then be utilized to create various flood damage curves that illustrate the extent of these polders' residents' losses and damages because of different cyclonic storms during the past 20 years. Parallel to this, FGD was used to document the community-based adaptation strategies used along the boundary of the chosen polders, talking to locals about the harms and how they're using their knowledge to make their own judgments. As well as concentrations have been given on the community involvement of the residents of these polders in the development, implementation, and monitoring of measures to control the risks and difficulties that people encounter because of climate change. For inundation analysis, Digital Elevation Model has been collected from SRTM and processed. The polder-wise rate of inundation was determined according to several depth.

3.2.2. Secondary Data

To evaluate the current state of the study, relevant historical study reports and secondary data have been gathered and examined. The table summarizes the secondary data that was gathered for the study.

Table 3-2: Collected Data from Secondary Source

Data	Source
Topography (DEM)	USGS
Meteorological Data (Rainfall 1953-2015)	BMD
Ground Water Table (GWT)	DPHE
Surface Water Level	BWDB
Agricultural Information	DAE-Satkhira & Khulna
Socio-Economic Data	KMC Survey Report
River Water Level [1987-2012]	BWDB
Average Flood Level	WARPO 2016
Population Density	BBS 2011

3.3 INUNDATION RATE ANALYSIS THROUGH GIS

3.3.1. Inundation Analysis based on Previous Study

In case of inundation analysis, DEM was first downloaded and processed. Then according to several depth from previous case study, rate of inundation has been identified. An average of maximum and minimum flood depth was taken under consideration from secondary sources for inundation analysis. The overall flow diagram of inundation analysis has been represented in the following figure.

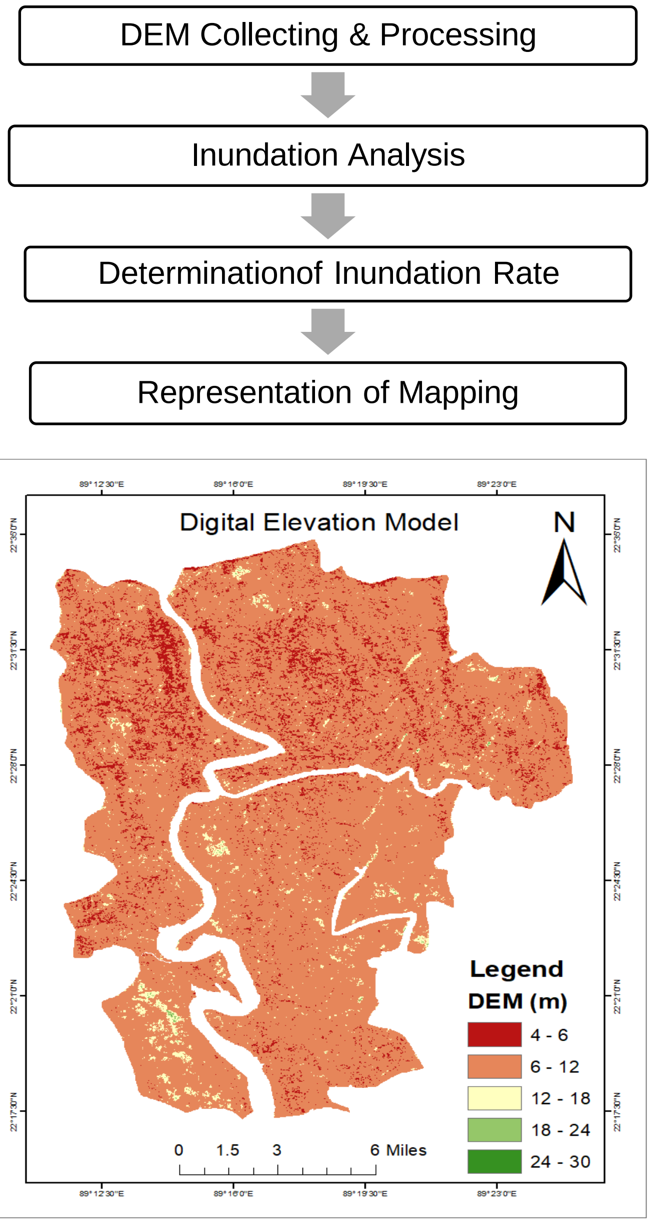


Figure 3-9: Flow Diagram of Inundation Rate Analysis & output of Four Polders

3.3.2. Predictive Inundation Analysis according to RCP 8.5

After identifying the inundation rate, a prediction has been made based on RCP 8.5 which has been described by Intergovernmental Panel on Climate Change (IPCC). In the fifth assessment report of IPCC, a projection has been made on global mean sea level (GMSL) rise. A prediction has been made that about 0.52 – 1 m GMSL will rise within 2100. In this study, we have taken under consideration from 2030 to 2100 having 10-year interval. The following table is representing the predicted inundation depth based on RCP 8.5.

Table 3-3: Year-wise Predicted Depth

Year	Predicted GMSL
2030	0.27
2040	0.273
2050	0.30
2060	0.47
2070	0.52
2080	0.62
2090	0.77
2100	1.00

3.4 FLOOD DAMAGE CURVE ANALYSIS

Stage–damage functions are important components in flood damage estimation model. Normally, stage damage function curves were developed for estimating flood losses. Stage–damage curves are the first essential stage in flood loss assessment. They are combined with field surveys of property at risk and with hydrological information (probability and extent of flooding, velocity, and the like) to give predictions of event damages from which average annual damages can be calculated. The methodology of synthetic approach was first suggested. Synthetic stage–damage curves are based on hypothetical analysis, where it doesn't depend on information from an actual flood event. A detailed procedure of synthetic stage–damage curves for several land use types had been produced by Penning- Rowsell and Chatterton. The procedure had been used to assess flood damage to both residential and commercial properties in the United Kingdom. It also provides an essential input into computer programs that are designed to evaluate the benefits of flood prevention measures.

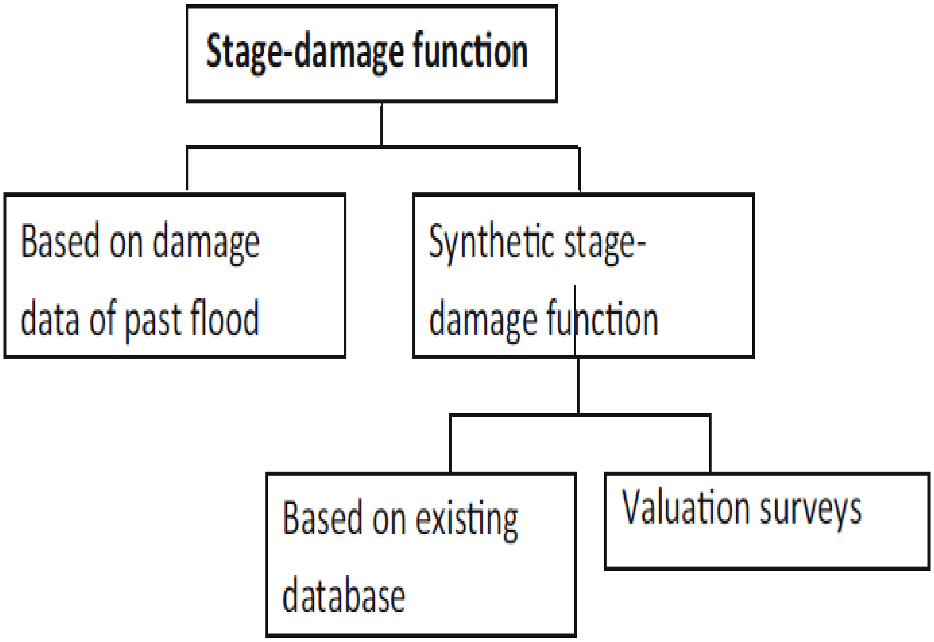
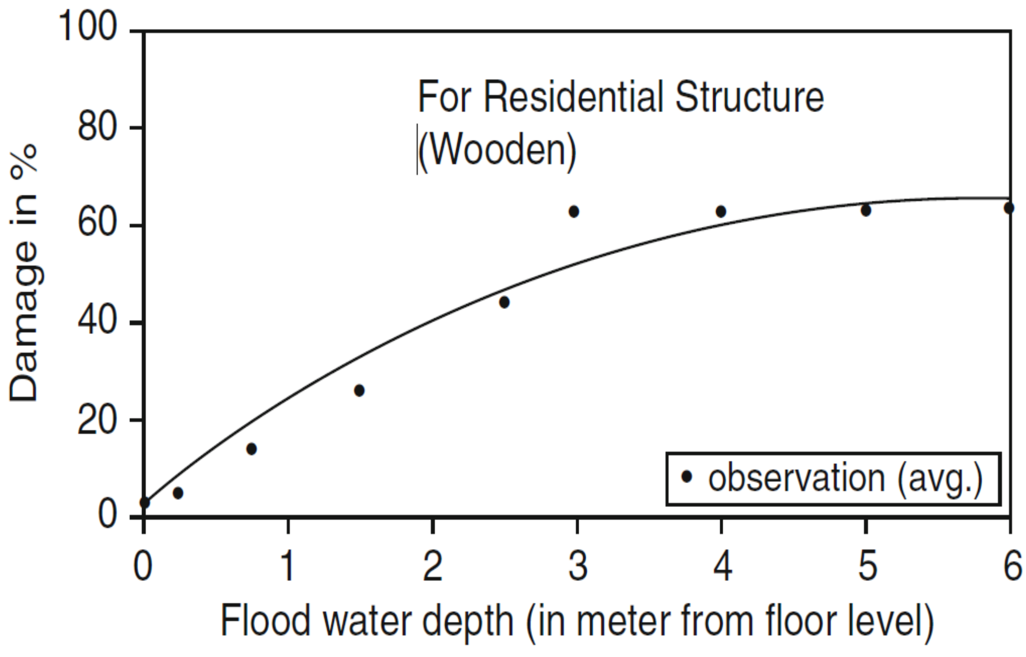


Figure 3-10: Types of Stage-Damage function



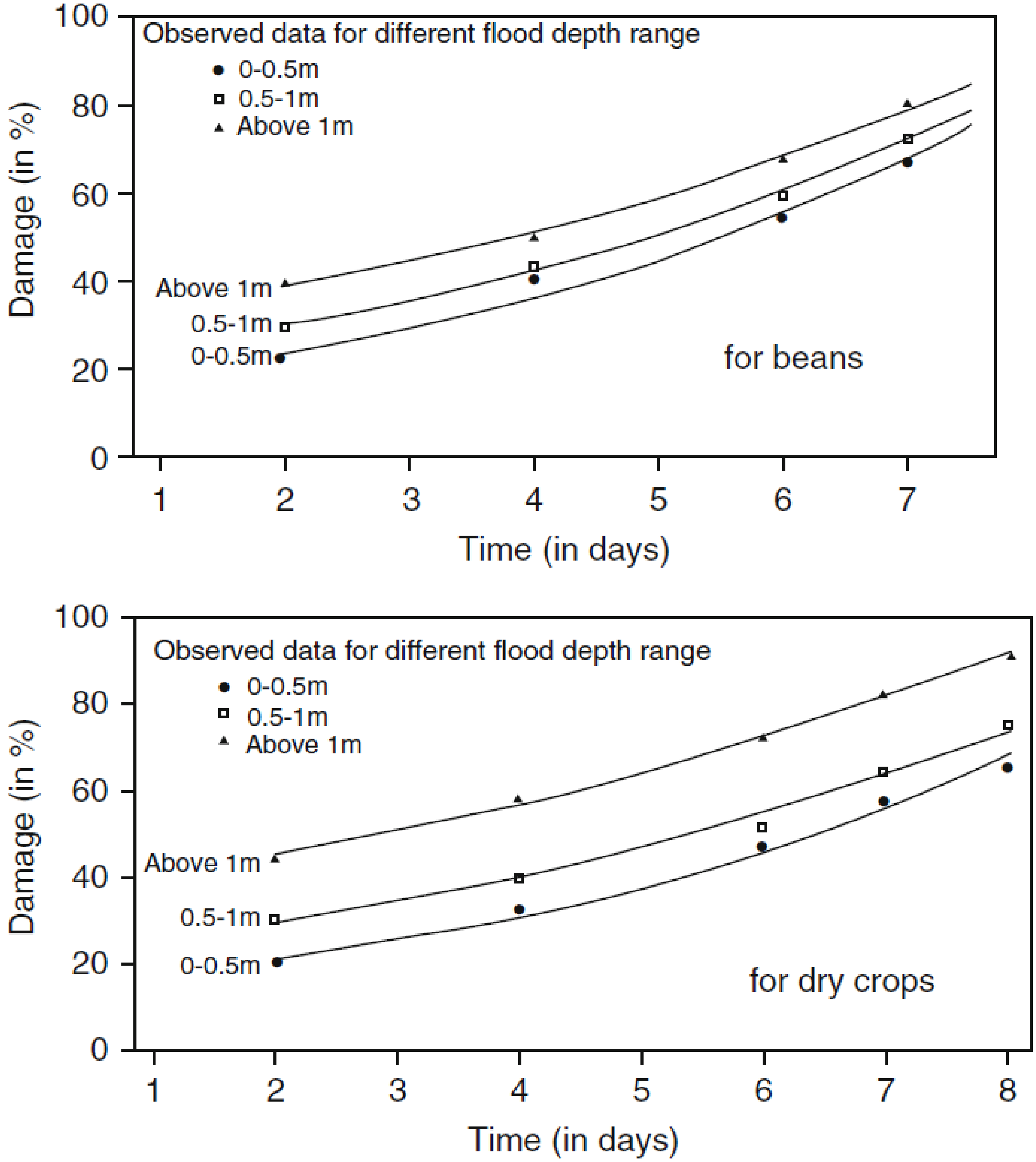


Figure 3-11: Agricultural flood stage-damage function for beans and dry crops category

Stage–damage curves may be developed using two types of approaches: either depth–damage or depth–percent damage-based approaches. In depth–damage approach, stage–damage relationships are determined directly from prototype data, and normally, the curves are developed separately for many types of structures. A sample of curves has been shown in the following figure.The first step in creating a stage-damage curve was to gather damage information from actual flood events. The creation of a questionnaire survey should include details about the various building kinds, room descriptions, household belongings, position (either in the basement, first floor, or second floor), quality, and age of the building and its components. The questionnaire survey can also ask about the height of each item above the floor as well as more general questions about the household or business revenue, the number of occupants in the homes or buildings, and how frequently flooding occurred there.

3.5 COVID-19 AND FLOOD AFFECTED PEOPLE

In Bangladesh, Covid-19 took a toll on human lives in the year 2020. On March 2020, first case of covid came out in the country and the number of infections increased rapidly, so did the number of deaths. The whole country went under strict lockdown. People could not go out for their basic needs. Government and non-government institutions announced work from home, schools, colleges were shut down. People could not go out for even grocery shopping. As a result, the worst sufferers were the daily labourers. Bangladesh has been devasted by such covid surge along with one of the worst and longest-lasting floods in the recent years. Around four million people were affected and a million homes were inundated. Such extreme flooding had left people with homes, schools, temples, and mosques under water. The socio-economic impact of COVID-19 worsened at that time. It pushed people into poverty. A majority of the population had become unemployed due to the pandemic, with vulnerable groups, such as daily wage workers, particularly impacted. Most of the agricultural lands went under water, and most of the crops had been damaged. People were not able to meet basic needs such as accessing food and drinking water due to income loss. We took a survey among the flood affected people. Most of the daily wage workers had the same situation. They hardly had any crops or goods to sell. Again, there was no customer due to strict lockdown.

3.6. PREDICTIVE ANALYSIS BY FUZZY LOGIC

Fuzzy is one of the best tools for uncertainty analysis. This is a computer-based programming language. One can develop it either in MATLAB or Python. MATLAB has been used in this case study. An overall knowledge, concepts and methodology of fuzzy model have been described in chapter 5.

CHAPTER 4: DATA ANALYSIS & RESULTS

4.1 FLOOD DAMAGE ANALYSIS

In this study, the rate of flood damage has been analyzed based on different disaster related events such as SIDR, Amphan, Aila, Bulbul, heavy rainfall, and tidal effect. Previously, it has been said that a survey has been conducted to determine the damage rate. There are some factors that have been taken under consideration to visualize the flood damage curve. The factors are household damages, crop damages, fish damages, cattle or poultry damages and other household damages. The polder wise damage rate due to different disasters as well as their damage comparison are represented in the following figures.

Table 4-1: Damage Percentage of the Study Area due to Sidr (2007)

Polder	Average Damages of House (%)	Average Crop Damage (%)	Average Fish Damage (%)	Average Damage of Cattle or Poultry (%)	Average Damage of other Household Asset (%)
7/1	40	69	63	54	44
7/2	24	3	9	9	6
10/12	20	15	12	9	45
13/14	16	13	16	28	4

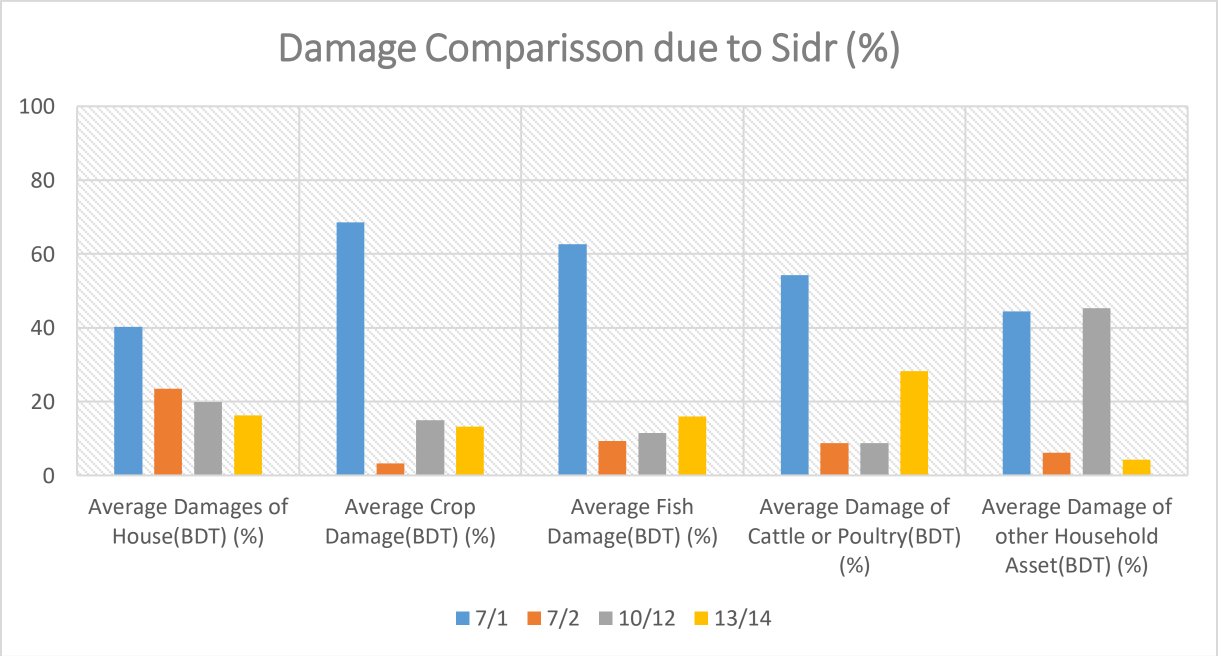


Figure 4-1: Polder wise Flood Damage Comparison due to SIDR

Table 4-2: Damage Percentage of the Study Area due to Aila (2009)

Polder	Average Damages of House (%)	Average Crop Damage (%)	Average Fish Damage (%)	Average Damage of Cattle or Poultry (%)	Average Damage of other Household Asset (%)
7/1	42	65	44	40	57
7/2	22	3	15	11	15
10/12	20	20	13	12	17
13/14	15	12	27	37	10

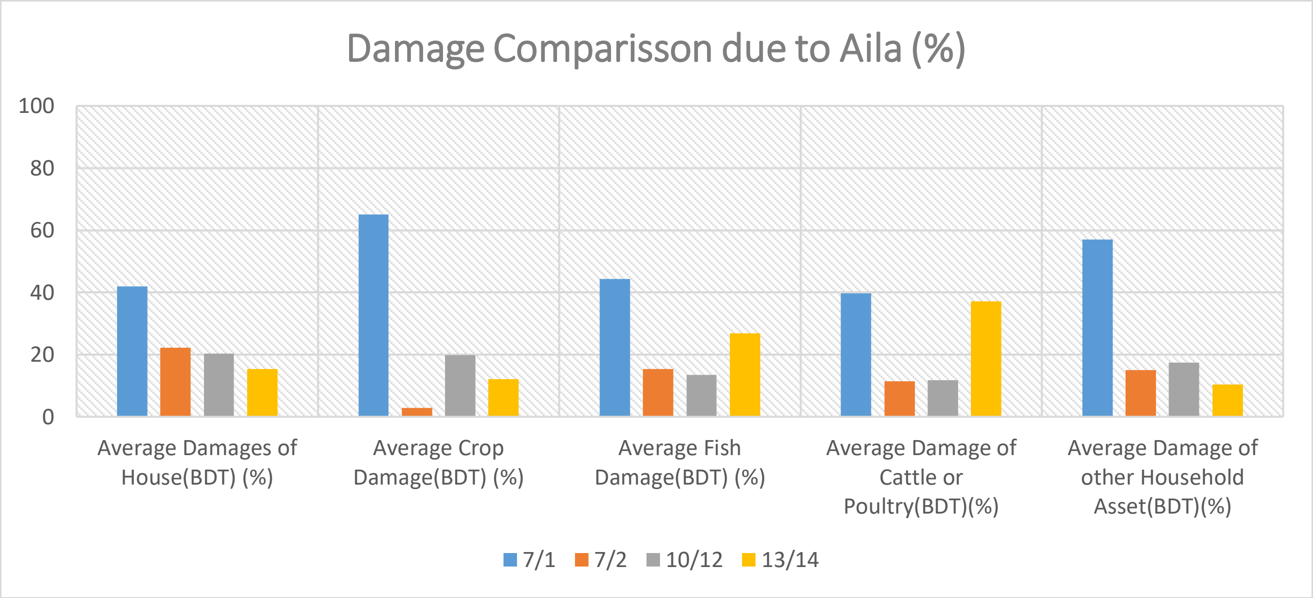


Figure 4-2: Polder wise Flood Damage Comparison due to AILA

Table 4-3: Damage Percentage of the Study Area due to Heavy Rainfall (2010)

Polder	Average Damages of House (%)	Average Crop Damage (%)	Average Fish Damage (%)	Average Damage of Cattle or Poultry (%)	Average Damage of other Household Asset (%)
7/1	26	42	40	20	15
7/2	36	26	29	58	15
10/12	37	30	26	22	69
13/14	1	2	4	0	0

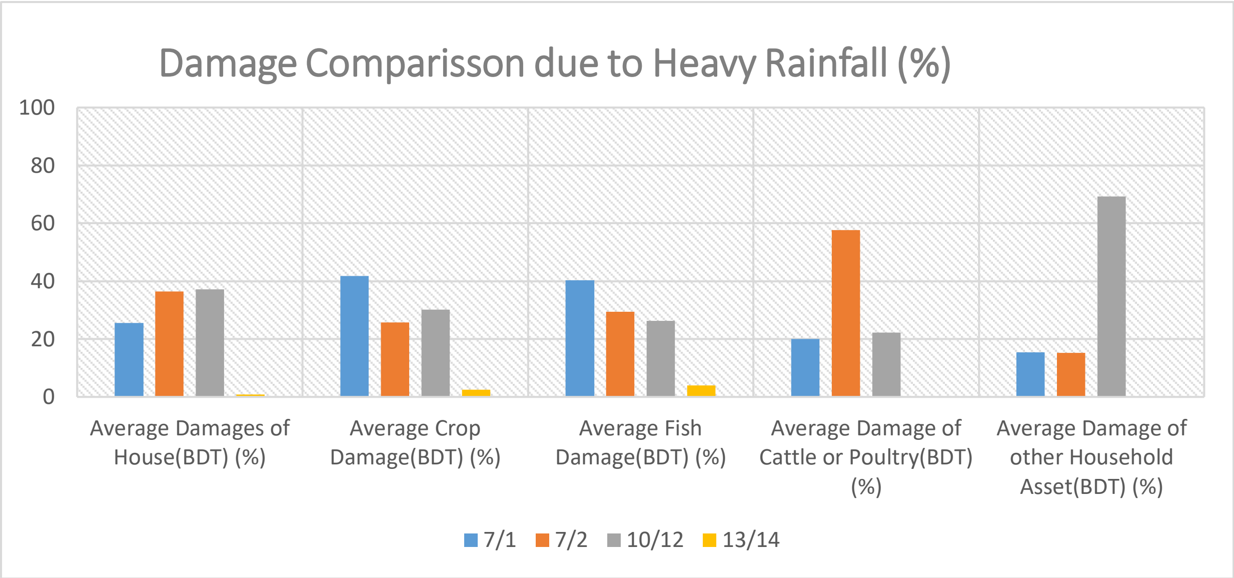


Figure 4-3: Polder wise Flood Damage Comparison due to Heavy Rainfall

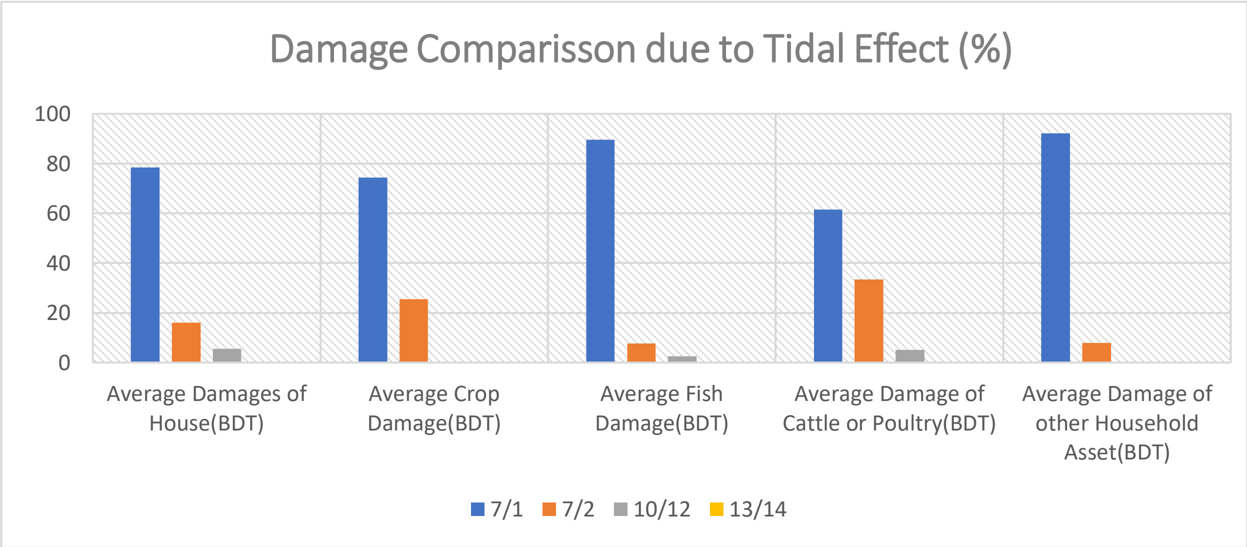


Figure 4-4: Polder wise Flood Damage Comparison due to Tidal Effect (2012)

Table 4-4: Damage Percentage of the Study Area due to Tidal Effect (2012)

Polder	Average Damages of House (%)	Average Crop Damage (%)	Average Fish Damage (%)	Average Damage of Cattle or Poultry (%)	Average Damage of other Household Asset (%)
7/1	79	74	90	61	92
7/2	16	26	8	33	8
10/12	5	0	3	5	0
13/14	0	0	0	0	0

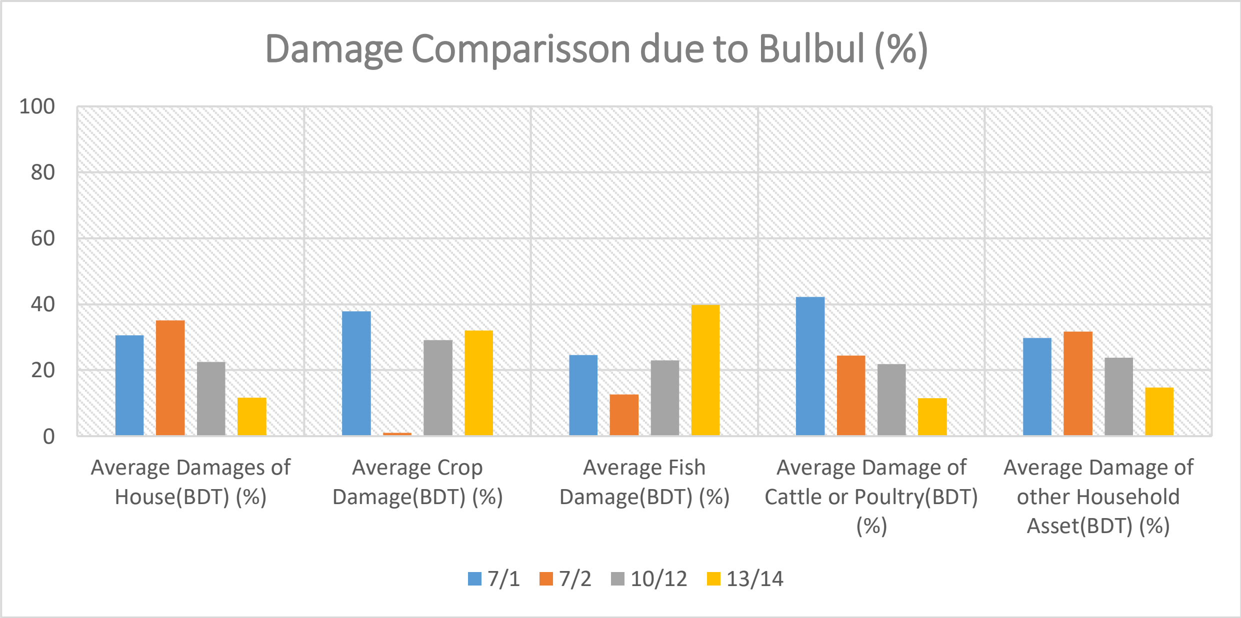


Figure 4-5: Polder wise Flood Damage Comparison due to Tidal Effect (2012)

Table 4-5: Damage Percentage of the Study Area due to Bulbul (2019)

Polder	Average Damages of House (%)	Average Crop Damage (%)	Average Fish Damage (%)	Average Damage of Cattle or Poultry (%)	Average Damage of other Household Asset (%)
7/1	31	38	25	42	30
7/2	35	1	13	24	32
10/12	23	29	23	22	24
13/14	12	32	40	12	15

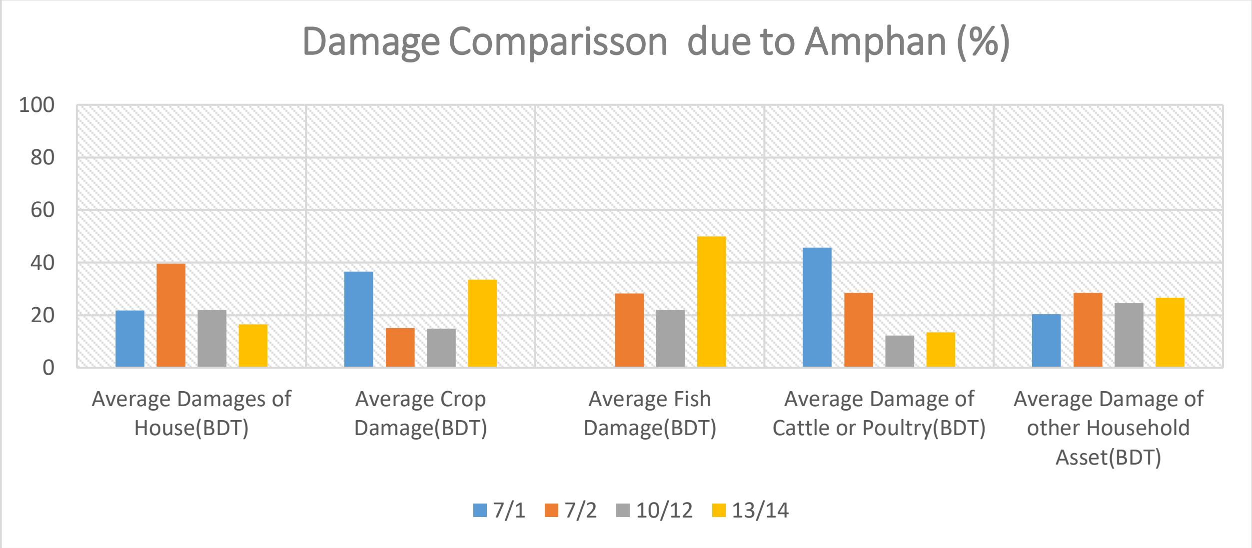


Figure 4-6: Polder wise Flood Damage Comparison due to Amphan

Table 4-6: Damage Percentage of the Study Area due to Amphan

Polder	Average Damages of House (%)	Average Crop Damage (%)	Average Fish Damage (%)	Average Damage of Cattle or Poultry (%)	Average Damage of other Household Asset (%)
7/1	22	37	0	46	20
7/2	40	15	28	29	28
10/12	22	15	22	12	25
13/14	17	33	50	13	27

From the damage rate analysis, it can be seen that 7/1 polder is the most vulnerable and affected among other polders. On the other hand, 13/14 polder is the less vulnerable and affected than other polders. The average total damage rate is almost 6,70,662 BDT in 7/1 polder from 2007 to 2020. The damage rate of 13/14 polder is nearly 2,92,950 BDT within this 14 years considering different disasters.

4.2 FLOOD DAMAGE CURVE ANALYSIS

After the determination of flood damage rate, various curve has been fitted to visualize the damage trend. The flood damage curve has been visualized according to four polders separately. The effect of different disasters can also be known from the flood damage curve.

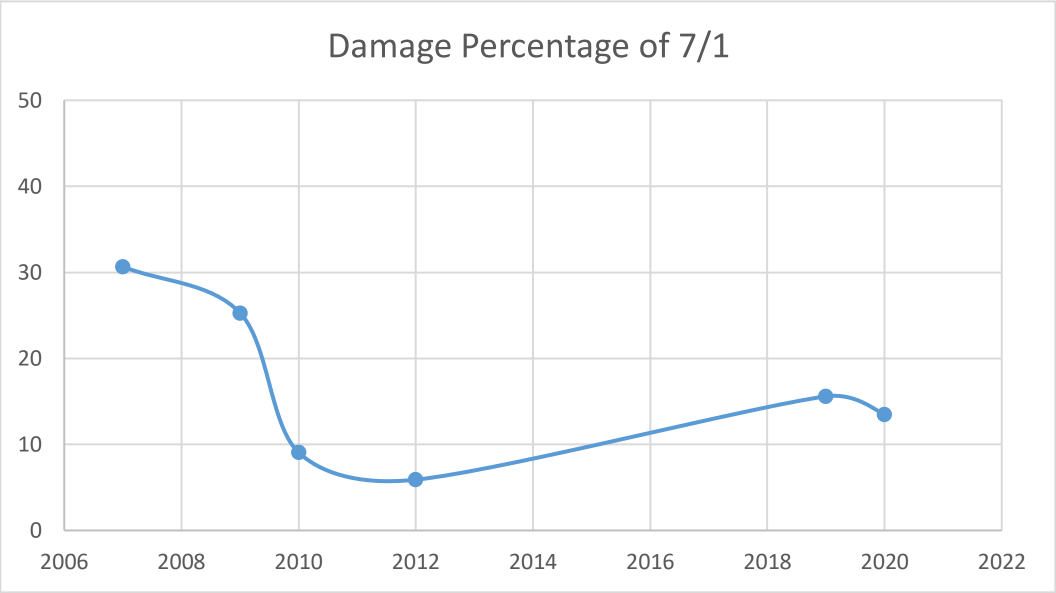


Figure 4-7: Flood Damage Curve of Polder 7/1

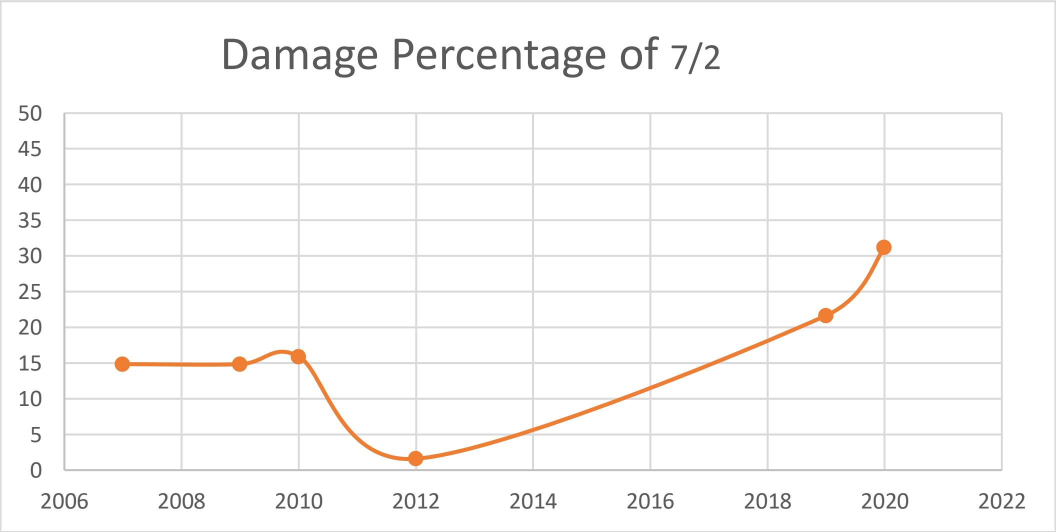


Figure 4-8: Flood Damage Curve of Polder 7/2

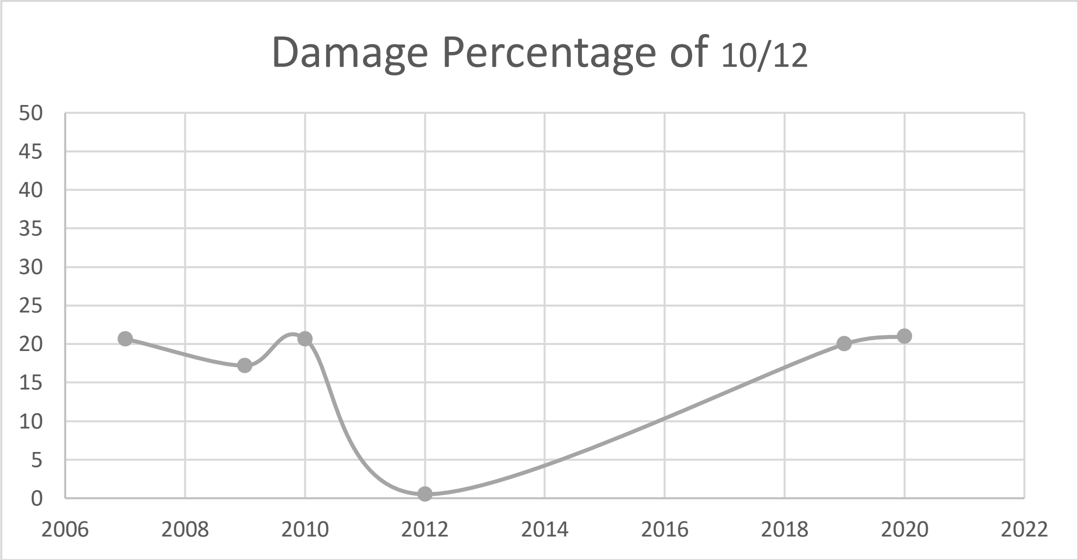


Figure 4-9: Flood Damage Curve of Polder 10/12

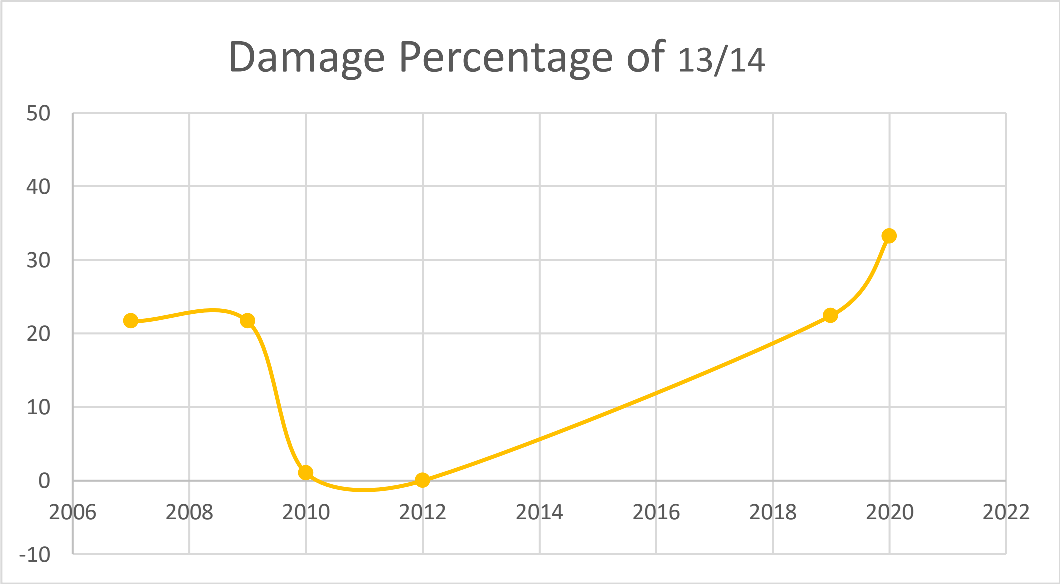


Figure 4-10: Flood Damage Curve of Polder 13/14

By visualizing the curves, it can be said that most of the polders are badly affected by SIDR and Amphan which were held in 2007 and 2020 simultaneously. Nearly 30% damage has been created by Sidr in polder 7/1 in 2007. This is the highest damage rate in case of polder 7/1. The next damage is created by Aila in 2009. The damage rate is almost 25%. The rest of the polders are highly affected by Amphan in 2020. The damage rate varies from 20% – 30% based on different polders.

4.3 INUNDATION RATE ANALYSIS

The inundation rate has been analyzed from digital elevation model (DEM). The rate has been analyzed considering several inundation level. According to WARPO 2016 report, the maximum flood level varies from 3 to 4 m in the region of the study area. Almost 95% of the study area will be inundated within this range of flood level if there is no flood protection structures. Therefore, we have taken inundation level from 6 to 8 m under consideration based on previous study and other secondary sources. The inundation rate has been determined for all the polders separately. It has been visualized by ArcGIS. It has been seen that if the inundation depth ranges from 6 to 8 m, the inundation rate varies from 5-50% according to the location and topography of the polders.

4.4 PREDICTED FUTURE INUNDATION

A predictive analysis has been made based on RCP 8.5 which is given by IPCC. Previously told that from 6 to 8 m inundation level has been taken for analysis. Therefore, the predicted yearly sea level rise is added to the considered inundation level in this case study. The predictive inundation rate has been determined from 2030 to 2100 for all the polders separately. The following figures are represented the predicted result.

- **Polder 7/1**

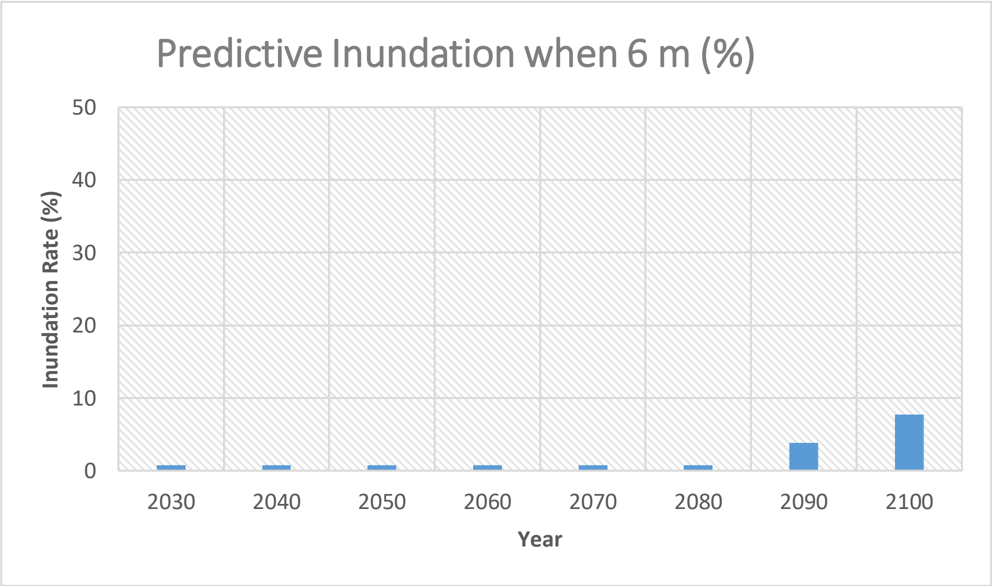


Figure 4-11: Yearly Inundation Rate Comparison at 6 m Inundation Level

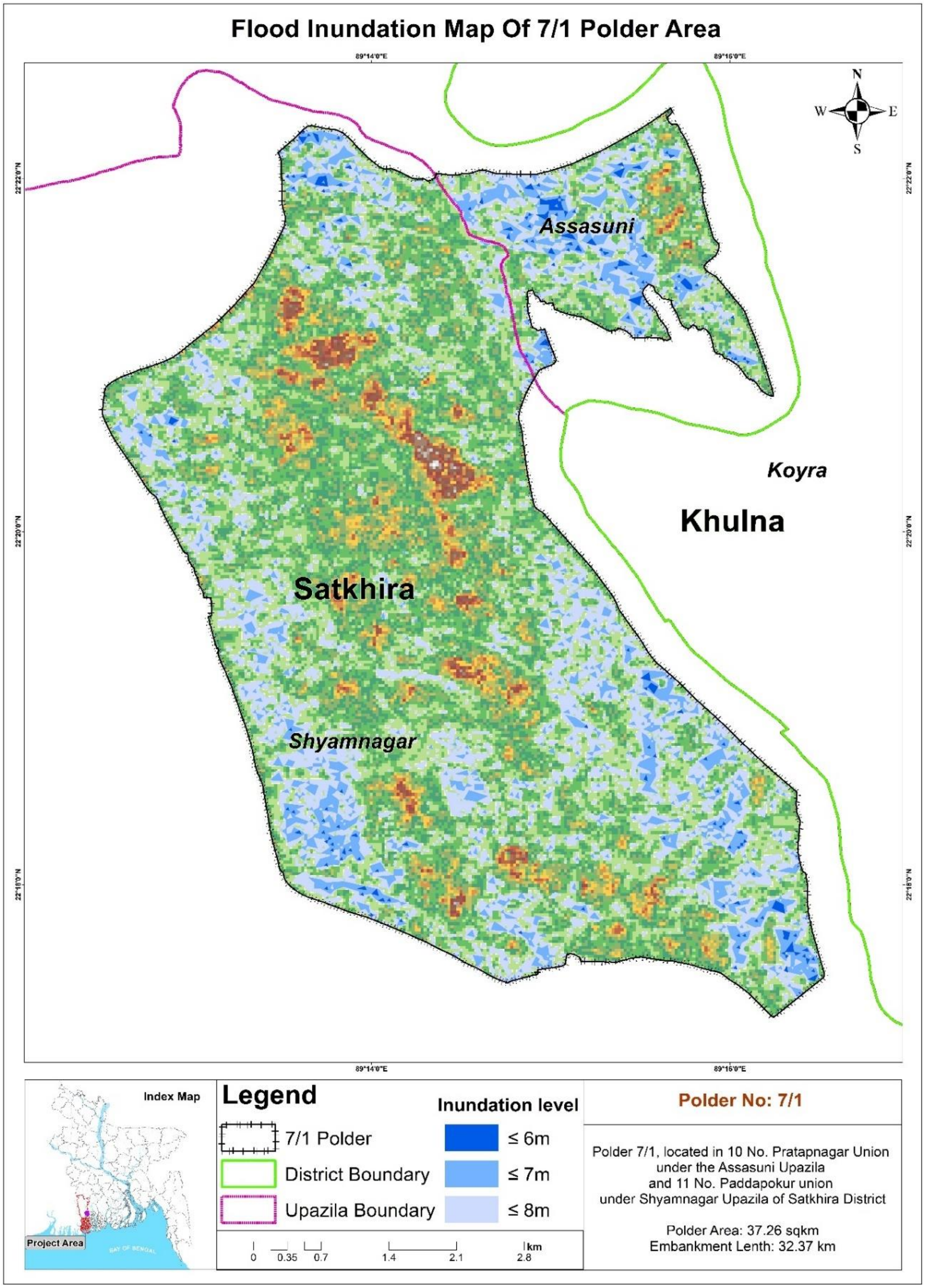


Figure 4-12: Inundation map of Polder 7/1

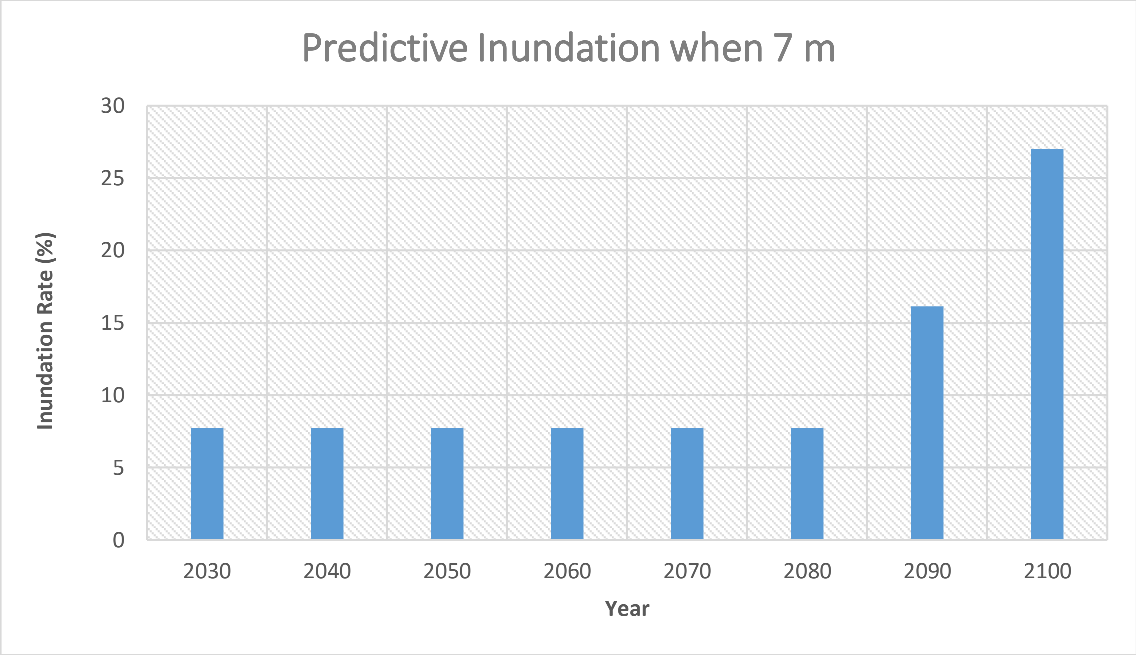


Figure 4-13: Yearly Inundation Rate Comparison at 7 m Inundation Level

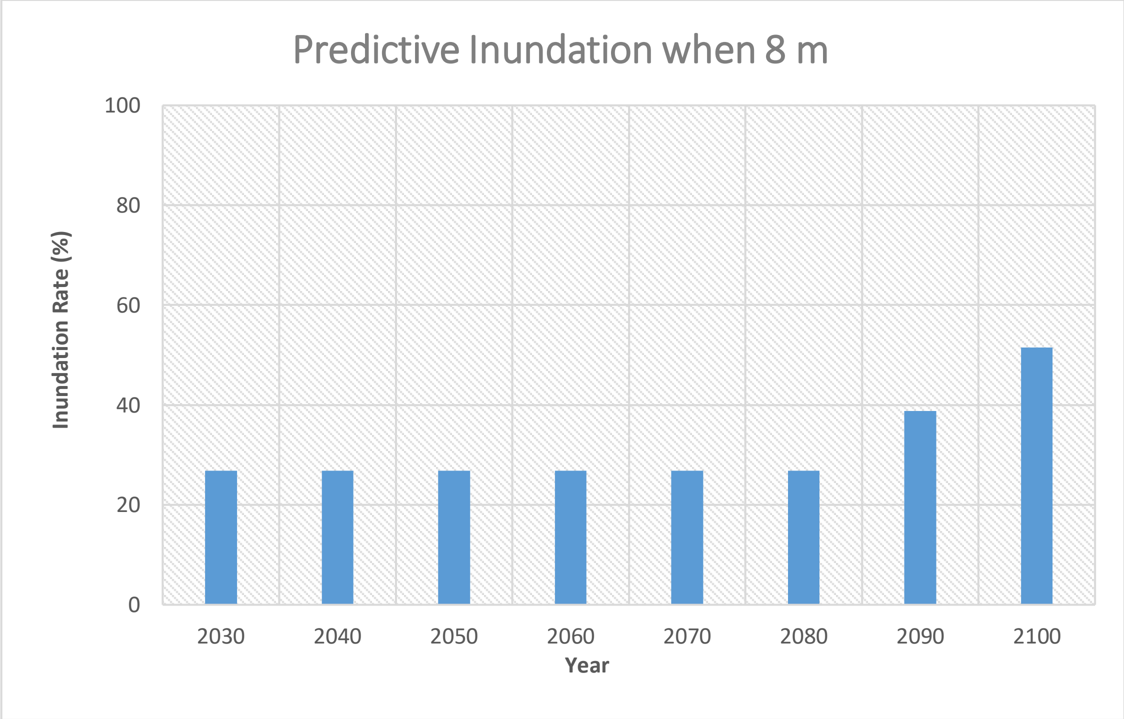


Figure 4-14: Yearly Inundation Rate Comparison at 8 m Inundation Level

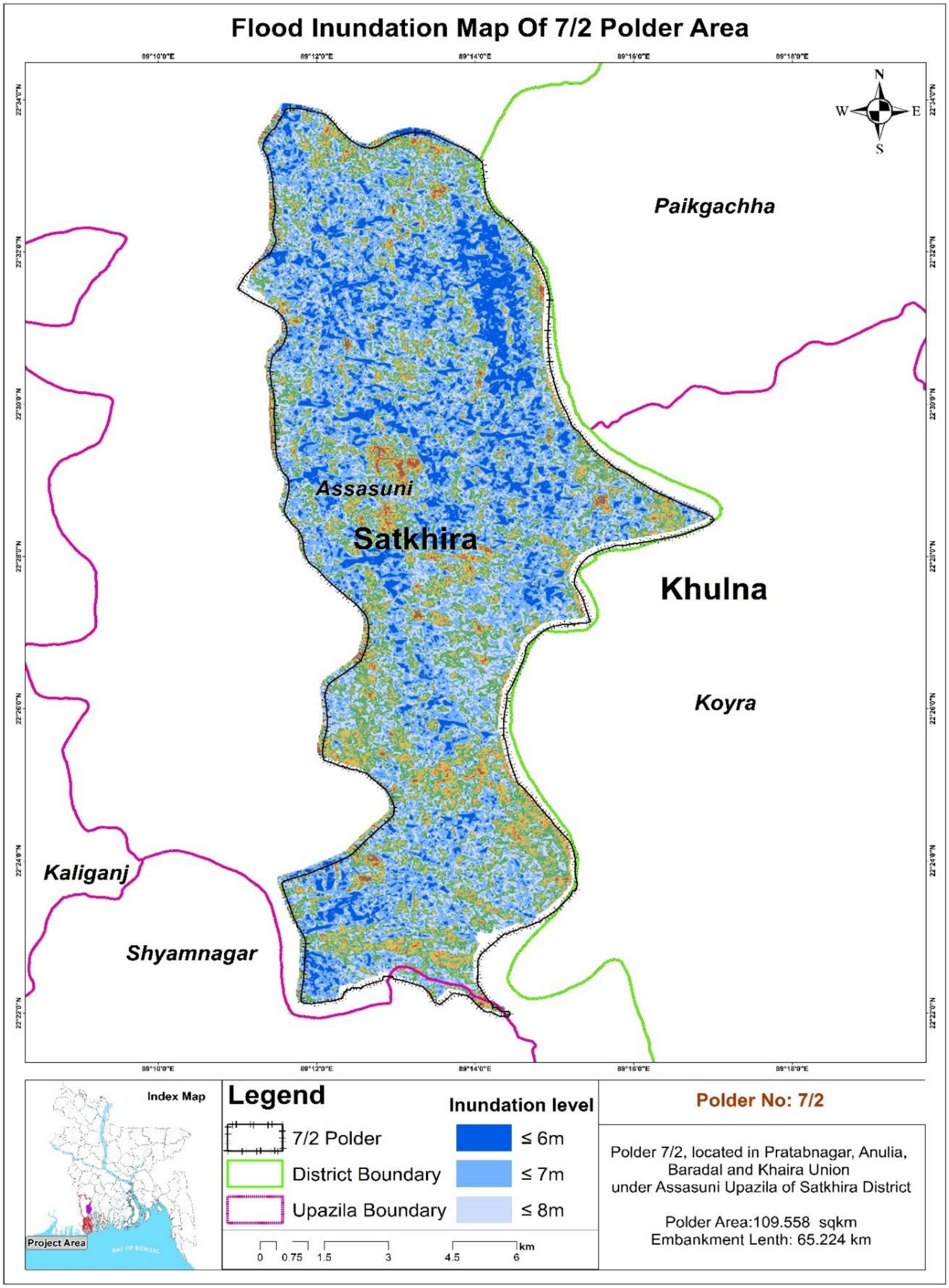


Figure 4-15: Inundation map of Polder 7/2

- **Polder 7/2**

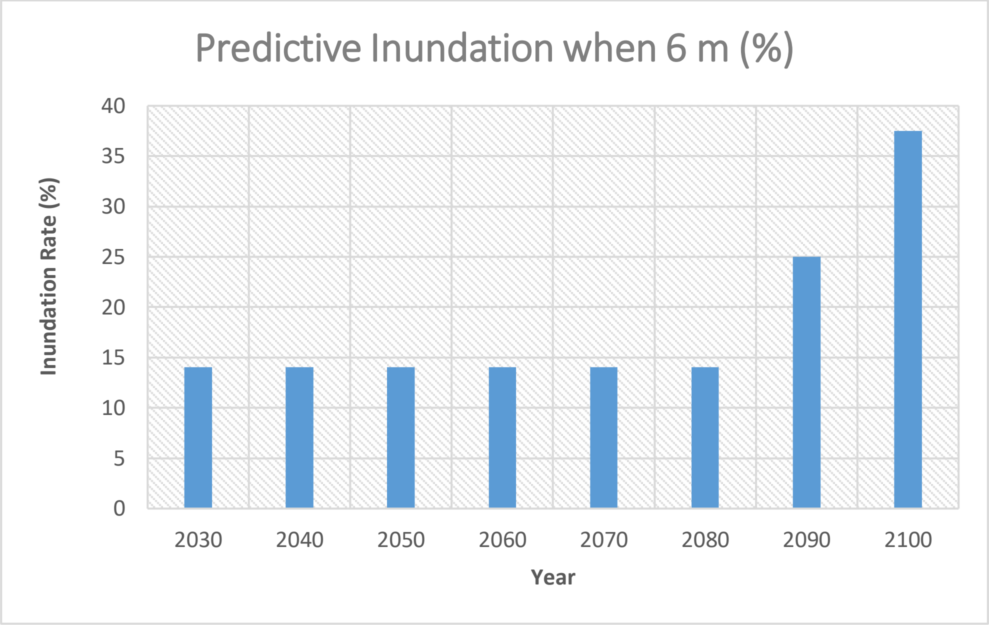


Figure 4-16: Yearly Inundation Rate Comparison at 6 m Inundation Level of Polder 7/2

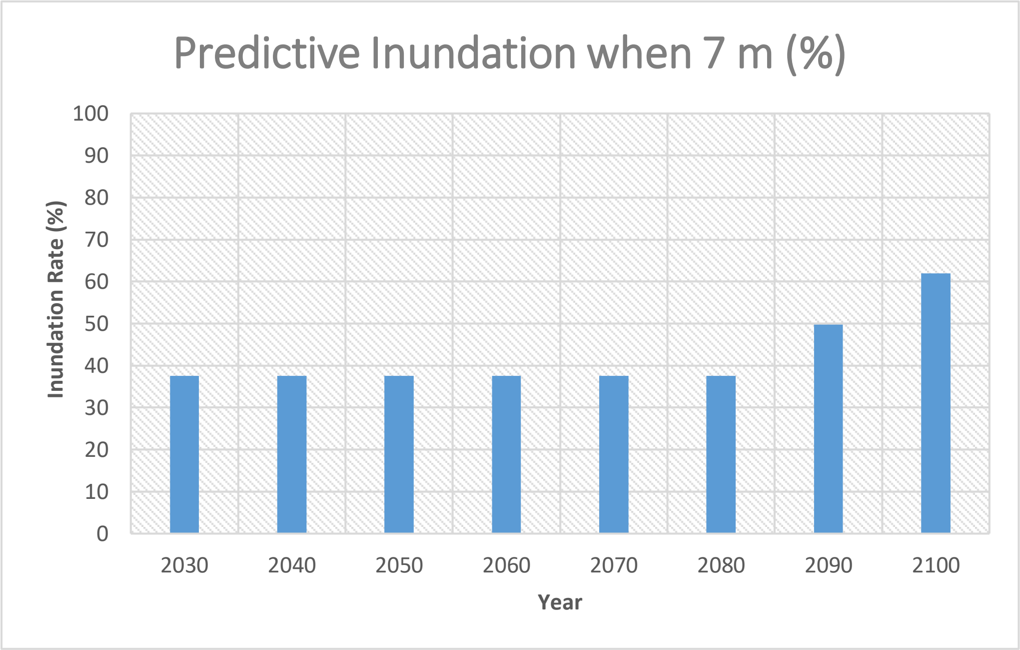


Figure 4-17: Yearly Inundation Rate Comparison at 7 m Inundation Level of Polder 7/2

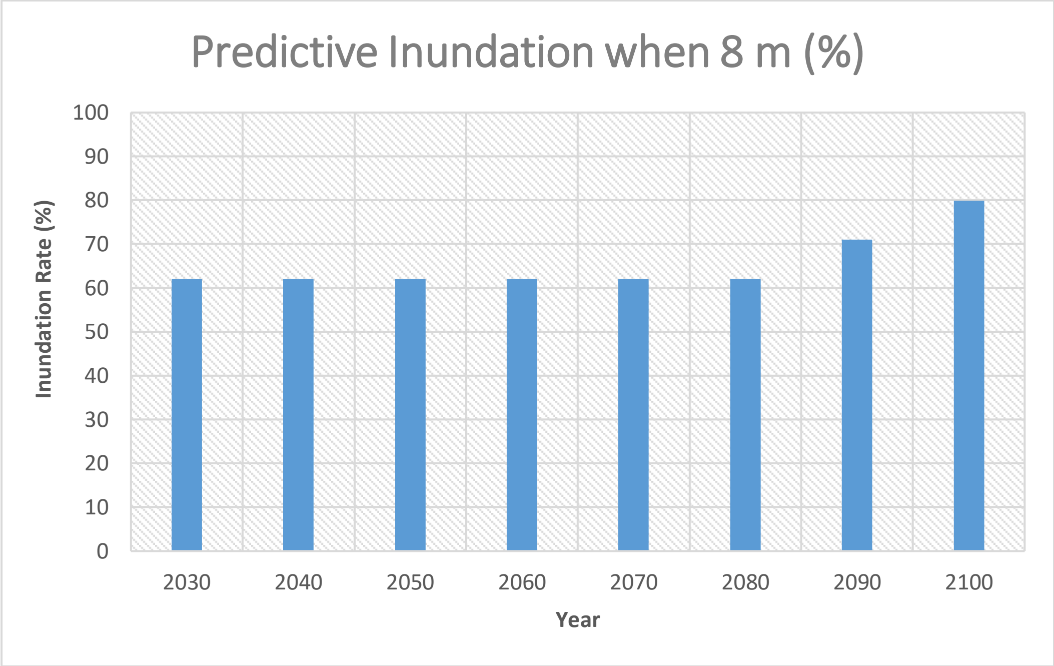


Figure 4-18: Yearly Inundation Rate Comparison at 8 m Inundation Level of Polder 7/2

- **Polder 10/12**

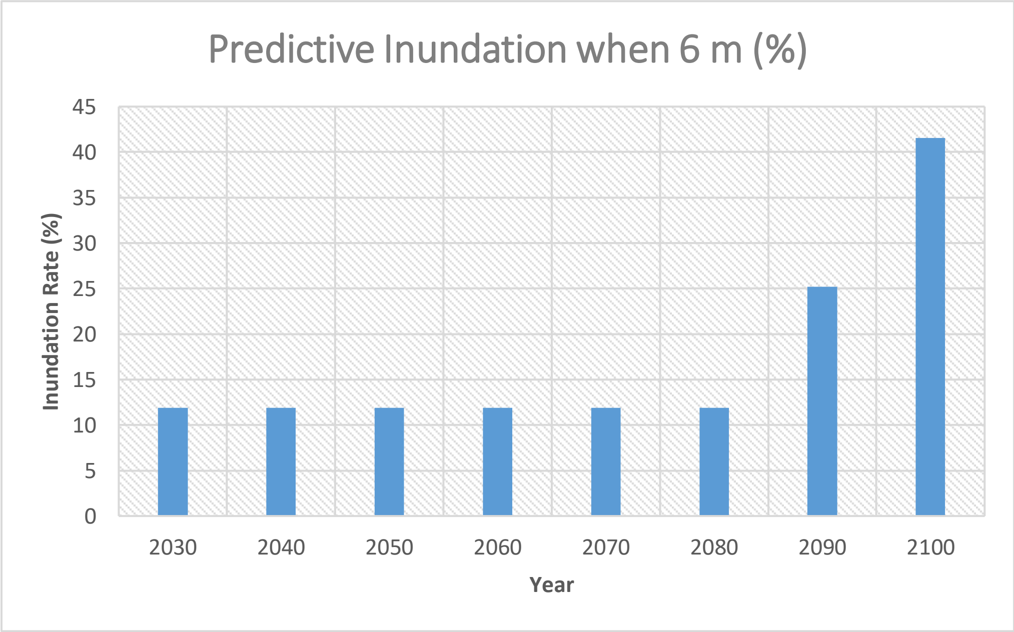


Figure 4-19: Yearly Inundation Rate Comparison at 6 m Inundation Level of Polder 10/12

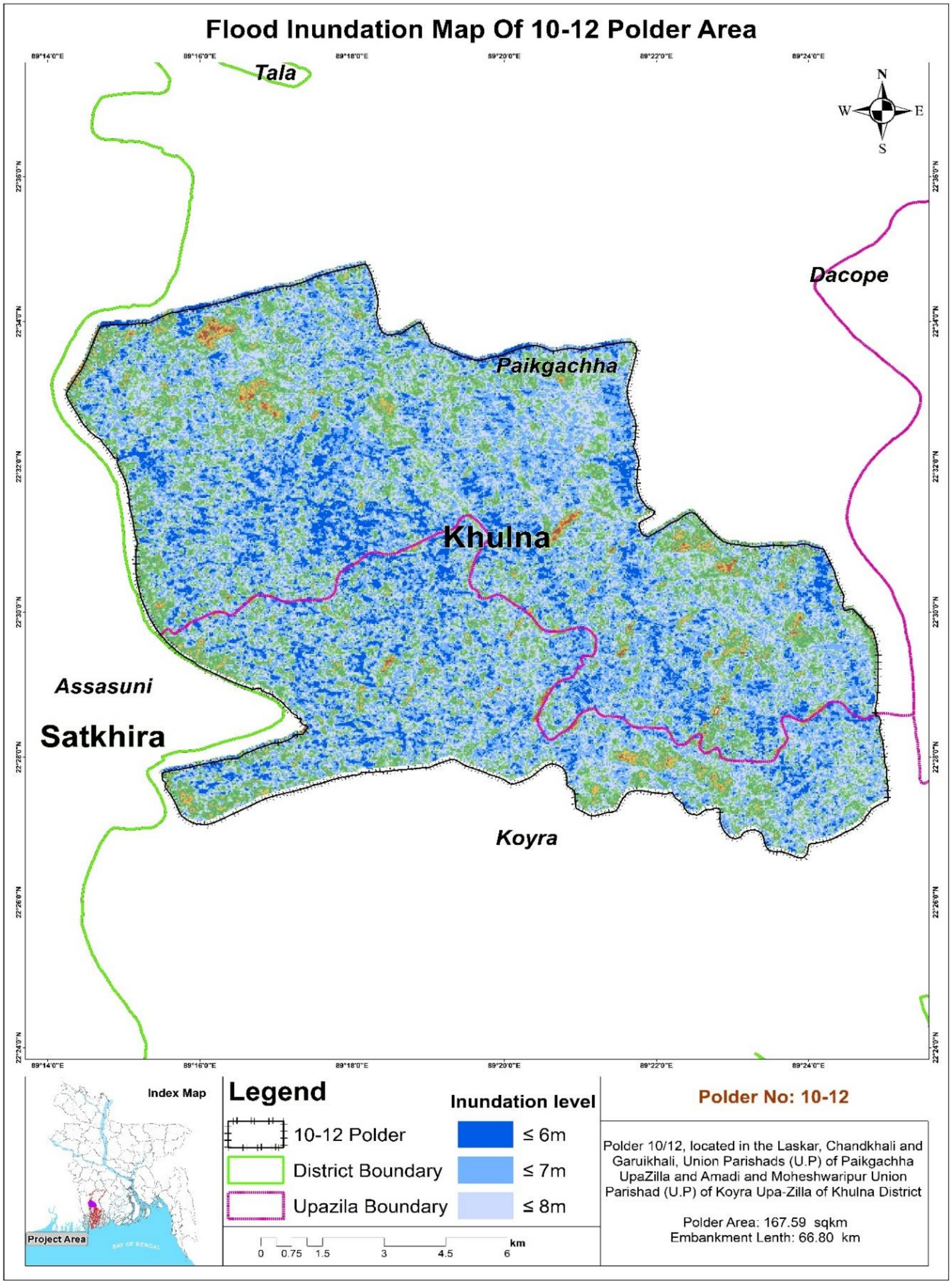

Flood Inundation Map Of 10-12 Polder Area
Tala
Dacope
Paikgachha
Khulna
Assasuni
Satkhira
Koyra
N
S
E
W
Index Map
Project Area
Legend
10-12 Polder
District Boundary
Upazila Boundary
Inundation level
≤ 6m
≤ 7m
≤ 8m
km
0 0.75 1.5 3 4.5 6
Polder No: 10-12
Polder 10/12, located in the Laskar, Chandkhali and Garuikhali, Union Parishads (U.P) of Paikgachha UpaZilla and Amadi and Moheshwaripur Union Parishad (U.P) of Koyra Upa-Zilla of Khulna District
Polder Area: 167.59 sqkm
Embankment Lenth: 66.80 km

Figure 4-20: Inundation map of Polder 10-12

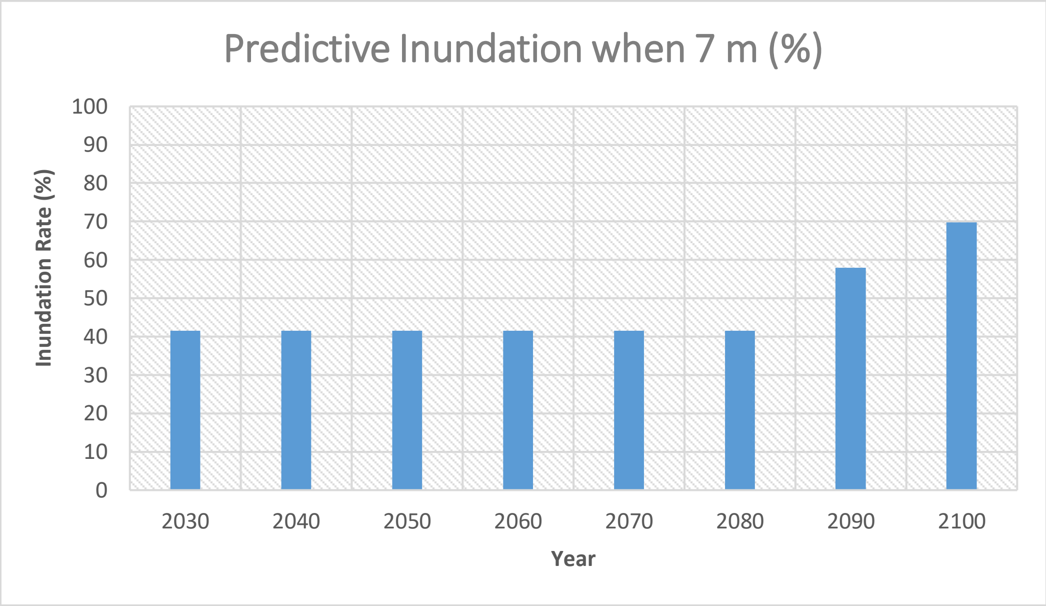


Figure 4-21: Yearly Inundation Rate Comparison at 7 m Inundation Level of Polder 10/12

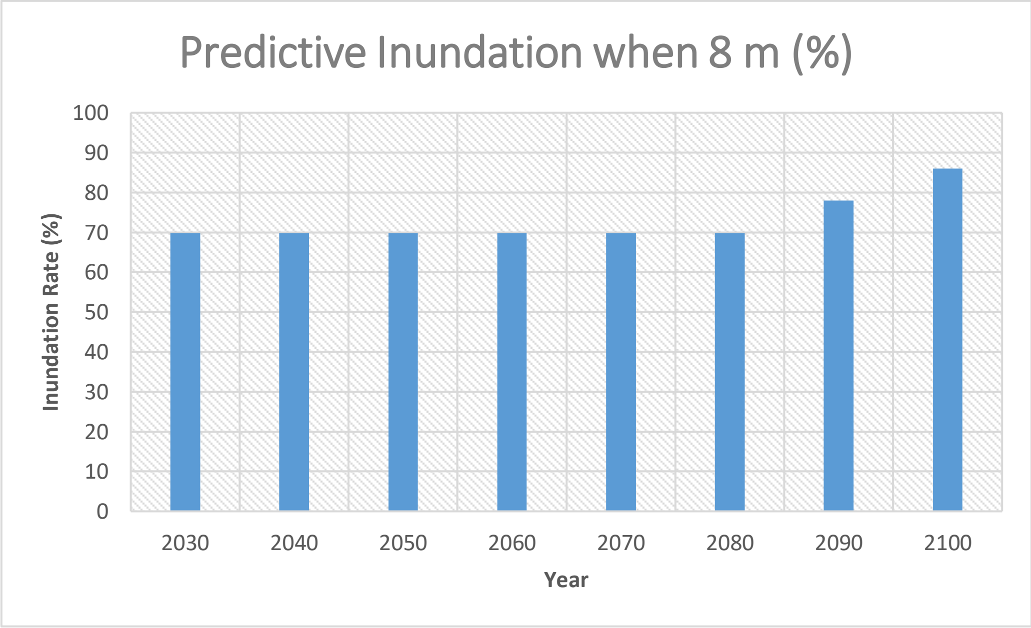


Figure 4-22: Yearly Inundation Rate Comparison at 8 m Inundation Level of Polder 10/12

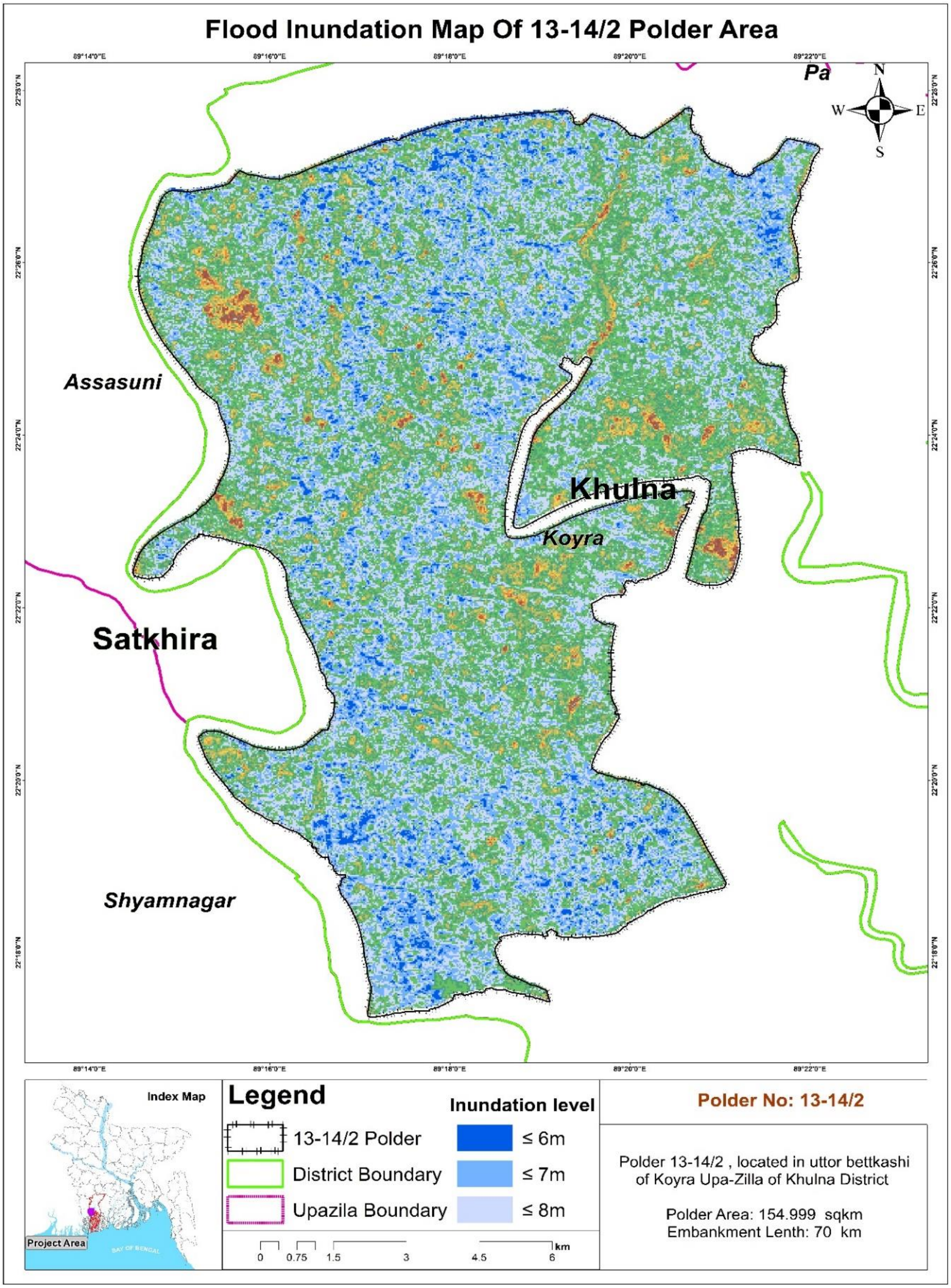


Figure 4-23: Inundation map of Polder 13-14/2

- **Polder 13/14**

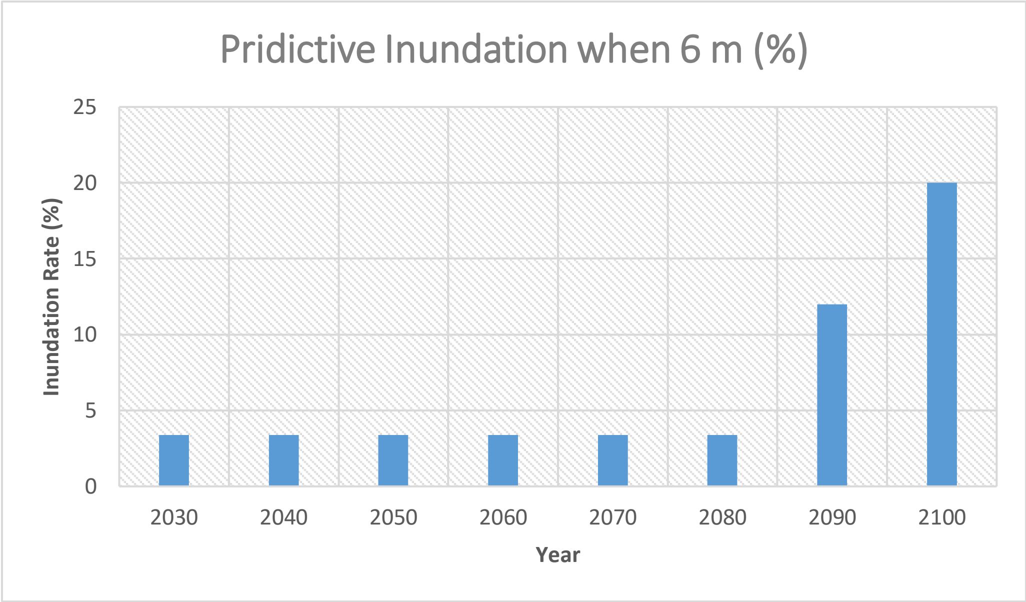


Figure 4-24: Yearly Inundation Rate Comparison at 6 m Inundation Level of Polder 13/14-2

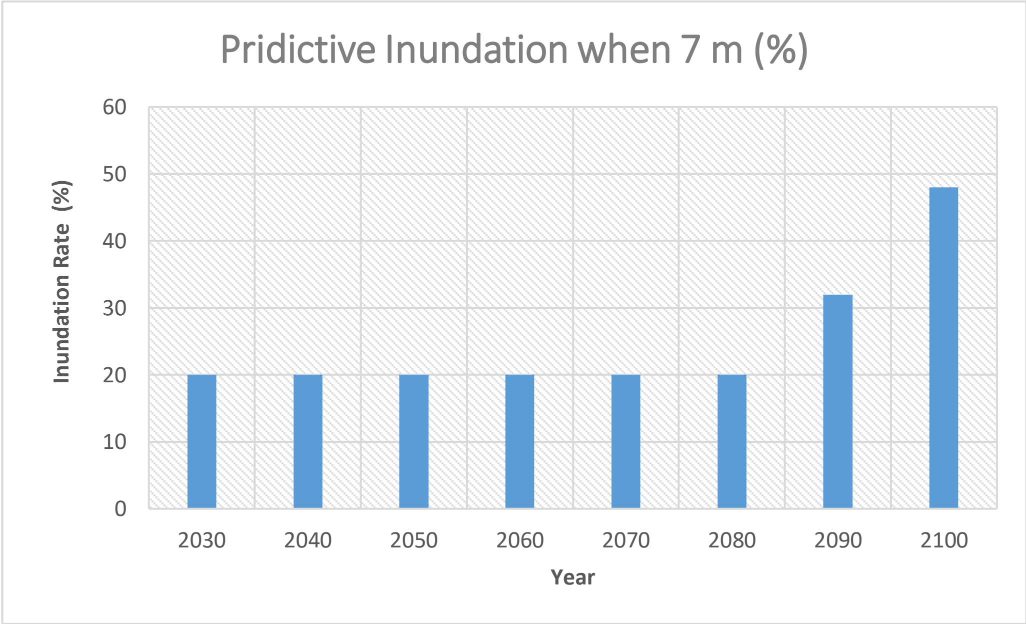


Figure 4-25: Yearly Inundation Rate Comparison at 7 m Inundation Level of Polder 13/14-2

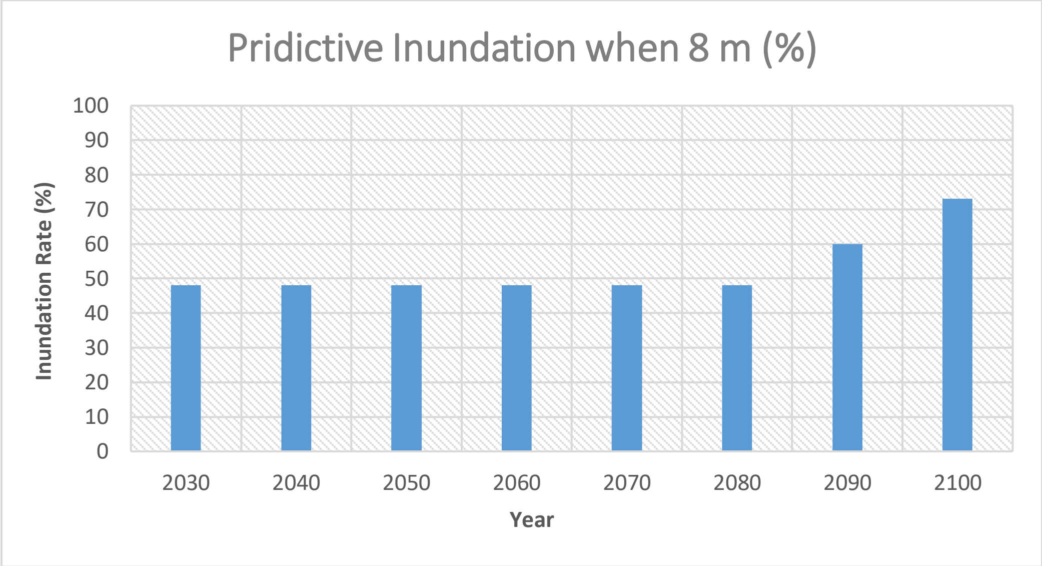


Figure 4-26: Yearly Inundation Rate Comparison at 8 m Inundation Level of Polder 13/14-2

From the above figures, it is seen that maximum inundation will occur in 2100. It can be said that if the flood depth is 8 m, greater than half of the area of all four polders will be inundated. The inundation rate is constant from 2030 to 2080 for all polders. Then, we have calculated yearly average inundation depth for all the polders. The following table is representing the average yearly inundation rate of the polders.

Table 4-7: Prediction of Average Yearly Inundation Rate of Polders

Year	Polder -7.1	Polder -7.2	Polder-10.12	Polder -13.14
2030	11.8	19.8	41.1	23.8
2040	11.8	19.8	41.1	23.8
2050	11.8	19.8	41.1	23.8
2060	11.8	19.8	41.1	23.8
2070	11.8	19.8	41.1	23.8
2080	11.8	19.8	41.1	23.8
2090	19.6	30.3	53.7	34.7
2100	28.8	42.2	65.8	47.0

4.5 FINDINGS & COMPARISON

Previously told that from the flood damage analysis, polder 7/1 has been identified as the most affected polder than others. On the other hand, 13/14 is identified as less vulnerable to flood. The total damaged amount for different polders is represented in the following table.

From the above table and figure, it is seen that Sidr and Amphan were the strongest disaster. They caused the most damages in the last 13 years. The rate is almost 25%. The percentage ratio of different disasters is represented in figure-. There are many reasons for this kind of damages. The reasons are described below.

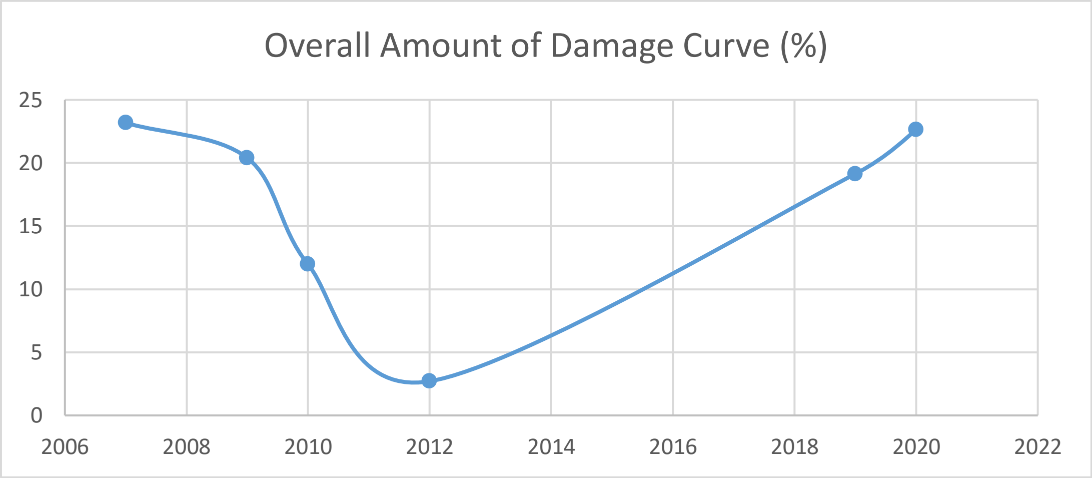


Figure 4-27: Percentage of Damages from 2007 to 2020

- **Geographical Location**

Geographical location is one of the main reasons of flooding. Distance from the river and location of major river are the factors of the geographical location which is used to take under consideration in case of flood damage analysis. Polder 7/1 is located between two major rivers called Kobotak and Kholpetua. Therefore Polder 7/1 is highly vulnerable to flood. On the other hand, rest of the polders are located either one major river or branches of the river.

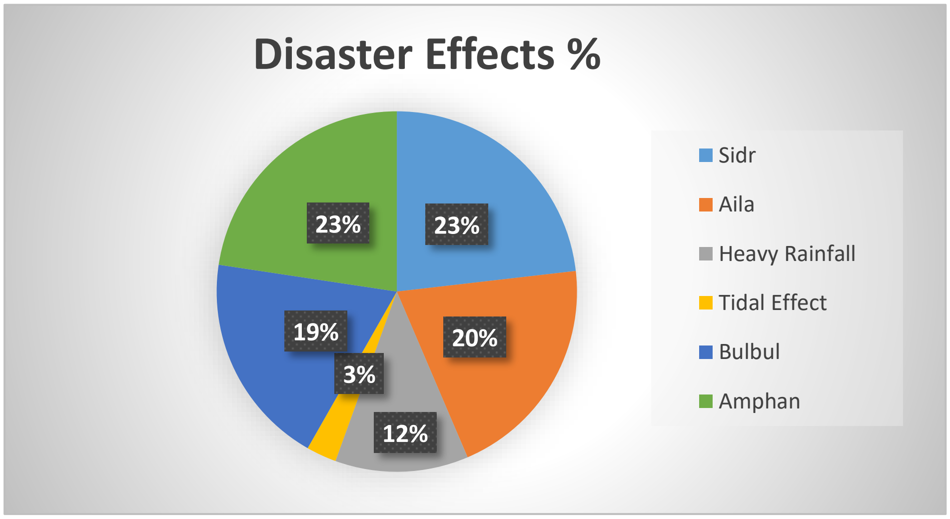


Figure 4-28: Percentage of Disaster Effects

- ### Slope & Elevation

The slope of the study area is lower as it is in the coastal region. The slope varies from 0 to 25 m in the study area. Polder 7/1 is in low slope condition. The flood water is stuck for longer time. Therefore, the flood duration in this polder is lengthier than another polder. The elevation of the study varies from 0 to 10 m. Due to different elevation the inundation level varies from polder

to polder. The comparison of predicted inundation level is represented in the following figure. From the figure, it is seen that the inundation rate of polder 10/12 is higher than other polders. Because the elevation of polder 10/12 is lower. The elevation of 10/12 varies from 0.2 to 5.29 m. Polder 7/1 varies from 0.3 to 6.3 m. Due to having high elevation, the inundation rate of this polder is lower.

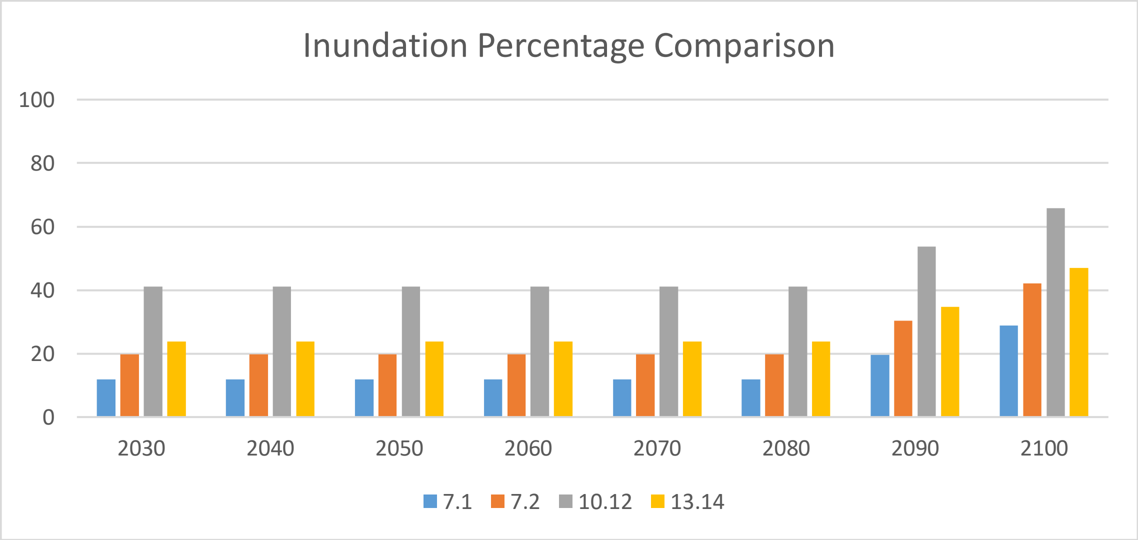


Figure 4-29: Comparison of Predicted Inundation Percentage from 2030 to 2100

- **Embankment Condition**

Poor embankment condition is another reason for flooding. Most of the polders were seriously damaged and breached at various locations with the landfall of hurricanes "SIDR" in 2007, "Ayla" in 2009, and "Amphan" in 2020. As a result of surge water overtopping during Cyclone landfall, some of the polder's hydraulic infrastructure were destroyed or swept away, while others sustained damage or were washed out due to their age and extensive use (CEIP). 7/1 is one of the polders which is badly damaged. This is one of the reasons behind the high damage rate.

- **Shrimp Farming**

Local people reported that there is no freshwater fish species in the natural water bodies inside the Polder. Regular saltwater intrusion in the Polder area is a common phenomenon after saltwater intrusion has caused disappearance of freshwater fisheries from this area. Shrimp farming is suitable for this water. To capture shrimp, fishermen are used to cut the flood protection structures for making a path to enter their region. This causes the area vulnerable to flood.

- **Tidal Surge Erosion**

Tidal surge causes a great damage to the embankments of the coastal areas. A tidal surge in the Bay of Bengal is wreaking damage on the coastal communities along the Bay of Bengal, rendering 35,000 people homeless and several dead, many of them children. Farmers fear that salt water from the sea and nearby rivers will enter the whole agricultural land in the district through the broken parts and damage Aman paddy fields (Daily Star, 7 Sep 2021).

CHAPTER 5: PREDICTIVE ANALYSIS BY FUZZY LOGIC

5.1. CONCEPTS OF FUZZY LOGIC

As already mentioned, fuzzy analysis is the best technique for examining uncertainty. This chapter will provide general information on fuzzy logic. In this case study fuzzy logic is applied to predict the damage rate due to sea level rise. In 1965, Zadeh created the first fuzzy set. Essentially, this theory was created to address issues that are difficult to resolve using statistical methods. Then, using fuzzy sets, a variety of real-world issues involving linguistic descriptions may be successfully resolved (Zadeh et al 1997). The fundamental approach to fuzzy inference entails passing input variables via a series of concurrent IF-THEN rules and fuzzy logical operations before reaching the output space. To explain the IF-THEN rules, human words are employed, and each word is regarded as a fuzzy set. All these fuzzy sets need membership functions to define them before they can be used to build IF-THEN rules. A membership function illustrates the degree of truth, that is, whether it is entirely or partially true. If it has a value of 0, it does not belong to the fuzzy set, and if it has a value of 1, it is entirely a member. Those fuzzy members that fall into the fuzzy set just partially are represented by values between 0 and 1. Because we have used if-else rules, we are familiar with Boolean logic. However, the rules format for fuzzy is if...then. For our study case, it can be stated as follows:

"If the elevation is low then flood damage will be high"

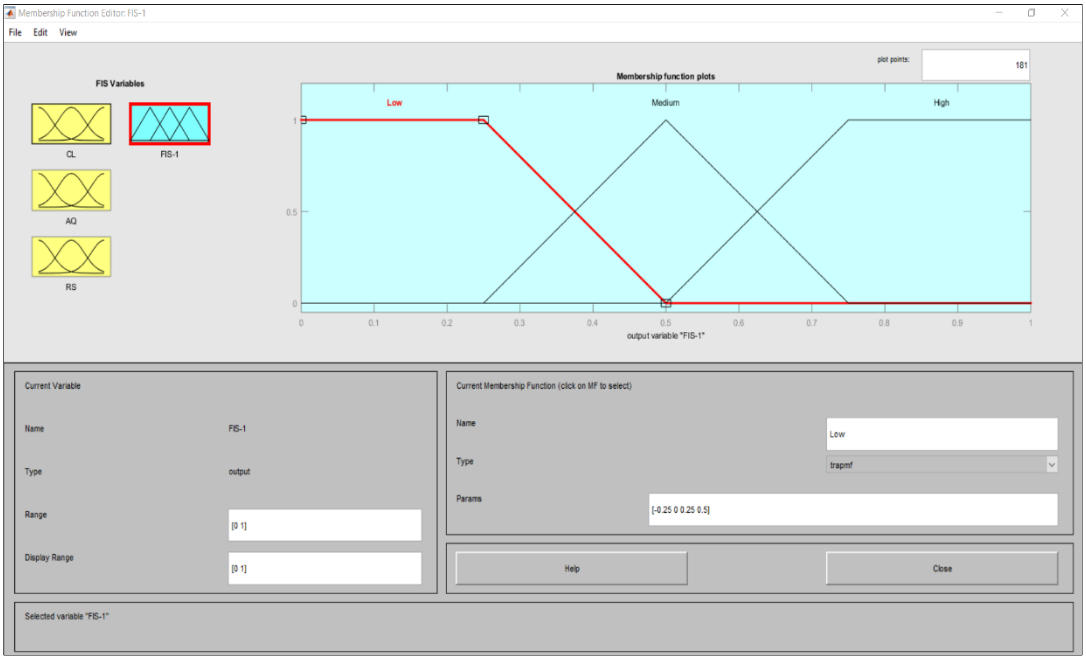


Figure 5-1: Sample of Adopted Fuzzy Model

As, previously defined the connections between the inputs, outputs, and fuzzy sets. In that instance, the following rules can be established: Z is z if X equals x; Z is z if Y is y. The subsets that are expressed for sets X, Y, and Z, respectively, have the following linguistic names: x, y, and z. Assume that there are three inputs and that the input variables are fuzzified into three sets: Low, Medium, and High. There will then be 27 potential rules. This is how the laws are established.

5.2. ADOPTED METHODOLOGY

There are two types of fuzzy model. One is Mamdani Fuzzy Inference System (FIS), another one is Sugeno FIS. In this case study Mamdani FIS has been selected due to its worldwide acceptance.

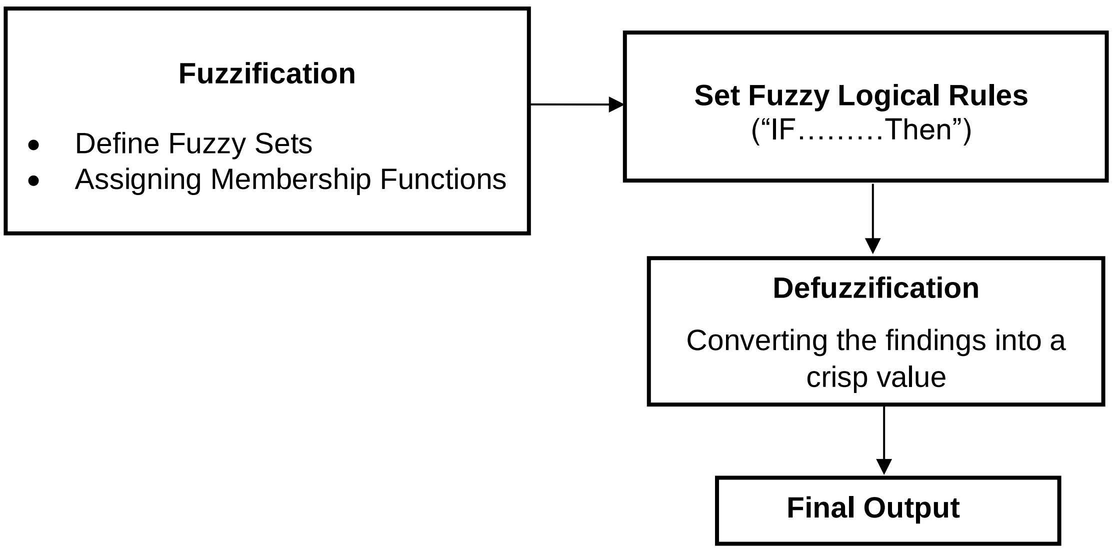


Figure 5-2: Adopted Fuzzy Sets and Membership Functions of the Model

The steps of Mamdani FIS is given below.

As, it’s a computer-based programming language, we have to insert some input. To give input, the collected data have been normalized into a standard form. The values have been converted into a range of 0 to 100 to predict the damage rate. The data normalization has been done by the following formula.

$$Normalized\ Form = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

Where, x_i = Value of the ith No.
x_{min} = Minimum Value of the Set
x_{max} = Maximum Value of the Set

As previously said that there will be several rules according to input variables and fuzzy sets. We have selected 8 inputs and three variables. Therefore, there will be nearly 6500 rules which is impossible for a human being to set such number of rules. To make it easier, all the inputs have been clustered into three groups and three different fuzzy model have been developed. Then considering these three models, a final fuzzy model has been developed. This final fuzzy model is represented the output of the damage rate prediction.

The adopted methodology has been shown in the following figure.

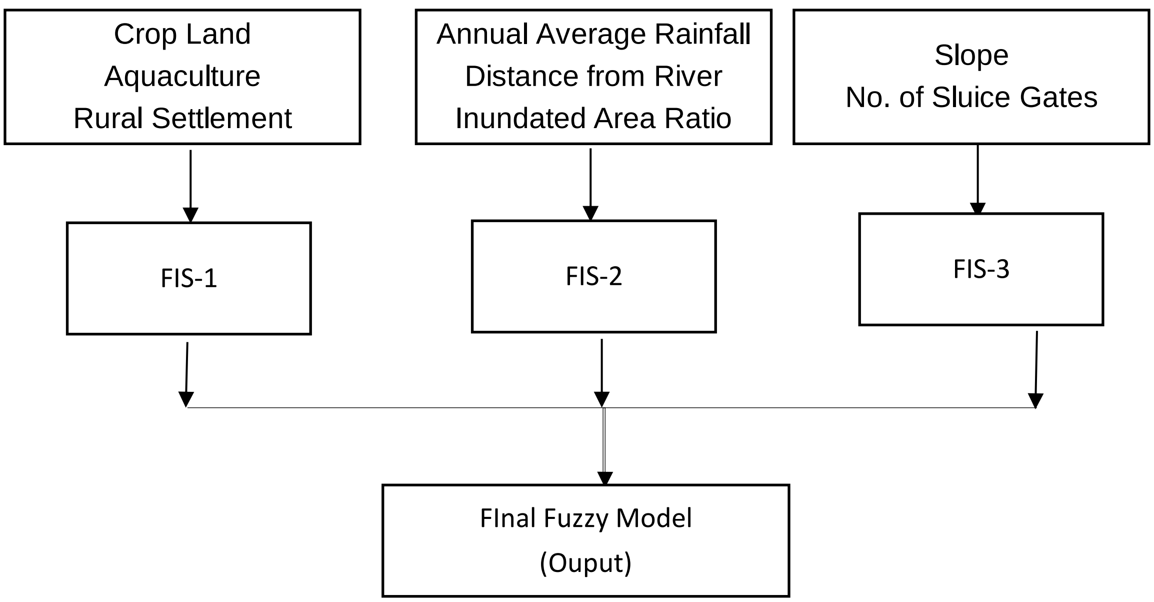


Figure 5-3: Development of Adopted Fuzzy Model

5.3. FINDINGS

The prediction has been given for 2100 based on RCP 8.5. IPCC suggested that sea level will be risen nearly to 1m. The predictive result has been shown in the following figures.

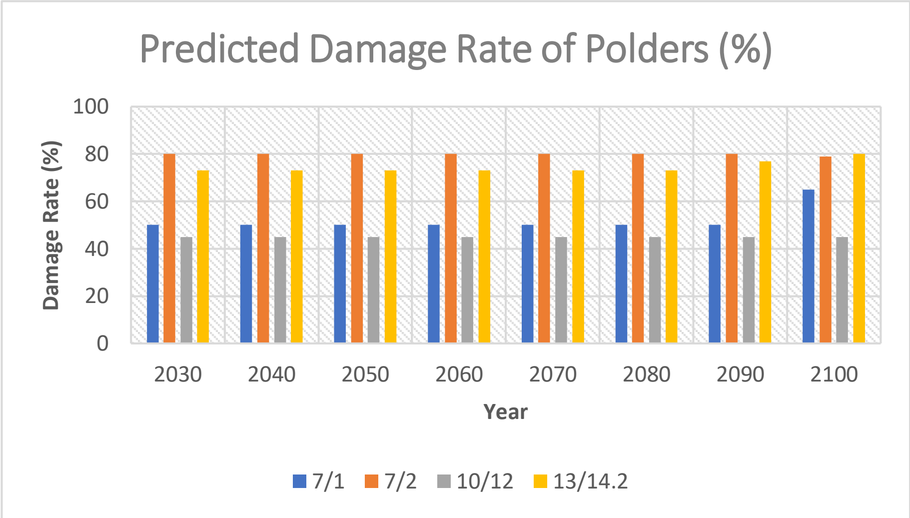


Figure 5-4: Predicted Damage Rate of Polders in future years

These data have been selected as input data for the development of fuzzy model. After normalizing the data, all the data have been given input to the model. The output value represents the predicted damage rate. It is observed that polder 7/2 can be highly damaged. The damaged rate is observed nearly 80%. The reason behind this kind of scenario is having more assets and less adapting capacity. Crop land, aquaculture, rural settlement, etc. are more than other polders. On the other hand, the adapting capacity is not good. It has flat slope and less sluice gates to control the floodwater.

Table 5-1: Predicted Damage Rate using Fuzzy Model

Variables	Polders-7/1	Polders-7/2	Polders-10/12	Polders-13/14
Crop Land	5.86	30	25.15	33
Aquaculture	79.87	45	54.49	46
Rural Settlement	9.43	17.18	13.13	14.48
Annual Avg. Rainfall	1876	1876	1876	1876
Distance from River	2115	7300	7300	9026
Inundated Area Ratio	28.8	42.2	65.8	47
Slope	10.5	8.77	12.8	10.35
No of Sluice Gates	7	7	15	15

From this comparison, it is seen that polder 10/12 is less vulnerable than other polders. Due to its higher adapting capacity than others, the damage rate has been shown lesser than other polders. The prediction has been made from 2030 to 2100. It is observed that the predicted value is almost similar till 2080. Because the predicted sea level rise according to RCP 8.5 is in a small interval. If the interval is 0.25-0.5 m, we can get a unique prediction having uniform flood damage curve. This fuzzy inference system is universal. It can be used in any sector for predictive analysis.

Table 5-2: Predicted Damage Rate using Fuzzy Model

Polder / Year	7/1	7/2	10/12	13/14.2
2030	50	80	45	73
2040	50	80	45	73
2050	50	80	45	73
2060	50	80	45	73
2070	50	80	45	73
2080	50	80	45	73
2090	50	80	45	77
2100	65	79	45	80

CHAPTER 6: CONCLUSION

6.1. CONCLUSION

The coastal Polders surrounded by embankments in the coastal region protect the lives and properties of people and agricultural lands with crops from tidal inundation; saline water intrusion; storms and cyclonic surges thereby releasing a large extent of land for permanent agriculture as well as congenial living condition.

The Polders have been playing a vital role in safeguarding the coastal area; ensuring and increasing agricultural production; improving the livelihoods of the people; and mitigating environmental damages. But these are vulnerable to storm surges; high tides; annual floods; land erosion and drainage congestion. In many cases, the structures as built have not been found adequate to cope with the diverse needs of the local people. Changes in the land use pattern have created water management conflicts and newer dimension needs to ask the structures to allow water to flow in both directions. So, maintenance of the polder system with embankments and structural elements has become of permanent importance. The GoB either with assistance from international donors and lending agencies or out of its own resources has been spending money almost on a regular basis to keep the Polders in good working condition eventually to save the coastal people. In our study, we have predicted flood inundation for the upcoming years. These will further help people to be well prepared for flooding and to mitigate the flood damage.

6.2. RECOMMENDATIONS

In this study various case study has been conducted such as water resources assessment by WARPO 2016, coastal embankment improvement project by BWDB 2022, etc. These case studies were required for the successful implementation of the work. Various flood damages have been analyzed based on qualitative & quantitative survey and the reports of the mentioned organization. The flood damages that have been taken under consideration are household assets, crop damages, fish damages, cattle & poultry damages and inundation condition of the region. Most of the damages have been caused by Sidra and Amphan. Some polders are badly affected by the disasters. Based on the effects and inundation condition, some recommendations are made.

Due to geographical location, the polders are very vulnerable to flooding. Having low slope and elevation, flooding is a very common occurrence in this region. So, strong flood protection structures are needed. But, the embankment condition of the polders are in poor condition. This causes the disasters to affect the region easily. Some of the polder's hydraulic infrastructure was damaged or washed away at Cyclone landfall as a result of surge water overtopping, while others suffered damage or were washed out due to their age and heavy use. The embankment condition should be improved as soon as possible. According to WARPO 2016, 90% of the polder areas will be inundated if there is no flood protection structures. So, the embankment repairing project should be taken by the concerned authority.

The polders are located in the southwest coastal region of Bangladesh. So, shrimp farming is very common in the coastal region. It is one of the fruitful income sources for the people of that area. Due to increase the amount of area of the farming, they used to break the embankment and other relevant infrastructure. This causes damage to the embankment. Therefore, there should be restriction in the shrimp farming area.

Tidal surge is another cause of creating damages to the people of that region. Global environmental change has negative repercussions on nations and megacities in coastal regions all over the world, including coastal flooding caused by storm surges, lower rainfall in dry lands, and water scarcity (Mohammad, 2012). To reduce the tidal surge effect, housing structure should be built in elevated place. Housing structures near the coastal bank and low elevated place are highly vulnerable to flooding. This place should be open or having well settlement. Housing structures should be built to a higher elevated place than the coastal bank.

Based on the analysis of this study, an approximate damage rate can be known. It will be easier to take necessary steps for the concerned authority for the adaptation measures. Therefore, necessary steps should be taken by the concerned authority such as BWDB, DoE, DDM and other relevant organizations. These are recommendations are suggested based on this case study.

REFERENCES

Abbas, A., Amjath-Babu, T. S., Kächele, H., Usman, M., & Müller, K. (2016). An overview of flood mitigation strategy and research support in South Asia: implications for sustainable flood risk management. *International Journal of Sustainable Development & World Ecology*, *23*(1), 98-111.

ADB, 1994, *Climate Change in Asia: Bangladesh Country Report*, Asian Development Bank (ADB), Manila

Agrawala, S., Ota, T., Ahmed, A. U., Smith, J., & Van Aalst, M. (2003). *Development and climate change in Bangladesh: focus on coastal flooding and the Sundarbans* (pp. 1-49). Paris: OECD.

Agrawala, S., T. Ota, A.U. Ahmed, J. Smith and M. van Aalst, 2003. *Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sunderbans*. Organisation for Economic Co-operation and Development (OECD).2003, Paris.

Ahmad Q.K. and Ahmed, A.U. (Eds.), 2002, *Bangladesh: Citizens' Perspectives on Sustainable Development*, Bangladesh Unnayan Parishad (BUP), Dhaka, pp. 225.

Ahmad Q.K., Ahmed, A.U., Khan, H.R. and Rasheed, K.B.S, 2001, 'GBM Regional Water Vision: Bangladesh Perspectives', in Q.K. Ahmad, A.K. Biswas, R. Rangachari and M.M. Sainju (eds.) *Ganges-Brahmaputra-Meghna Region: A Framework for Sustainable Development,* University Press Limited, Dhaka, pp. 31-80.

Ahmad, Q.K. (Ed.), 2000, *Bangladesh Water Vision 2025: Towards a Sustainable Water World*, Bangladesh Water Partnership (BWP), Dhaka, 73 p.

Ahmad, Q.K. and Ahmed, A.U., 2000. 'Social Sustainability, Indicators and Climate Change', in M. Munasinghe and R. Swart (Eds.), *Climate Change and Its linkages with Development, Equity, and Sustainability*, Jointly published by LIFE, RIVM and World Bank for IPCC, Geneva, pp. 95-108.

Ahmad, Q.K. and Ahmed, A.U., 2003, 'Regional Cooperation in Flood Management in the Ganges-Brahmaputra-Meghna Region: Bangladesh Perspectives', *Natural Hazards*, 28, pp. 191-198.

Ahmad, Q.K., A.K.A. Chowdhury, S.H. Imam, and M. Sarker (Eds.), 2000, *Perspectives on Flood 1998*, The University Press Limited (UPL), Dhaka, 142 p.

Ahmad, Q.K., Ahmed, A.U., Karim, Z., Prasad, K., and Poudel, S.N., 2004. 'Community Based Flood Management in South Asia', *Asia Pacific Journal on Environment & Development*, Special Issue, 12(1-2).

Ahmad, Q.K., N. Ahmad, and K.B.S. Rasheed, (Eds.), 1994, *Resources, Environment and Development in Bangladesh With Particular Reference to the Ganges, Brahmaputra and Meghna Basins*, Academic Publishers, Dhaka, 134 p.

Ahmed, A.U. and Alam, M., 1998, 'Development of Climate Change Scenarios With General Circulation Models', in S. Huq, Z. Karim, M. Asaduzzaman, and F. Mahtab (Eds.), *Vulnerability and Adaptation to Climate Change for Bangladesh*, Kluwer Academic Publishers, Dordrecht, pp. 13-20.

Ahmed, A.U. and Haque, N., 2002. Climate Change and Sustainable Development. Paper presented at the Dhaka Meet on Sustainable Development, March 14-18, 2002. Incorporated in Q.K. Ahmad and A.U. Ahmed (eds.), Citizens' Perspectives on Sustainable Development, Bangladesh Unnayan Parishad (BUP).

Ahmed, A.U. and Mirza, M.M.Q, 2000, 'Review of Causes and Dimensions of Floods with Particular Reference to Flood '98: National Perspectives'. In Q.K. Ahmad, A. K. A. Chowdhury, S.H. Imam, M. Sarker, (Eds.) *Perspectives on Flood 1998*, The University Press Limited, Dhaka,

Ahmed, A.U., 2005a. 'Adaptation Options for Managing Water Related Extreme Events Under Climate Change Regime: Bangladesh Persectives', in M.M.Q. Mirza and Q.K. Ahmad (eds.), Climate Change and water Resources in South Asia, Balkema Press, Leiden, pp. 255-278.

Ahmed, A.U., 2005b. 'Toward Integrating Adaptation to Climate Change in Current Policy regime: Perspectives on Bangladesh's Water Resources and Associated Sectors', *Asia Pacific Journal on Environment and Development*, 12(1): 35-54.

Ahmed, A.U., Alam, M. and Rahman, A.A., 1998a, 'Adaptation to Climate Change in Bangladesh: Future Outlook', in *Vulnerability and Adaptation to Climate Change for Bangladesh*, S. Huq, Z. Karim, M. Asaduzzaman, and F. Mahtab (Eds.), Kluwer Academic Publishers, Dordrecht, pp. 125-143.

Ahmed, A.U., Huq, S., Karim, Z., Asaduzzaman, M., Rahman, A.A., Alam, M., Ali, Y. and Chowdhury, R.A., 1996. 'Vulnerability and Adaptation Assessments for Bangladesh'. In *Vulnerability and Adaptation to Climate Change*, J.B. Smith, S. Huq, S. Lenhart, L.J. Mata, I. Nemesova and S. Toure (Eds.), Kluwer Academic Publishers, Dordrecht/Boston/London, 1996.

Alam, M., Nishat, A., and Siddiqui, S,M, 1998, 'Water Resources Vulnerability to Climate Change With Special Reference to Inundation', in S. Huq, Z. Karim, M. Asaduzzaman, and F. Mahtab (Eds.), *Vulnerability and Adaptation to Climate Change for Bangladesh,* Kluwer Academic Publishers, Dordrecht, pp. 21-38.

Ali, A., 1999. Climate Change Impacts and Adaptation Assessment in Bangladesh, *Climate Research*, 12: 109-116.

Ali, M, Bhattacharya, B, Islam, A, Islam, GMT, Hossain, M, Khan, AS. Challenges for flood risk management in flood-prone Sirajganj region of Bangladesh. *J Flood Risk Management*. 2019; 12: e12450

Asaduzzaman, M, Reazuddin, M. and Ahmed, A.U. (Eds.), 1997, *Global Climate Change: Bangladesh Episode*, Department of Environment, Government of Bangladesh, July 1997.

Asaduzzman, M., Ahmed, A.U., Haq, E. and Chowdhury, S.M.Z.I., 2005. *Climate Change and Bangladesh: Livelihoods Issues for Adaptation*. Bangladesh Institute for Development Studies (BIDS), Dhaka.

BANCID, 1997. Cooperation in the Ganges-Brahmaputra-Meghna Basins, Bangladesh National Committee for Irrigation and Drainage (BANCID).

Baten, A., González, P. A., & Delgado, R. C. (2018). Natural disasters and management systems of Bangladesh from 1972 to 2017: Special focus on flood. *OmniScience: A Multi-disciplinary Journal*, *8*(3), 35-47.

BBS, 2005, *Statistical Pocketbook of Bangladesh: 2004*, Bangladesh Bureau of Statistics (BBS), Government of the People's Republic of Bangladesh (GOB), Dhaka BCAS-RA-Approtech, 1994, *Vulnerability of Bangladesh to Climate Change and Sea Level Rise: Concepts and Tools for Calculating Risk in Integrated Coastal Zone Management*; in Four Volumes (Summary report, Main reports and Institutional report), Bangladesh Centre for Advanced Studies (BCAS), Resource Analysis (RA), and Approtech Consultants Ltd., Dhaka.

Bernard, A., Long, N., Becker, M., Khan, J., & Fanchette, S. (2021). Bangladesh's vulnerability to cyclonic coastal flooding. *Natural Hazards and Earth System Sciences Discussions*, 1-28.

Bogardi, I., & Duckstein, L. (2003). The fuzzy logic paradigm of risk analysis. In *Conference Proceeding Risk-Based Decision making in Water Resources X, Reston: American Society of Civil Engineers*.

BRTC-BUET, 2005. Final report of the Sectoral Working Group on Industry and Infrastructure, Bureau of Research, Testing and Consultation (BRTC), Bangladesh University of Engineering and Technology (BUET), Dhaka.

BUP, 2001. *Options for the Ganges Dependent Area: Climate Change Impacts and Adaptation*, as Annex A: Appendix 5, to the OGDA Study Report, in association with Halcrow and Associates and under the Water Resources Planning

Organization, 62 p.
BUP-CEARS-CRU, 1994. *Bangladesh: Greenhouse Effect and Climate Change, Briefing Documents No. 1-7*, Bangladesh Unnayan Parishad (BUP), Centre for environmental and Resource Studies (CEARS), University of Waikato, New Zealand and Climate Research Unit (CRU), University of East Anglia, Norwich, UK.

Burton, I., 1992, *Adapt and Thrive*. Canadian Climate Centre unpublished manuscript, Downsview, Ontario.

Burton, I., 1997, 'Vulnerability and Adaptive Response in the Context of Climate and Climate Change', *Climatic Change* **36**, 185-196.

CEGIS, 2006. Impacts of Sea Level Rise on Landuse Suitability and Adaptation Options, Draft Final Report. Submitted to the Ministry of Environment and Forest, Government of Bangladesh and United Nations Development Programme (UNDP) by Centre for Environmental Geographic Information Services (CEGIS), Dhaka.

Choudhury, A.M., Neelormi, S., Quadir, D.A., Mallick, S. and Ahmed, A.U., 2005. Socio-economic and Physical Perspectives of Water related Vulnerability to Climate Change: results of Field Study in Bangladesh, *Science and Culture* (Special Issue), 71(7-8): 225-238.

Choudhury, A.M., Quadir, D.A., Neelormi, S., and Ahmed, A.U., 2003. Climate Change and Its Impacts on Water Resources of Bangladesh, in A. Muhammed (ed.), *Climate Change and water Resources in South Asia*, Asianics AgroDev International, Islamabad, pp. 21-60.

Dutta, D., Herath, S., & Musiake, K. (2001, September). Direct flood damage modeling towards urban flood risk management. In *Joint Workshop on Urban Safety Engineering* (pp. 127-143). Tokyo, Japan: International Center for Urban Safety Engineering (ICUS/INCEDE), IIS, University of Tokyo.

Ericksen, N.J., Ahmad, Q.K. and Chowdhury, A.R., 1996. Socio-economic Implications of Climate Change for Bangladesh, in R.A. Warrick and Q.K. Ahmad (eds), The Implications of Climate and Sea-level Change for Bangladesh, Kluwer Acedemic Publishers, Dordrecht, pp. 205-287.

Faisal, I.M. and Parveen, S., 2004. Food Security in the Face of Climate Change, Population Growth and Resource Constraints: Implications for Bangladesh, Environmental Management 34(4): 487-498.

Faisal, I.M., Kabir, M.R., and Nishat, A., 2003. The Disastrous Flood of 1998 and Long Term Mitigation Strategies for Dhaka City, Natural Hazards, 28(1): 85-99.

Hasan, A. S., Saha, R. R., & Biswas, B. A. (2018, March). A Study on the flood damage and mitigation measures of floods occurring in Bangladesh at the last decade. In *Proceedings of the 1st National Conference on Water Resources Engineering (NCWRE), Chittagong University of Engineering and Technology, Chittagong, Bangladesh* (pp. 21-22).

Huq, S., Ali, S. I., & Rahman, A. A. (1995). Sea-level rise and Bangladesh: A preliminary analysis. *Journal of Coastal Research*, 44-53.

IPCC, 2001, "Climate Change 2001, Scientific Basis; Summary for the Policy Makers", Intergovernmental Panel on Climate Change (IPCC), WMO-UNEP, Geneva, Switzerland, pp. 20.

Iqbal, A. and M. H. Ali. 2001. Agricultural Drought: Severity and Estimation. A Report prepared under the project BGD/95/006 under the Ministry of Agriculture, Government of the People's Republic of Bangladesh, Dhaka, April 2001.

Islam, S.M.R., Huq, S. and Ali, A., 1998, 'Beach Erosion in the Eastern Coastline in Bangladesh', in S. Huq, Z. Karim, M. Asaduzzaman, and F. Mahtab (Eds.), *Vulnerability and Adaptation to Climate Change for Bangladesh*, Kluwer Academic Publishers, Dordrecht, pp. 71-92.

Karim, M. F., & Mimura, N. (2008). Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. *Global environmental change*, *18*(3), 490-500.

Karim, Z., 1996. 'Agricultural Vulnerability and Poverty Alleviation in Bangladesh', in T.E., Downing, (Ed.) *Climate Change and World Food Security*, NATO ASI Series I37.

Karim, Z., Hussain, S.G. and Ahmed, M., 1990b, "Salinity Problems and Crop Intensification in the Coastal Regions of Bangladesh", Bangladesh Agricultural Research Council (BARC), Dhaka.

Karim, Z., Hussain, S.G. and Ahmed, M., 1996, "Assessing Impacts of Climate Variations on Foodgrains Production in Bangladesh", *Journal of Water, Air and Soil Pollution*, 92, 53-62.

Karim, Z., Hussain, Sk.G. and Ahmed, A.U., 1998, "Climate Change Vulnerability of Crop Agriculture", in S. Huq, Z. Karim, M. Asaduzzaman and F. Mahtab (Eds.), *Vulnerability and Adaptation to Climate Change for Bangladesh*, Kluwer Academic Publishers, Dordrecht. pp 39-54.

Karim, Z., Ibrahim, A.M., Iqbal, A., and Ahmed, M., 1990a, "Drought in Bangladesh Agriculture and Irrigation Schedules for Major Crops", Bangladesh Agricultural Research Council (BARC), Soils Public. No. 34, 11 p.

Khan, D. M., Rahman, S. M. M., Haque, A. K. E., Chen, A. S., Hammond, M. J., Djordjević, S., & Butler, D. (2012). Flood damage assessment for Dhaka City, Bangladesh. *Flood Risk Management: Science, Policy and Practice: Closing the Gap*, 138.

Khan, D. M., Rahman, S. M. M., Haque, A. K. E., Chen, A. S., Hammond, M. J., Djordjević, S., & Butler, D. (2012). Flood damage assessment for Dhaka City, Bangladesh. *Flood Risk Management: Science, Policy and Practice: Closing the Gap*, 138.

Khan, T.A. 2000, "Water Based Disasters in Bangladesh", in Q.K. Ahmad (ed.) *Bangladesh Water Vision 2025: Towards a Sustainable Water World*, Bangladesh Water Partnership (BWP), Dhaka, pp. 54-62.

Koelle, K., Pascual, M. and Yunus, M., 2005. Pathogen Adaptation to Seasonal Forcing and Climate Change, Proceedings of the Royal Society B: Biological Sciences, 272 (1566): 971-977.

Mahtab, F., 1989. Effect of Climate Change and Sea Level Rise on Bangladesh, (for Expert Group on Climate Change and Sea Level Rise). Commonwealth Secretariat, London, United Kingdom.

Meraz, M. M., Hossain, M. R., Sultana, R., & Esraz-Ul-Zannat, M. (2022). Flood Prediction and Risk Assessment at the South-western Region of Bangladesh.

Messner, F., & Meyer, V. (2006). Flood damage, vulnerability and risk perception–challenges for flood damage research. In *Flood risk management: hazards, vulnerability and mitigation measures* (pp. 149-167). Springer, Dordrecht.

Mirza M.M.Q., Warrick, R.A., Ericksen, N.J. and Kenny, G.J., 2001, "Are Floods Getting Worse in the Ganges, Brahmaputra and Meghna Basin?", *Environmental Hazards*, 3, pp. 38-48.

Mirza, M.M.Q., 1997, "Modeling the Effects of Climate Change on Flooding in Bangladesh", D.Phil. Thesis, International Global Change Institute (IGCI), University of Waikato, Hamilton, New Zealand.

Mirza, M.M.Q., 2002, "Global Warming and Changes in the Probability of Occurrence of Floods in Bangladesh and Implications", *Global Environmental Change*. Vol 12: 127-138.

Mirza, M.M.Q., 2005. Hydrologic Modeling Approaches for Climate Impact Assessment in South Asia, in M.M.Q. Mirza and Q.K. Ahmad (eds.), Climate Change and Water Resources in South Asia, Balkema Press, Leiden, pp. 23-54.

Mirza, M.M.Q., A. Dixit and A. Nishat (eds.), 2003, "Flood Problem and Management in South Asia", Kluwer Academic Publishers, Dordrecht, pp. 230.

Mirza, M.M.Q., and Ahmed, A.U., 2003. Climate Change and Water Resources in South Asia: Vulnerabilities and Coping Mechanisms – A Synthesis, in A. Muhammed (ed.), Climate Change and Water Resources in South Asia, Asianics AgroDev International, Islamabad, pp. 202-228.

Mirza, M.Q. and Paul, S., 1992, "Natural Disaster and Environment in Bangladesh" (in Bengali), Centre for Environmental Studies and Research, Dhaka.

MPO, 1991, "National Water Management Plan: Phase II, Final Report", Master Planning Organization (MPO), Ministry of Irrigation, Water Development and Flood Control, Government of the People's Republic of Bangladesh, Dhaka.

Mullick, M. R. A., Tanim, A. H., & Islam, S. S. (2019). Coastal vulnerability analysis of Bangladesh coast using fuzzy logic based geospatial techniques. *Ocean & Coastal Management*, *174*, 154-169.

Mushar, S. H. M., Ahmad, S. S. S., Kasmin, F., & Kasmuri, E. (2019). Flood Damage Assessment: A Preliminary Studies. *Environmental Research, Engineering and Management*, *75*(3), 55-70.

Mushar, S. H. M., Ahmad, S. S. S., Kasmin, F., & Kasmuri, E. (2019). Flood Damage Assessment: A Preliminary Studies. *Environmental Research, Engineering and Management*, *75*(3), 55-70.

Nelson, D.I., 2003. 'Health Impacts Assessment of Climate Change in Bangladesh', *Environmental Impact Assessment Review*, **23**, pp. 323-341.

Neumayer, E., Plümper, T., & Barthel, F. (2014). The political economy of natural disaster damage. *Global Environmental Change*, *24*, 8-19.

Nizamuddin, K., Khuda, Z.R.M.M., and Ahmad, N., 2001, "Women-headed Households Displaced by River Bank Erosion: Problems and Strategies of Survival", in Nizamuddin, K. (ed.) *Disaster in Bangladesh: Selected Readings*, Disaster Research Training and Management Centre, Dhaka, pp. 49-60.

Rahman, A.A., Huq, S., and Conway, G.R., 1990, "Environmental Aspects of Surface Water Systems of Bangladesh: An Introduction", in *Environmental Aspects of Surface Water Systems of Bangladesh,* A. A. Rahman, S. Huq and G. R. Conway (Eds.), University Press Ltd. Dhaka, Bangladesh.

Rahman, M. H., Rahman, M. S., & Rahman, M. M. (2017). Disasters in Bangladesh: Mitigation and management. *Barisal University Journal Part*, *1*(4), 1.

Rahman, M. M., Hossain, M. A., & Bhattacharya, A. K. (2014). An analytical study of flood management in Bangladesh. *IOSR Journal of Engineering (IOSR-JEN)*, *4*(1), 01-06.

Rashid, H.E., 1991, "Geography of Bangladesh" (Second Revised Edition), The University Press Ltd., Dhaka.

Rodó, X., M. Pascual, G. Fuchs, and A.S.G. Faruque. 2002. ENSO and Cholera: A Nonstationary Link Related to Climate Change? *Proceedings of the National Academy of Sciences* 99:12901-12906.

RVCC, 2003. Report of a Community Level Vulnerability Assessment Conducted in Southwest Bangladesh. A report prepared by the Reducing Vulnerability to Climate Change (RVCC) Project, CARE Bangladesh, Dhaka.

Schaerer, C. and Ahmed, A.U., 2004. Adaptation to Climate Change in Vulnerable Communities: Lessons from Practice in Southwestern Bangladesh, in A.U. Ahmed and Haque, N. (eds.), Adaptation to Climate Change: Knowledge Sharing for Capacity Building, Proceedings of Workhop held on 10 december 2003 at COP 9 Milan, Climate Action Network South Asia (CANSA) and RVCC, Dhaka.

Siddiqi, M.H., 1997, "Floods: Problems and Prospects", Paper presented at the Workshop on observance of the International Decade for Natural Disaster Reduction 1997, Organized by the Disaster Management Bureau, Ministry of Disaster Management and Relief, The Government of the People's Republic of Bangladesh (GoB), Dhaka, 8 October 1997.

Siddique, Q.I. and Chowdhury, M.M.H., 2000, "Flood '98: Losses and Damages", in Q.K. Ahmad *et al*., (Eds.), *Perspectives on Flood 1998*, The University Press Limited (UPL), Dhaka, pp. 1-13.

Smit, B. (ed.): 1993, *Adaptation to Climatic Variability and Change*, Environment Canada, Guelph.

Smit, B., Burton, I., Klien, R.J.T., and Wandel, J., 2000. An Anatomy of Adaptation to Climate Change and Variability, Climatic Change, 45(1): 223-251.

Smith JB, Bhatti N, Menzhulin G, Benioff R, Campos M, Jallow B, Rijsberman F, Budyko MI, Dixon RK (eds) 1996. Adapting to Climate Change: An International Perspective. New York: Springer-Verlag. 476p.

Stakhiv, E.: 1993, *Evaluation of IPCC Adaptation Strategies*, Institute for Water Resources, U.S. Army Corps of Engineers, Fort Belvoir, VA, draft report.

Thieken, A. H., Ackermann, V., Elmer, F., Kreibich, H., Kuhlmann, B., Kunert, U., ... & Seifert, J. (2009). Methods for the evaluation of direct and indirect flood losses. In *RIMAX Contributions at the 4th International Symposium on Flood Defence (ISFD4)*. Deutsches GeoForschungsZentrum GFZ.

Thomalla, F., Cannon, T., Huq, S., Klien, R.J.T. and Schaerer, C., 2005. Mainstreaming Adaptation to Climate Change in Coastal Bangladesh by Building Civil Society Alliances. An IIED Publication available in website: *www.iied.org/CC/documents/CC_Publications_List.pdf*

UNEP, 1996, *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*, Version 1.3, United Nations Environment Programme. Later on published as Feenstra *et al*, 1998 by UNEP.

Uzzaman, M. A. (2014). Impact of sea level rise in the coastal areas of Bangladesh: A macroeconomic analysis. *Journal of Economics and Sustainable Development*, *5*(18), 105-109.

WARPO-Halcrow et al., 2004. National Water Management Plan, Water Resources Planning Organization (WARPO), Government of the People's Republic of Bangladesh (GOB) and Sir William Halcrow and Associates, Dhaka.

Warrick, R.A. and Ahmad, Q.K. (Eds.), 1996, "The Implications of Climate and Sea-Level Change for Bangladesh", Kluwer Academic Publishers, Dordrecht, Boston, London. 415 pp.

Watson, R.T., Zinyowera, M.C., and Moss, R.H.: 1996, *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analysis*. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

WB, 2000, "Bangladesh: Climate Change and Sustainable Development. Report No. 21104-BD", Rural Development Unit, South Asia Region, The World Bank (WB), Dhaka, pp. 95.

Zadeh, L 1997, 'Toward a theory of fuzzy information granulation and its centrality in human reasoning and fuzzy logic', Fuzzy Sets and Systems, vol. 90, No. 2, pp. 111–127.

ANNEXURES 01: SAMPLER QUESTIONS

Polder NO

Group

Record your current location

GPS location of the respondent's

latitude (x.y °)

longitude (x.y °)

altitude (m)

accuracy (m)

Village name

Union name

Upazila name

District name

Name of the respondent

Mobile Number

Age

Main income source of the household

Total monthly income of the household

- No income
- 0-5000
- 5001-10000
- 10001-15000
- 15001-20000
- 20001-30000
- 30001-40000
- 40001-60000
- 60001-above

Is the respondent receive any flood early warning?

- Yes
- No

If yes, then lead-time?

Total asset value of the Household

Lands (amount in BDT)

Ponds (amount in BDT)

Household assets (amount in BDT)

Cattle (amount in BDT)

Poultry (amount in BDT)

Others (amount in BDT)

Flood duration (days)

____

Water depth (m)

____

Type of house

____

Size of house (sqm)

____

Total damages of house (taka)

____

Cost of repair of house (taka)

____

Market value of the house (taka)

____

Total agricultural lands (acres)

____

Total crop damage

____

Total pond area damage (acres)

____

Total fish damage

____

Total damage of cattle/poultry

____

Total damage of other household assets

____

Costs to buy drinking water

____

Flood (Aila, May 2009) Information with damages of the household

Flood duration (days)

____

Water depth (m)

Type of house

Size of house (sqm)

Total damages of house (taka)

Cost of repair of house (taka)

Market value of the house (taka)

Total agricultural lands (acres)

Total crop damage

Total pond area damage (acres)

Total fish damage

Total damage of cattle/poultry

Total damage of other household assets

Costs to buy drinking water

Flood (Heavy Rainfall 2010) information with damages of the household

Flood duration (days)

Water depth (m)

Type of house

Size of house (sqm)

Total damages of house (taka)

Cost of repair of house (taka)

Market value of the house (taka)

Total agricultural lands (acres)

Total crops damage

Total pond area damage (acres)

Total fish damage

Total damage of cattle/poultry

Total damage of other household assets

Costs to buy drinking water

Flood (Tidal affect, 2012) information with damages of the household

Flood duration (days)

Water depth (m)

Type of house

Size of house (sqm)

Total damages of house (taka)

Cost of repair of house (taka)

Market value of the house (taka)

Total agricultural lands (acres)

Total crops damage

Total pond area damage (acres)

Total fish damage

Total damage of cattle/poultry

Total damage of other household assets

Costs to buy drinking water

Flood (Bulbul, Nov 2019) information with damages of the household

Flood duration (days)

Water depth (m)

Type of house

Size of house (sqm)

Total damages of house (taka)

Cost of repair of house (taka)

Market value of the house (taka)

Total agricultural lands (acres)

Total crops damage

Total pond area damage (acres)

Total fish damage

Total damage of cattle/poultry

Total damage of other household assets

Costs to buy drinking water

Flood (Amphan, May 2020) information with damages of the household

Flood duration (days)

Water depth (m)

Type of house

Size of house (sqm)

Total damages of house (taka)

Cost of repair of house (taka)

Market value of the house (taka)

Total agricultural lands (acres)

Total crops damage

Total pond area damage (acres)

Total fish damage

Total damage of cattle/poultry

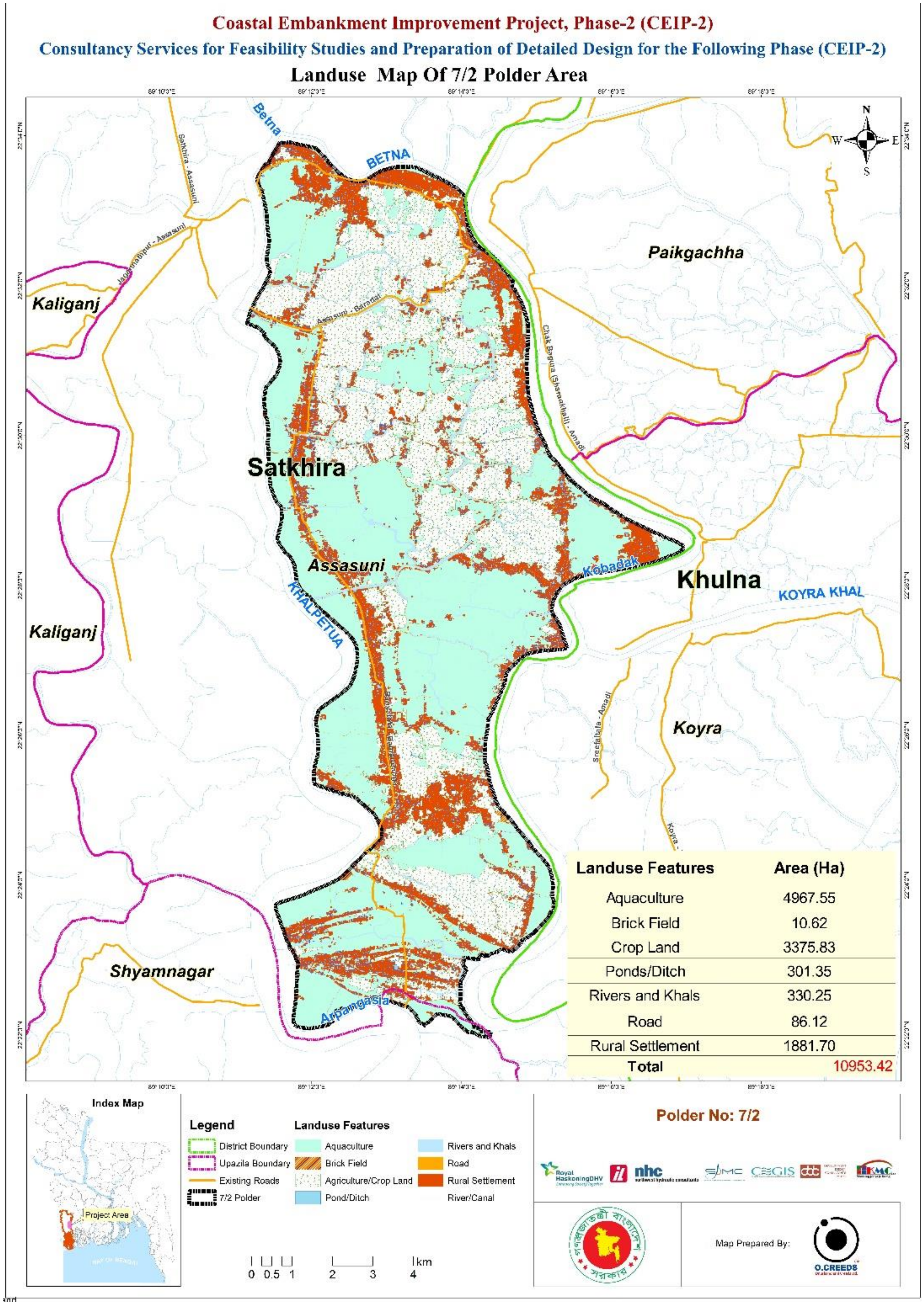
Total damage of other household assets

Costs to buy drinking water

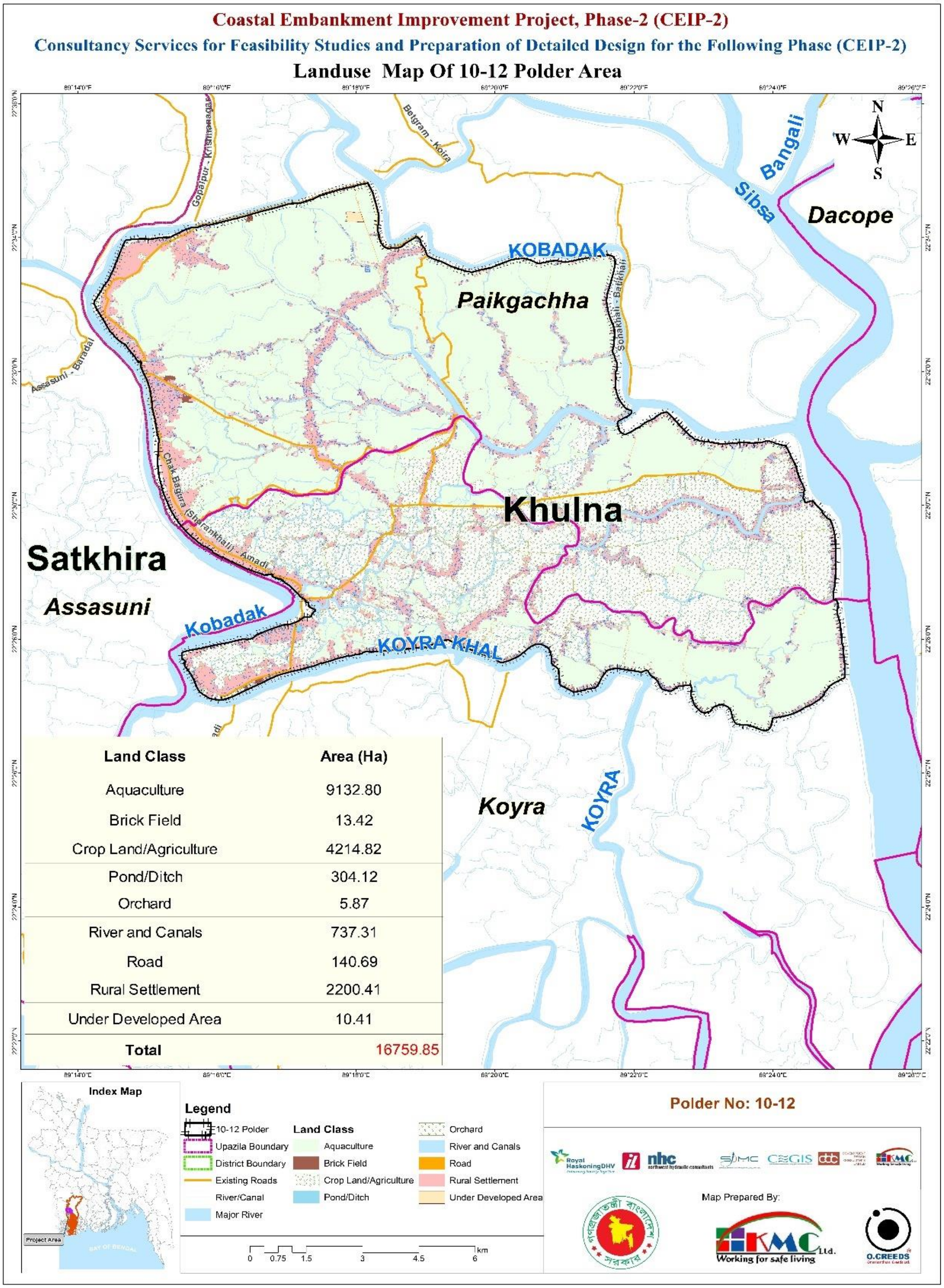
Surveyor Name

Remarks

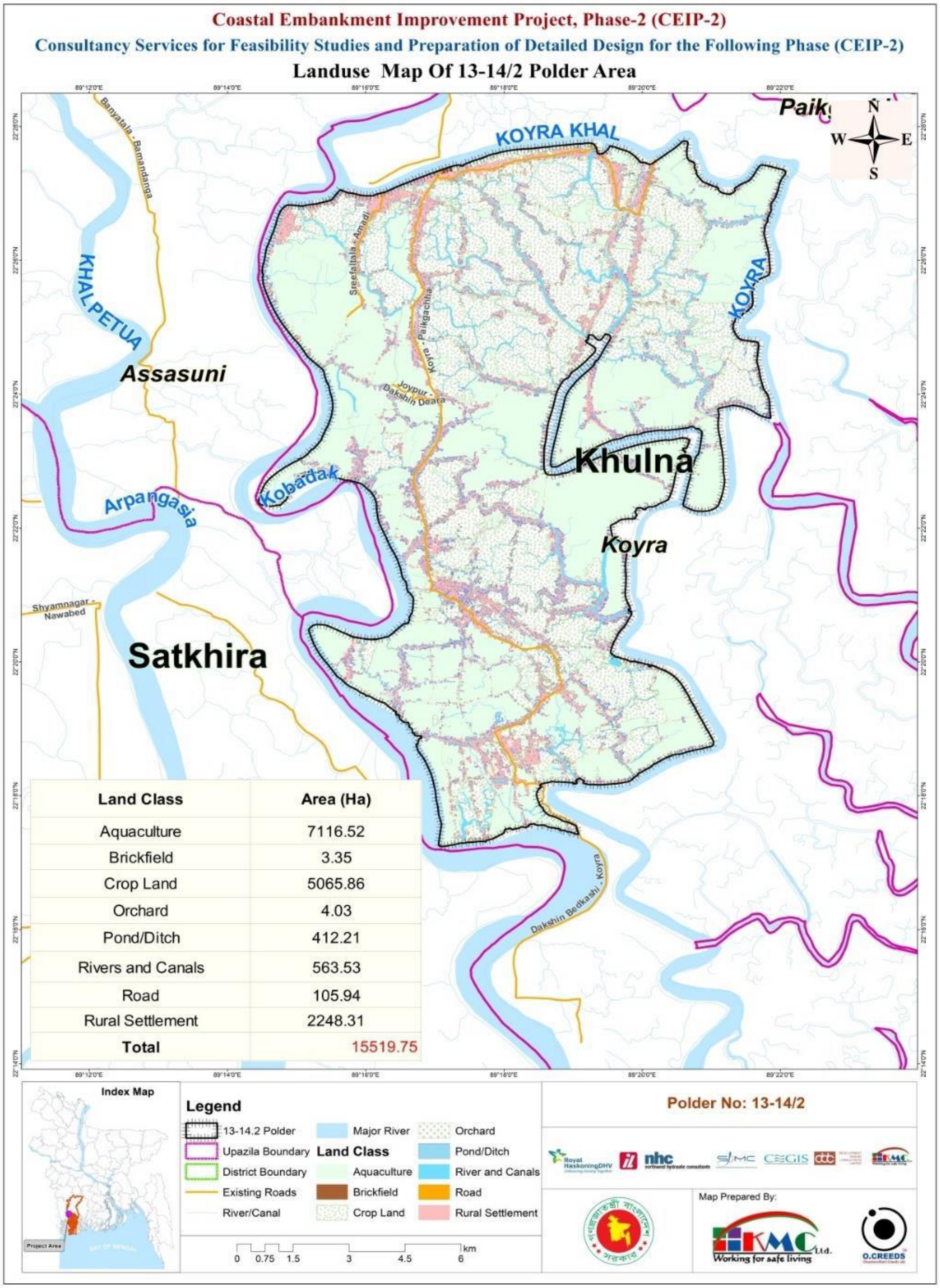
ANNEXURES 02: DIFFERENT MAP SCENARIO



Landuse Features	Area (Ha)
Aquaculture	4967.55
Brick Field	10.62
Crop Land	3375.83
Ponds/Ditch	301.35
Rivers and Khals	330.25
Road	86.12
Rural Settlement	1881.70
Total	10953.42



Land Class	Area (Ha)
Aquaculture	9132.80
Brick Field	13.42
Crop Land/Agriculture	4214.82
Pond/Ditch	304.12
Orchard	5.87
River and Canals	737.31
Road	140.69
Rural Settlement	2200.41
Under Developed Area	10.41
Total	16759.85



Land Class	Area (Ha)
Aquaculture	7116.52
Brickfield	3.35
Crop Land	5065.86
Orchard	4.03
Pond/Ditch	412.21
Rivers and Canals	563.53
Road	105.94
Rural Settlement	2248.31
Total	15519.75

ANNEXURES 03: FGD SAMPLES

CCD 522 THESIS

FOCUS GROUP DISCUSSION (FGD) OF POLDERS

GENERAL INFORMATION

a. Polder ID:	10-12
b. Polder Description:	
c. Lat-Long	Lat: Long:
d. FGD Number:	01
e. FGD Meeting Date:	18.08.2022
f. FGD Meeting Place:	Santa Bazar
g. Name of Village & Union located:	Village: Santa Union: Goroimari
h. Name of Upazila & District located:	Upazila: Paikgacha District:

FLOOD - DAMAGE

Q1. What are the experiences on the current Flooding situation of the existing Polder?	2'-3' Water over topped. Houses Damaged.
Q2. What are the damages of the polder or structures due to cyclones?	School Building Damaged Bazar damaged Houses, shops.
Q3. How would you like to see your Polder ensure safety at any Cyclone?	5~6 feet ensure safety. Many people stay. here.
Q4. What would you suggest for the embankment height of the Polder due to the SLR and Climate Change?	15~20 Hazar BDT. Gate damaged. BWDB no sanctions.
Q5. What are the impacts of Cyclones for daily livelihoods and agricultures?	Small small NGO. No government donation Paddy → 18 mon/acre.

1 | Page

CCD 522 THESIS

Q6. Who do you think to monitor the proper use of Polder during Normal time and Disaster time?	Normal time: No monitor fr. BWDB Disaster time No monitor fr. BWDB Small foods.
Q7. On average how many people used the Polder for staying during the last cyclone?	4000 Voter of this WARD. NO CS. Need s at leaft one cs.
Q8. On average how many days do the refugees stay at the top of a Polder?	I km (5/6 days) Collage. (600 BDT for work) when poldor will be constr:
COMMUNITY BASED ADAPTATION (CBA)	
Q9. Do you have any idea about the CBA? (YES/ NO)	Ans: NO.
1. What is CBA?	Community-Based Adaptation (CBA) is an important component of the larger picture of management and avoidance of Climate Change impacts and pressures by local people. It provides information and concrete examples on potential impacts of climate change and mitigative measures which are location specific and community managed.
2. Any Example of CBA?	Commonity based adaptaion floating garden.
LOCALLY LED ADAPTATION (LLA)	
Q10. Do you have any idea about the LLA? (YES/ NO)	NO
1. What is LLA?	Locally Led Adaptation (LLA) can unlock, support and leverage the enormous potential and creativity of communities to develop and implement solutions. Shifting power to local stakeholders, without expecting them to shoulder the burden of adaptation, can catalyze adaptation that is effective, equitable, and transparent.
2. Any Example of LLA?	No LLA of

2 | Page

CCD 522 THESIS

FOCUS GROUP DISCUSSION (FGD) OF POLDERS

GENERAL INFORMATION	
a. Polder ID:	13 - 14
b. Polder Description:	
c. Lat-Long	Lat: Long:
d. FGD Number:	02
e. FGD Meeting Date:	18.08.2022
f. FGD Meeting Place:	
g. Name of Village & Union located:	Village: 4 No. KOIRA Union: KOIRA
h. Name of Upazila & District located:	Upazila: District:

FLOOD - DAMAGE	
Q1. What are the experiences on the current Flooding situation of the existing Polder?	2'-3' Flood water over topped.
Q2. What are the damages of the polder or structures due to cyclones?	Houses dmaged.
Q3. How would you like to see your Polder ensure safety at any Cyclone?	02 CS nearby
Q4. What would you suggest for the embankment height of the Polder due to the SLR and Climate Change?	4'-5' over top for embankment top.
Q5. What are the impacts of Cyclones for daily livelihoods and agricultures?	05~06 livelihood days affected. Fisheries.

1 | Page

CCD 522 THESIS

COVID 19 IMPACTS	
Q11. Do you have any negative or positive impacts of COVID19 at your community?	No movements. No sell.
Q12. Any Impacts on Livelihood?	Loan by people.
Q13. Any Impacts on Agriculture?	No agri.
Q14. Do you all get vaccination?	YES.
Q15. Any COVID 19 Patitent or dead people into the community?	NO. (Age 75+)
NATURE-BASED SOLUTIONS (NbS) Nature-based solutions (NbS) involve working with nature to address societal challenges, providing benefits for both human well-being and biodiversity.	
Q16. Do you have any idea about the NbS?	No idea.
Q17. Any implementation of NbS in your community?	No idea. Not Clear.
Q18. Do you wish to learn more about the implementation of NbS?	YES.

FIELD SURVEY COMPILED BY:	
Name: MD. Shahadat Hossain	Signature: Shahadat
Designation: M.Sc. Thesis	Date: 18/08/2022

3 | Page

ANNEXURES 04: KII SAMPLES

CCD 522 THESIS

KEY INFORMANT INTERVIEW (KII) OF POLDERS

GENERAL INFORMATION	
a. Polder ID:	10-12
b. Polder Description:	
c. Lat-Long	Lat: Long:
d. Name of the Person:	MD. SHAFIQUL GAZI
e. Contact Number:	01828286235
f. Signature:	[illegible]
g. Name of Village & Union located:	Village: FOKIRABAD Union: KOPILMONI
h. Name of Upazila & District located:	Upazila: PAIKGACHA District:

FLOOD - DAMAGE	
Q1. What are the experiences on the current Flooding situation of the existing Polder?	FLOODED. 2 KM CYCLONE
Q2. What are the damages of the polder or structures due to cyclones?	Houses and roads damaged. People go to CS.
Q3. How would you like to see your Polder ensure safety at any Cyclone?	Water canals to gates. BWDB control.
Q4. What would you suggest for the embankment height of the Polder due to the SLR and Climate Change?	3'-4' → Better for damaged. con..
Q5. What are the impacts of Cyclones?	Libelihoods: Agriculture: Horina, Bagda, Renu Rivers. (300~500 BDT)

1 | Page

CCD 522 THESIS

Q6. Who do you think to monitor the proper use of Polder during Normal time and Disaster time?	Normal time: No time of BWDB for OnM. Disaster time: No one come.
Q7. On average how many people used the Polder for staying during the last cyclone?	Some people came by people. Madrasha. Per ~~yr~~ 4/5 times.
Q8. On average how many days do the refugees stay at the top of a Polder?	5~7 at CS. CS almost (2.5 km/3 km)
COMMUNITY BASED ADAPTATION (CBA)	
Q9. Do you have any idea about the CBA? (YES/ NO)	**Ans:** NO
1. What is CBA?	Community-Based Adaptation (CBA) is an important component of the larger picture of management and avoidance of Climate Change impacts and pressures by local people. It provides information and concrete examples on potential impacts of climate change and mitigative measures which are location specific and community managed.
2. Any Example of CBA?	Saline water. cows, gun.
LOCALLY LED ADAPTATION (LLA)	
Q10. Do you have any idea about the LLA? (YES/ NO)	**Ans:** NO
1. What is LLA?	Locally Led Adaptation (LLA) can unlock, support and leverage the enormous potential and creativity of communities to develop and implement solutions. Shifting power to local stakeholders, without expecting them to shoulder the burden of adaptation, can catalyze adaptation that is effective, equitable, and transparent.
2. Any Example of LLA?	

CCD 522 THESIS

COVID 19 IMPACTS	
Q11. Do you have any negative or positive impacts of COVID19 at your community?	nothing
Q12. Any Impacts on Livelihood?	Stop.
Q13. Any Impacts on Agriculture?	Totally stop.
Q14. Did you get vaccination?	YES.
Q15. Any COVID 19 Patitent or dead people into the community?	NO. (Age → 70+)

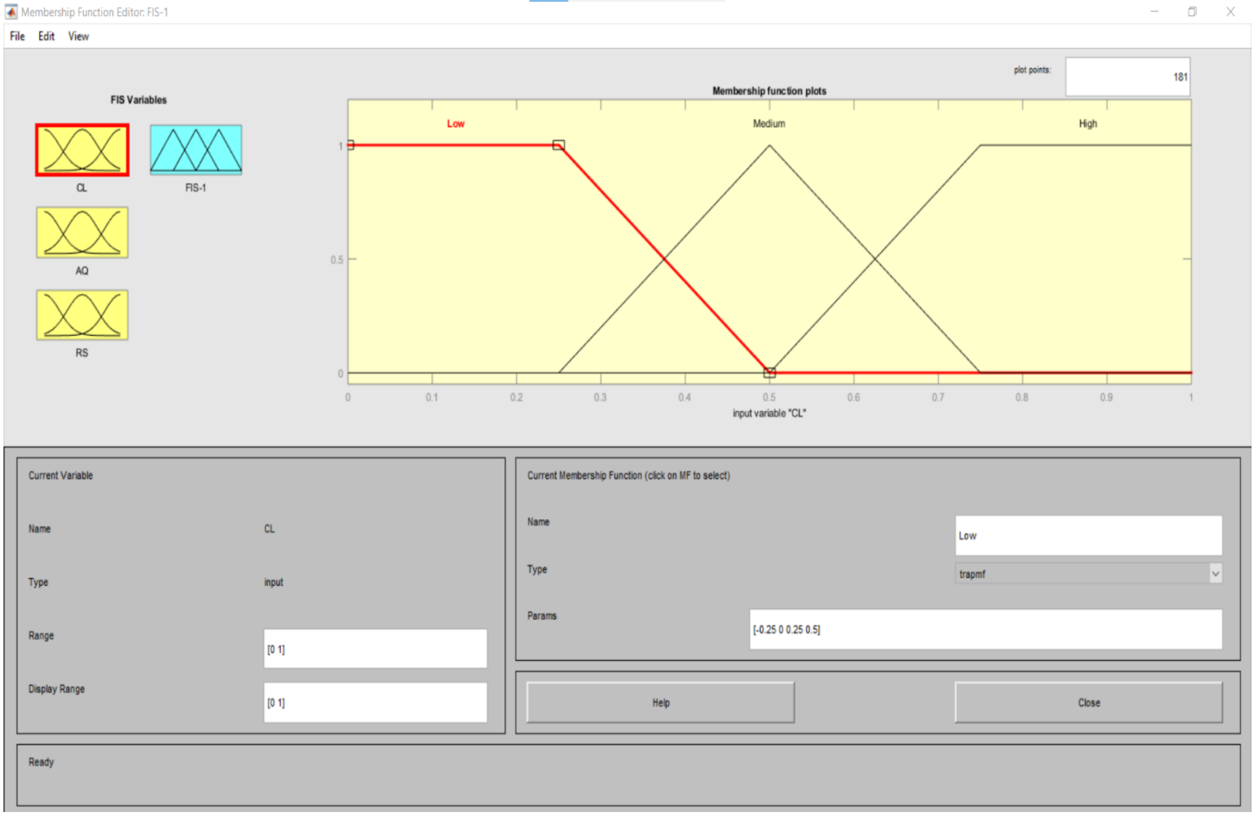
NATURE-BASED SOLUTIONS (NbS) Nature-based solutions (NbS) involve working with nature to address societal challenges, providing benefits for both human well-being and biodiversity.	
Q16. Do you have any idea about the NbS?	Ans:
Q17. Any implementation of NbS in your community?	
Q18. Do you wish to learn more about the implementation of NbS?	

FIELD SURVEY COMPILED BY:	
Name: Shahadat Hossain	Signature:
Designation: M.Sc.	Date: 18/08/2022

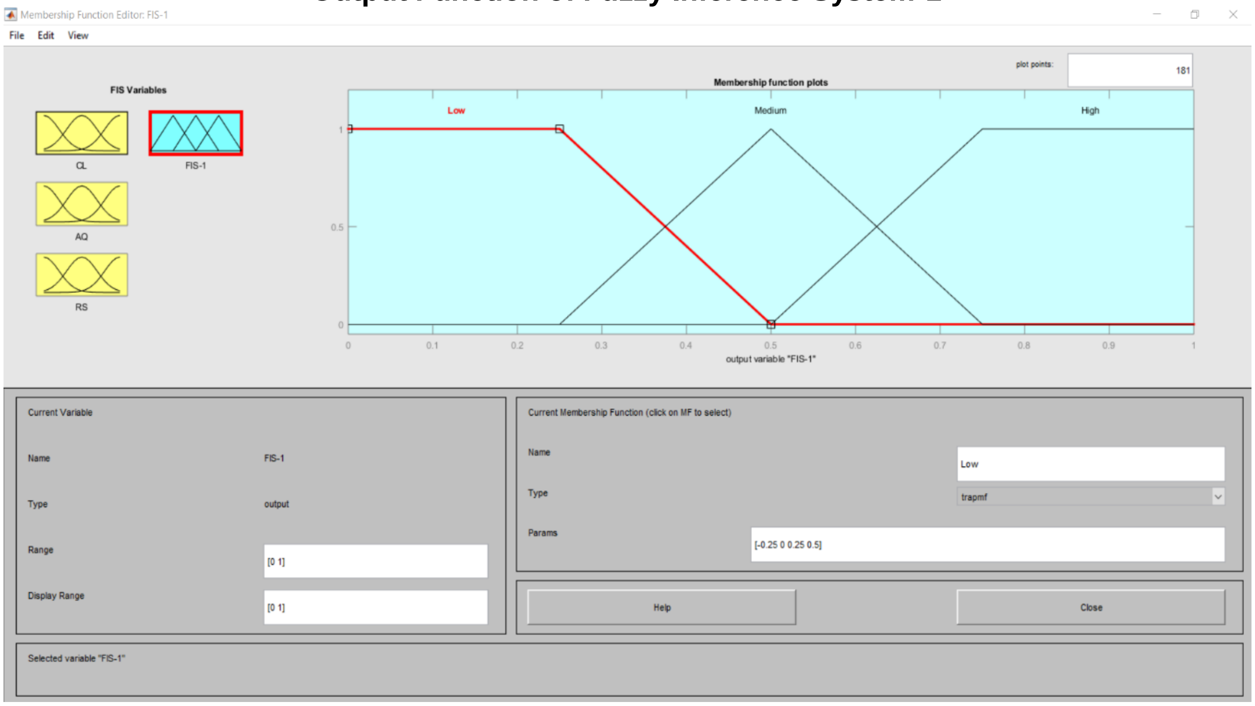
3 | Page

ANNEXURES 05: FUZZY INFERENCE SYSTEM- MODEL SNAPSHOT

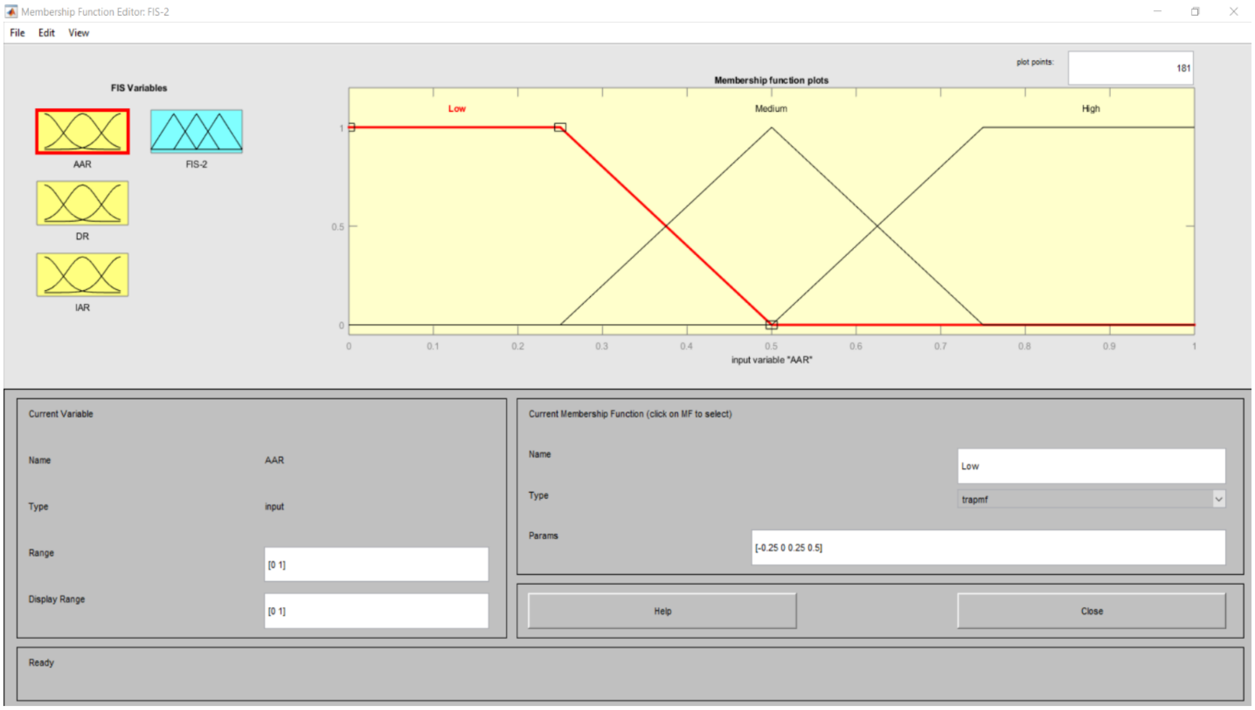
Input Function of Fuzzy Inference System-1



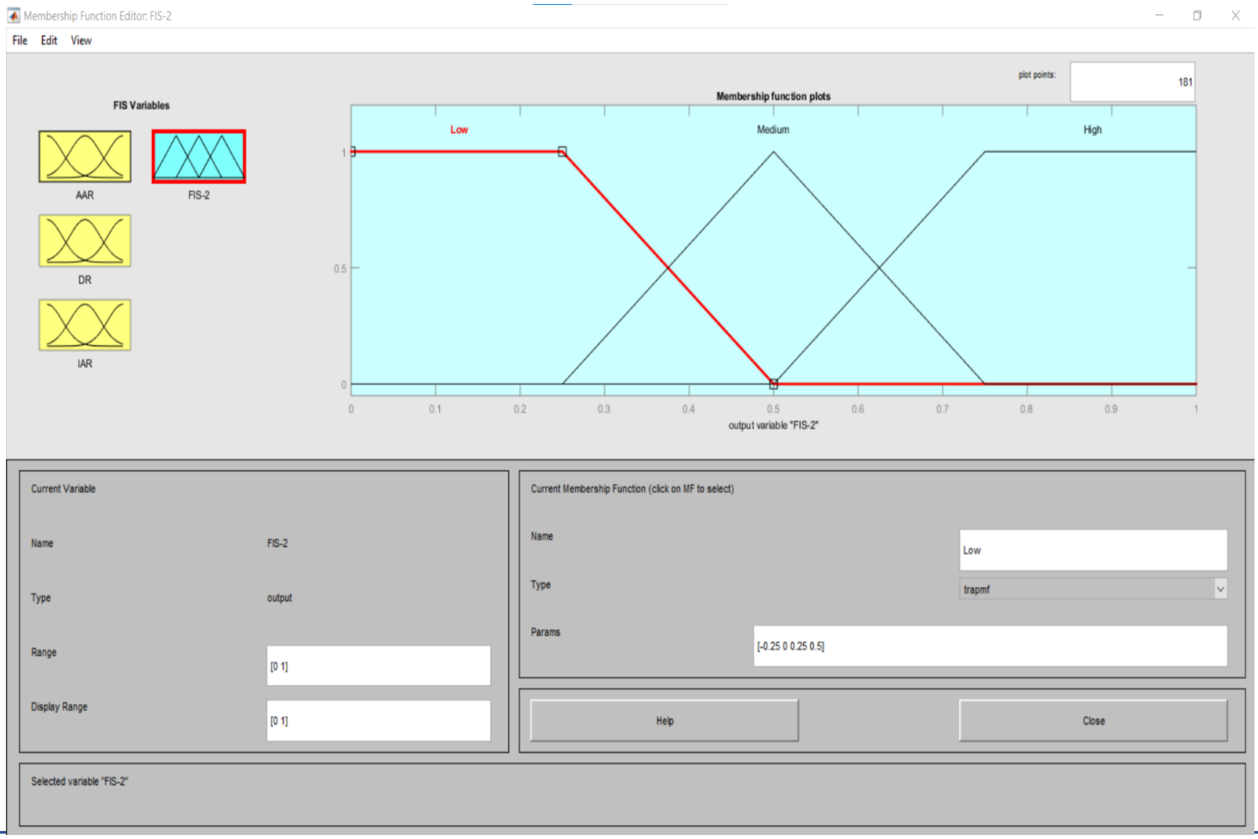
Output Function of Fuzzy Inference System-1



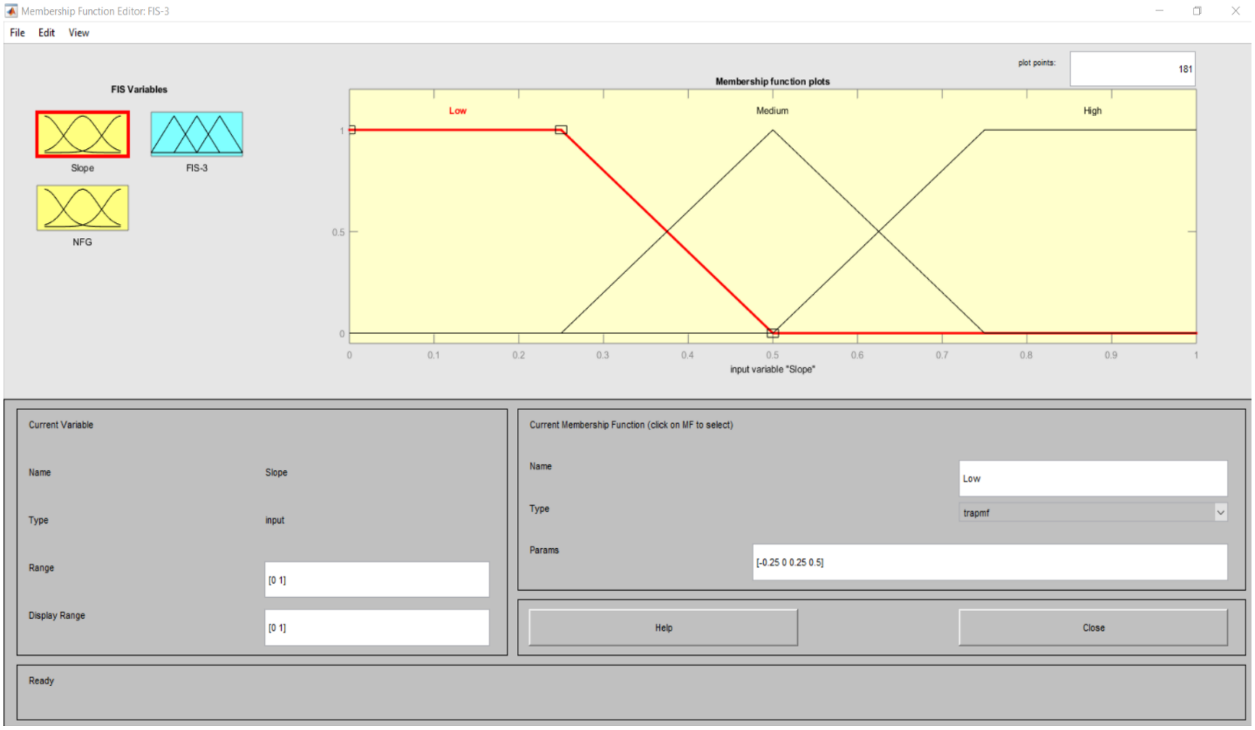
Input Function of Fuzzy Inference System-2



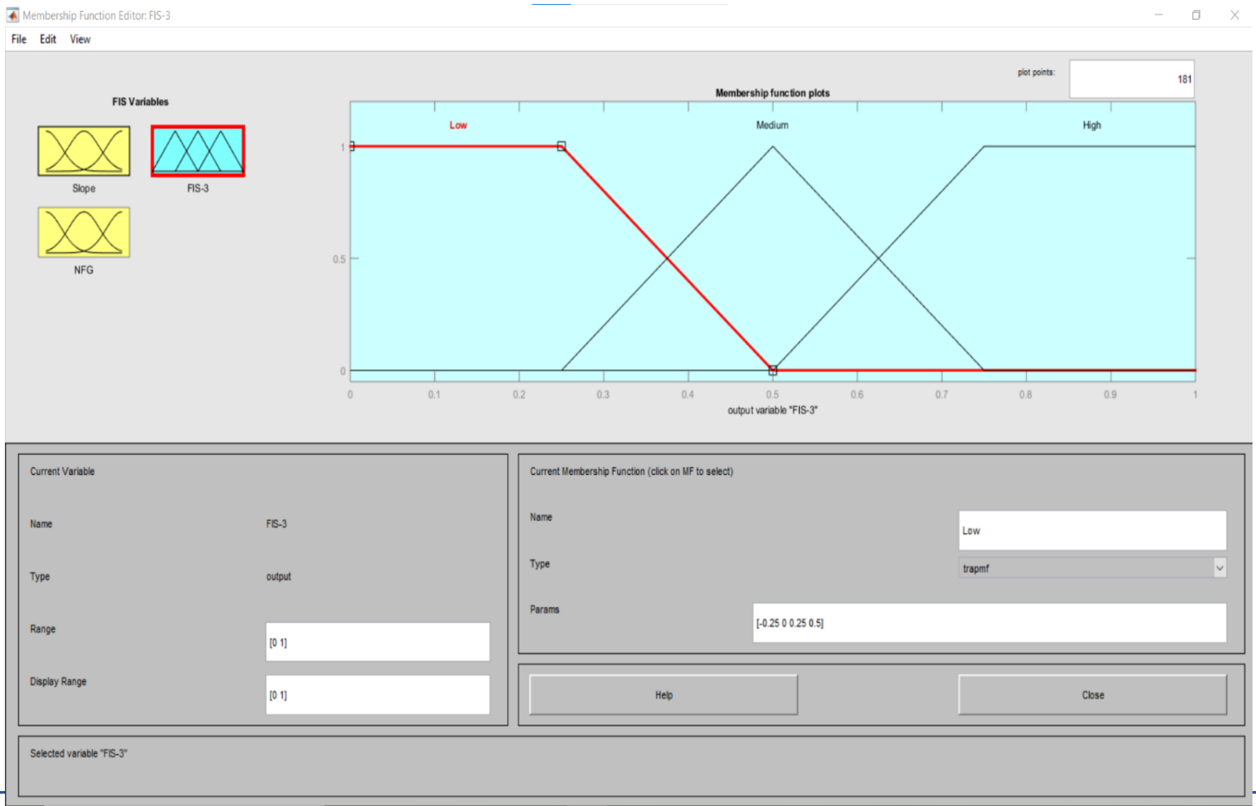
Output Function of Fuzzy Inference System-2



Input Function of Fuzzy Inference System-3

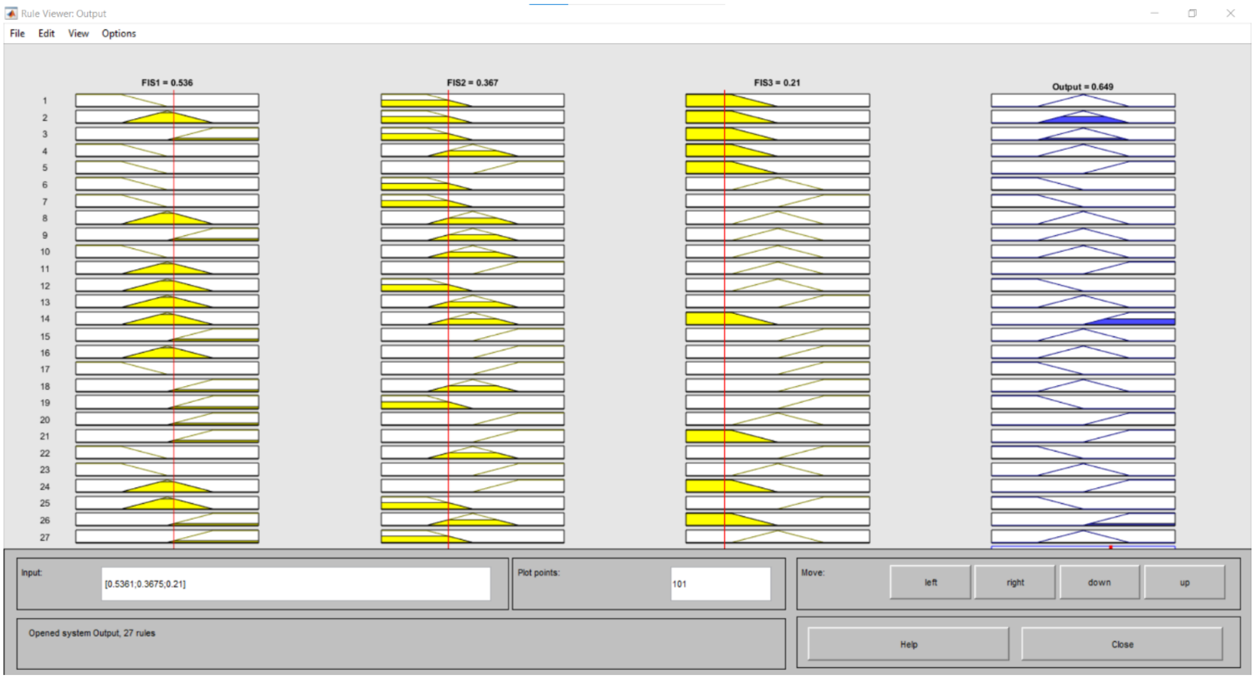


Output Function of Fuzzy Inference System-3

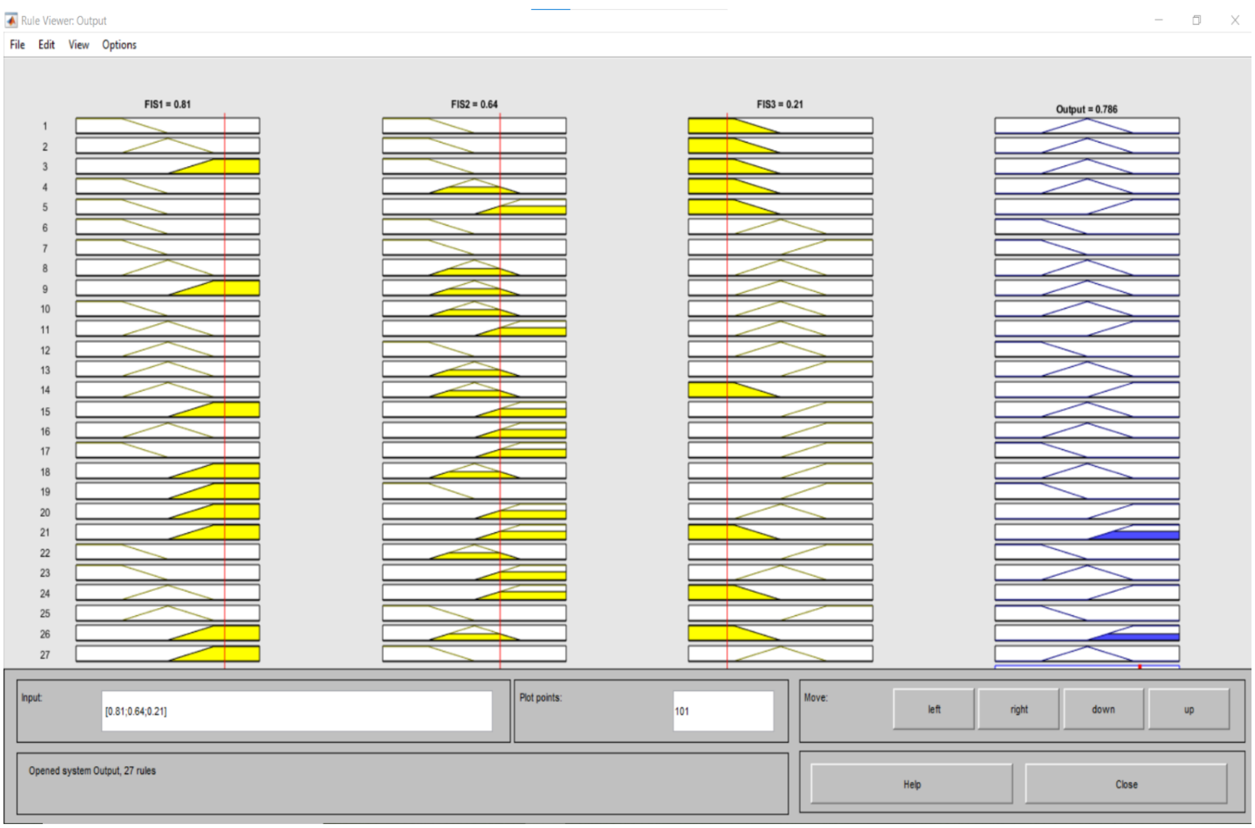


Final Output Combining Three Fuzzy Systems

Polder- 7/1



Polder- 7/2



Polder- 10/12

Polder- 13/14