IMPACTS OF STRUCTURAL FLOOD MITIGATION MEASURE ON LIVELIHOOD: COMPARATIVE STUDY OF THREE SETTLEMENTS IN TANGUAR HAOR, SUNAMGANJ, BANGLADESH

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A thesis submitted to the Department of Architecture in partial fulfillment of the requirements for the degree of Master in Disaster Management

Department of Architecture
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Declaration

It is hereby declared that.

1. This thesis paper I submitted for my master's degree at BRAC University is entirely my own original work.
2. Unless properly credited and referenced, no published or written content from other parties is utilized in the thesis.
3. Nothing that has been submitted or approved for credit towards any other degree or certificate from a university or other organization is included in the thesis.
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Approval

The thesis with a title "Impacts of Structural Flood Mitigation Measures on Livelihood: Comparative Study of Three Settlements in Tanguar Haor, Sunamganj, Bangladesh." submitted by Alvi Md. Ragib Nihal Khan (ID: 24168001) of Spring, 2024 has been certified as having completed the requirements for the Master of Disaster Management degree on 30th August 2025.

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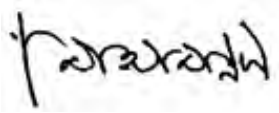

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Ethics Statement

Full procedure was executed along honesty, ethical and moral appropriateness, considering the social, financial, and ecological consequences of choices and actions, as well as legal obligations.

First, each authority agreed to participate in the survey. After that, everyone in the research regions granted their consent.

Before the field survey could begin, all authorities agreed to participate in the survey. After receiving permission from each authority to inspect their facilities, survey respondents were informed of the study's objectives. The technique and sample size were used to choose each responder. Every action, including talking to staff and volunteers and taking photos, was carried out with their permission. The "not harm" strategy and beneficence principles were followed while conducting the field survey. Throughout the examination of their home amenities, without interfering with their everyday routine, their confidentiality and honor were maintained. One of the core ethical principles guiding this study is respect for law and policy, while also protecting privacy throughout the data-gathering and analysis process. There were no activities in the trial that may have put participants at risk or caused them any discomfort.

Every instance of intellectual property utilized in this research is properly acknowledged and referenced. The entire study procedure is carried out impartially. The entire research design, data analysis, and portrayal are comprehensive and exhaustive, ensuring that any potential bias or prejudice is addressed.

Abstract

Tanguar Haor is in Sunamgonj, Bangladesh, adjacent to the Indian border. This area experiences flooding annually due to its geographical conditions and location. In the north lie the Meghalaya hills, from which the Haor receives several hill streams. During the monsoon, water from upstream flows north and fills the Haor area. During this flood, villages are submerged by floodwater. Specifically, the water-edge houses face the risk of floodwater and erosion. Every year, flash floods and seasonal floods cause damage to their household, cattle shed, and other properties, resulting in repair and rebuilding costs that impact their economy and growth. To prevent this damage and ensure a good livelihood, every village has a protection wall. Three types of protection walls, brick walls, concrete blocks, and earth-filled sack walls, are seen in the Tanguar Haor area.

This is a Comparative study where three different villages are selected based on the types of protection walls; they have. The study examined which type of protection wall is more beneficial for sustained livelihood this will provide policymakers with vital knowledge for future interventions for flood mitigation in the Haor region.

This study uses a mixed-method approach. Three villages, Nichodropur, Solaimanpur, and Anondopur, were selected for the study. where a triangular analysis will be conducted to validate the findings, incorporating the results from the Questionnaire survey, Focus Group Discussions (FGD), Key Informant Interviews (KII), and all points that can be obtained from the FGD, KII, and questionnaire for justification will be justified by creating a link based on the DFID and Rural Housing's Livelihood Framework.

Among these three types of protection walls, brick protection walls were found to be the most effective, concrete blocks are moderately impactful, while earth-filled sack walls were the least beneficial to protect villagers' livelihoods.

By applying this knowledge, policymakers and various organizations can understand the results and implement this idea to improve the livelihoods of Tanguar Haor villagers.

Keywords: Structural flood mitigation, Protection wall, Livelihood, Flood, Tanguar Haor, Sunamganj

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I would like to thank BRAC University's Postgraduate Program in Disaster Management (PPDM) for allowing me to do this thesis paper on "Impacts of Structural Flood Mitigation Measures on Livelihood: Comparative Study of Three Settlements in Tanguar Haor, Sunamganj, Bangladesh."

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Chapter One
Introduction

1.1 Background

Bangladesh is located inside the floodplain of one of the biggest waterway systems in the world. Bangladesh is a country of swampland and waterways due to its extensive network of rivers and canals, as well as the seasonal infiltration of water into its low-lying areas. The physical coordinates of Tanguar Haor, it covers 9,727 hectares and is situated near the Indian border in Bangladesh's northeast, are 25° 06' to 25° 11' N and 91° 01' to 91° 06' E. (Chowdhury, 2010) The Meghalayan Hills are located to the north. The communities of Haor are isolated and in an island state. Tanguar Haor is home to approximately 25,000 people (Chowdhury, 2010) and comprises about 46 villages (Raihan & Hossain, 2021).

The Tanguar Haor Region resembles a basin. This region has been shaped by the Surma, Jadukata and Baulai Rivers. Approximately 31% of Tanguar Haor is allocated for agriculture, while around 50% is comprised of water bodies. (Chowdhury, 2010.) It has around fifty beels. In certain areas, rivers are connected to extensive beels, and these beels are linked to one another, lending the region a unique character. (Raihan & Hossain, 2021)

Summer, monsoon, and winter are likely the three primary seasons of Tanguar Haor (TH), which has a subtropical monsoon climate. The summer months of April through June have thermal condition range is from 30.9 °C to 33.4 °C. Temperatures vary from 8.5 to 16.6 degrees Celsius throughout the winter months of October through February. The wet season humidity is 83%, whereas the dry season humidity is 64%. People experience floods every year during the monsoon season (March to May), when large amounts of water flow from upstream. (Gourab Saha, Md. Najmul Kabir, Afrin Khandaker, 2022). In every year average rainfall is 8,000 mm. Spring receives 21-23% of the year's rainfall, while the autumn receives 6-8%. Flash floods occur in the Tanguar Haor (TH) region during the spring when evaporation increases rainfall.

There are 206 birds, 31 mammals, 141 species of fish, more than 200 species of wetland plant, 34 reptiles, 21 snakes, 7 lizards, and may all be found in this ecosystem (Gieson and Rashid, 1997). An average of 50,000 individuals of 70–80 species are found in Tanguar Harbour each year during the 1999–2000 fiscal year. Since Tanguar Harbour is the ideal place for their food and habitat, over 60 different species of migratory birds visit the area every winter. The Haor's fisheries alone brought in Tk 70,73,184 for the government (Talukder, 2006). More than 800

old, severely lopped trees make up the 8-hectare Rongchi "forest" (Gieson and Rashid, 1997). In recent years, Barringtonia racemosa has been transplanted on Kandas once again.

The hoar is a huge area that floods with structural mitigation. Levees or the banks of major river systems. As a result, water is always here, but more significantly, it is there even during the dry season. The water supply varies between 7000cbm per second in July and 220cbm per second in February.

Most of the villagers are farmers. Abedin & Khatun (2020) stated floods in the early and monsoon seasons significantly disrupt farming activities such as seedbed preparation, planting, harvesting, fishing, and everyday labour. Hailstorms mostly harm crops grown for vegetables. Villagers live in kands and, for the prevention of flood damage, build a protection wall in their kandas or village.

Food shortages, illegal hunting and human pressure, declining fish populations, and contaminated water because of as the loss of swamp forests and reed beds (GoB, 2004). heavy rainfall creates many problems, disrupting labour-intensive tasks, including soil excavation, fishing, and vegetable farming. Waterlogging and neither western-style seasonal storms have a detrimental impact on farming, agriculture, and vegetable output. According to (Abedin & Khatun, 2020), 53% of homes collapsed during floods, while the remaining 47% had significant damage that necessitated considerable repair costs. To prevent these villages, need durable protection walls.

Ramsar Convention recognition for global wetland importance and preservation of fish species, aquatic plants, and swamp forests (Ramsar site, 1999). To prevent damages, better livelihood and preserve biodiversity Bangladesh government take master plan and, prevent property damage Government organization LGED build protection wall with concrete block and brick. (Master Plan of Haor Area, 2012)

1.2 Problem Statement

Flooding is recognized as a significant natural catastrophe that alters lives and livelihoods by destroying homes, agricultural production, interrupting communication networks, and impacting the economy. (Islam et al., 2014; DeClerk et al., 2006).

They have to rebuild their houses every year, which impacts their living conditions and hampers their quality of life. Many properties were damaged due to the 1999, 2000, 2002, 2004, 2007, 2010, 2017, 2019, and 2020 flash floods. (Correspondent, 2022)

In Tanguar Haor, 2017 flood 8,642 houses damaged. Villagers were forced to migrate or sell cattle and assets. 19,100 families were affected. 1.41 lakh hectares of Boro paddy submerged.

Farmers lost their entire harvest. ("ANNUAL FLOOD REPORT 2017," n.d.), (Bangladesh: Floods in Northeast (Haor) Areas (April-May 2017) - Bangladesh, 2017), (Bangladesh: Flood Situation, 2017), (Roy, 2017) In 2022 flood, 4,900 hectares submerged after 3 levees destroy. Farmers guarded embankment overnight to prevent erosion. 5,000 hectares of crops were damaged in Haor area. (Star, 2022), (Shawn, 2022) and 2023 flood, 10,000 homes damaged. 1,000 people were affected and displaced. (UNB, 2023) To prevent local people from building non-durable protection walls which need repair and rebuilding every year. So, Bangladesh government also take a master plan on the Haor area and built protection wall by concrete blocks and brick but these protection wall also need maintenance cost and villagers spent money on it.

Villagers of the household try to cut costs for the household. In the attempt to rebuild houses they must sell other properties such as farming or non-farming land, bulls, trees, utensils etc.

Subsequently, in order to protect settlements and infrastructure from further flooding, people took some initial measures: people elevated their houses and the area of settlement (63%), sowed trees around the house for the prevention of soil erosion and wind action (74%) planted, protection wall around their village (31%) for preventing wave but this every year they (Joynal Abedin, Hafiza Khatun, 2019)

1.3 Aim and Objective

1.3.1 Aim

This research aims to examine the impact of the structural flood protection measures on the livelihoods of the villagers in Tanguar Haor.

1.3.2 Objectives

1. Evaluation of the effectiveness of three types of structural flood prevention measures on safeguarding livelihood.
2. Find out the impact of these three types of protection walls on the villagers' settlement and infrastructure, financial capacity, and social bondage.

1.4 Research Questions

1. What is the impact of a protection wall on livelihood?
2. Is the protection wall effective in safeguarding the settlement and infrastructure?
3. Does a structural mitigation system create a financial burden?
4. Does the protection wall impact neighbourhood bondage?

1.5 Study area

1.5.1 Tanguar Haor

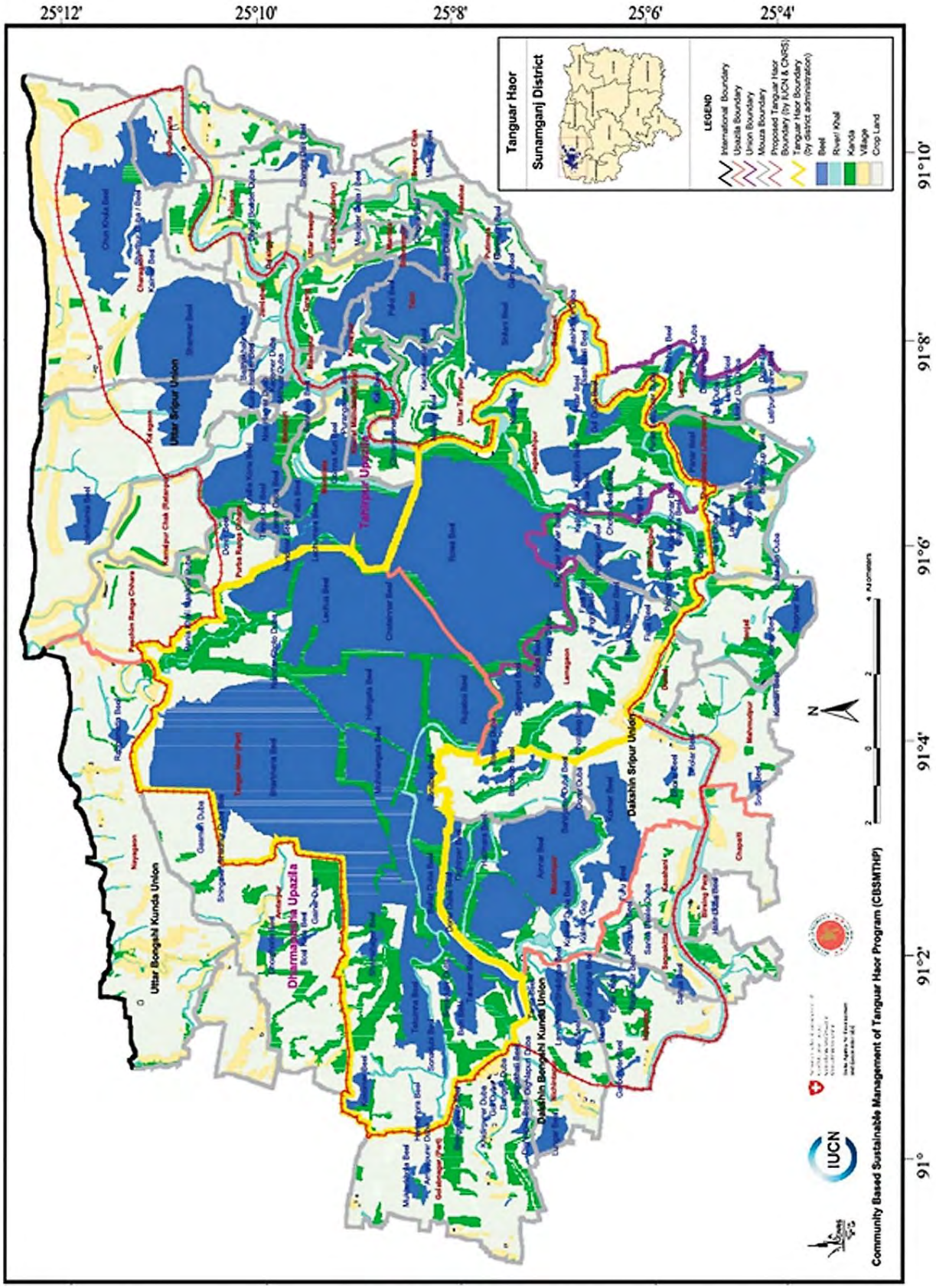


Fig-1: Tanguar Haor (IN FOCUS TANGUAR HAOR, 2009)

Tahirpur Road in Sunamgonj's Tanguar Haor (TH), which spans 9,727 hectares, was selected as the research site. The geographic coordinates are 91°01" to 91°06" E and 25° 06" to 25°11" N. The Dhanu Baulai, Surma, and Jadukata Rivers have an impact on this location. Several hill streams run to the Haor from the Meghalayan Hills in the north. Administratively, Tanguar Haor is located in the Sunamganj District of the Sylhet Division, with one-third of it in the Tahirpur Upazila and the remaining portion in the Dharmapasha Upazila. Water bodies comprise over 50% of Tanguar Haor's land area, with 31% designated as agricultural land. (Chowdhury, 2010) The Haor region fills with upstream water that travels north during the monsoon.

The terrain of Tanguar Haor is made up of five sizable centre depressions: Rowar, Rupaboi, Bherberia, Tangua, and Leehchamara. Low-lying plains, rising hills, and Indian Hills surround these areas. Approximately 30% of the 44 narrow water canals that slope down to these beels from Indian territory flow with water year-round. In contrast, the remaining ones only survive during the monsoon season. (Chowdhury, 2010) Huge sediments are produced by these water flows (small canals and rivers) to the Beels and nearby upland areas (villages), which are plainly traceable on a satellite map.

There are around fifty beels in Tanguar Haor. In some locations, deeper beels are linked to rivers, but these beels are also interconnected, giving them a distinct personality. The beels combine to create a single, sizable body of water known as a haor during the monsoon season, which runs from April or May until October. (Raihan & Hossain, 2021) Moreover, 55,000 people depend on it for their livelihood. (Karim, 2019)

1.5.2 Site

Fig-2: Location of three villages in Tahirpur, Tanguar Haor. (Source: Google Map)

Sunamgonj, Tahirpur Road, Tanguar Haor (TH) were the site areas. Indian Meghalaya lies to the north of Tahirpur Upazila, while Jamalganj Upazila lies to the south, Bishawmvarpur lies to the east, and Dharmapasha Upazila lies south. Sunamganj district is located 69 kilometres from the city of Sylhet, whereas Tahirpur upazila is 40 kilometres away from Sunamganj district. There are 129 km of embankments, 5 rivers, 14 canals, and 300.04 km of highways in this upazila. In all, this upazila is 336.70 square kilometres in size. Among the soil types found are loamy, sandy loamy, and buisues. There are 129 km of embankments in Tahirpur Upazila. Land used for agriculture is made up of sandy loam and loamy soils, which are quite fertile. Roads, pond sides, and irrigation canals are all naturally sandy and loamy. Mineral resources include sand and stones.

There are 20192 residences in the whole Tahirpur upazila. Of those, 1427 are being built, while 18765 are huts. Tahirpur Upazila has witnessed a wide range of residences. Huts, buildings, semi-brick homes, and tin homes are important types of these. Clay, tin, bamboo, ikar, and other materials are typically used to construct hut dwellings.

In Tahirpur Upazila, Joypur, Solaimanpur, and Ikrampur have concrete block protection walls. Chilani Tahirpur and Anondonagar have brick protection walls. Roton Sri, Poundu, Lamagau, and Nichodropur have earthen-filled sandbag protection walls. Those villages that did not have permanent protection walls have earthen-filled sandbag protection walls.

In these villages, Nichodropur, Solaimanpur, and Anondonagar are more convenient to visit; they have easy access by boat, approximately 6 km away from Tahirpur Bazar. Nichodropur has an earth-filled sandbag, Solaimanpur has a concrete block, and Anondonagar has brick wall protection. These three villages are geographically located close together, and there is no noticeable change in climate or floodwater levels between these three villages. During the monsoon season, from April or May to October, the beels converge to create a single, expansive water body. (Raihan & Hossain, 2021)

So, in this pilot study, three villages, Nichodropur, Solaimanpur, and Anondonagar, were selected in Tahirpur. Because these three villages are geographically located close together. No significant change in climate or floodwater levels. So that these three villages are in almost in same condition according to their geographical position. Three villages cover three different types of protection walls. Convenient to visit; they have easy access by boat, approximately 6 km away from Tahirpur Bazar.

Nichodropur:

Fig-3: Nichodropur village

Nichodropur is a village located in Tahirpur Upazila. Geo location is at 25° 5'26.79" N and 91° 7'28.68 "E. There is a total of 45 houses in this village, and 35 of these houses are located along the water's edge, protected by a wall.

Fig-4: Scenario of flood impacts over time (2004,11,13&16) in Nichodropur village

Fig-5: Scenario of flood impacts over time (2018,17,22&23) in Nichodropur village

In figures (4 & 5), earth photographic timeline analysis indicates that floods occur after April, and water remains in villages until November. In November 2004, almost half of the village areas were under water. In November 2011, the water edge and the village were submerged under floodwater. In November 2017, December 2016, and November 2023, Parts of the village were submerged in floodwaters, and some areas were affected by flood erosion, resulting in some of the land along the water edge appearing to be missing.

Solaimanpur:


Fig-6: Solaimanpur village

Solaimanpur is another village of Tahirpur Upazila. Geo location is at 25° 5'26.52 "N and 91° 7'2.19" E. There are approximately 140 households in this village. There are 23 houses with a protection wall along the water's edge.

Fig-7: Scenario of flood impacts over time (2004,11,13&16) in Solaimanpur village

Fig-8: Scenario of flood impacts over time (2018,17,22&23) in Solaimanpur village

In figures (7 & 8), November 2004, 2011, December 2016, and November 2017, the Village's waterfront areas were submerged in floodwater, and some areas were affected by flood erosion. For this erosion, villagers lost their land and properties in between houses along the water's edge that were not subject to erosion but were submerged by floodwater. In 2017, LGED

provided a concrete block protection wall at Solaimanpur village. (Local Government Engineering Department, n.d.) After that, the protection wall was later damaged by floodwaters, but the houses along the water edge of the Village remained safe from erosion and floodwater.

Anondonagar:

Fig-9: Anondonagar village

Anondonagar's geo location is 25° 5'35.15 "N, 91° 7'11.43 "E, and the total number of houses in this village is 70, and 17 houses are built on the water edge and have a protection wall around their house.

Fig-10: Scenario of flood impacts over time (2004,11,13&16) in Anondonagar village

Fig-11: Scenario of flood impacts over time (2018,17,22&23) in Anondonagar village

In November 2004 and 2011, the water edge of the village was submerged by floodwater. After 2011, the village was safe. There is no trace of erosion and submergence by floodwater. After 2011, villagers' properties are safe from flood erosion and floodwater.

1.6 Research Gap

To protect the Haor village, one of the many structural mitigations is the protection wall. Governmental organizations LGED built different types of protection wall. As a structural mitigation protection wall built by Brick Bonding with cement mortar and concrete block. Mud wall in the sack protection wall built by residents as a barrier from floodwater.

But there is not enough knowledge about the impact of the three types of protection walls on the villagers' livelihood.

1.7 Significance of Research

This study will describe the consequences of a structural mitigation (protection wall) system on villagers' livelihood, specifically in three aspects: settlement and infrastructure, financial capacity and neighbourhood bondage of Tanguar Haor peoples.

This study provides knowledge on which protection wall is more durable and sustainable, so that villagers get a durable and strong protection wall that will prevent damage to settlements and infrastructure from floodwater and erosion.

If the damage level prevents flood water and erosion. In that case, villagers cannot spend money every year on repairing the settlement, infrastructure, and the protection wall so that they can save their money.

When there are no rebuilding or repair issues with the neighbour, there will be no chance of misunderstandings or conflicts with the neighbour, and there will be a good neighbourhood bond.

The idea from this paper will help the policymaker to guide current policies or develop new policies, and the government organisations can also act or take initiative to build a durable and strong protection wall, which can give the villagers a good livelihood.

1.8 Scope of The Research

This study will help many stakeholders, such as government authorities, local people, NGOs, media, private organizations, and local organizations working to reduce disaster risk reduction (DRR) for the flood-prone Tanguar Haor region and provide a better livelihood to the villagers. These findings can create a better scope of geographical condition, will stop kanda's (village) erosion, generate income during flood, stakeholders will continue their work, and in research, a new scope will be created to work on protection wall types, wall durability, villagers' livelihood, environment, and biodiversity.

Policymakers, government disaster management agencies, and other NGOs have the scope to work on an effective protection wall for the villagers' livelihoods in Tanguar Haor.

Chapter Two

Literature Review

2. Structural Mitigation Measures

Among the most important steps in risk management is creating mitigation strategies that lower current risk to a controllable level of residual risk. Active measures and passive measures are the two categories of mitigation solutions that are included in this group. (Zollinger, 1985)

These two criteria are essential to risk management because they set the time and location goals for the required level of protection and define the allowable residual risk.

Active mitigation techniques may change the frequency and intensity of floods or waste material by changing their source, path, or deposition. (Zollinger, 1985) Both disposition management and event management may do this by altering the flow or the chance of occurrence. One may categorize active measures into two main groups: structural and non-structural.

Strategies for structural mitigation that will lessen erosion. Discharge management techniques (reducing peak discharge to avoid damage) and sediment control techniques (transformation process, regulated deposition, diverting debris flow to other regions, and filtration of organic material) must be applied at the structure. (Hubl et al., 2005)

The foundation of passive control is potential failures. For instance, passive mitigation measures alter the temporal and geographical aspects of the harm caused by flows or the associated susceptibility, thereby reducing the potential loss. Disaster response can either prevent or lessen a crisis, while land use planning, including hazard mapping, can alter vulnerability to the disaster. (Zollinger, 1985)

2.1 Types of Active Structural Mitigation

2.1.1 Dams and Reservoirs

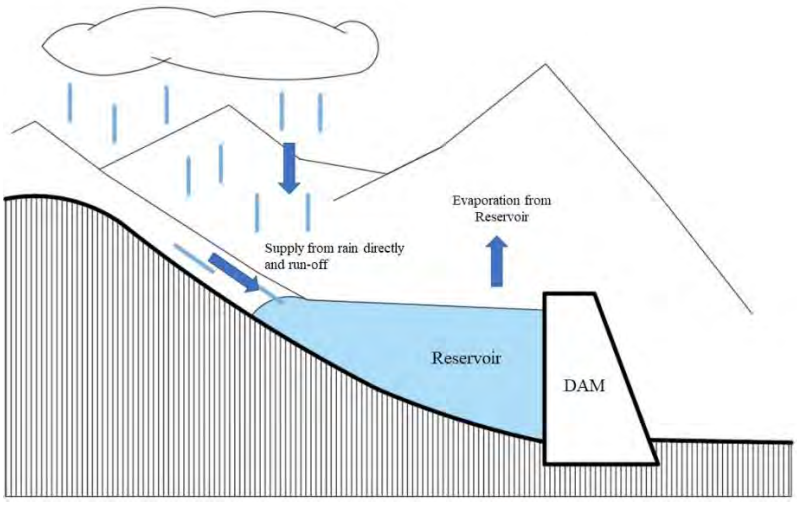


Fig-12: Reservoir formed by a dam. (Brouwer et al., 1992)

The earliest dams were built in the Middle East 5000 years ago. Two thousand years ago, they spread over the Mediterranean, China, Central America, and South Asia. Reservoirs and dams are some of the manufactured structures that block the flow of rivers in nature. One of its many functions is flood control. Dams, meanwhile, are defined as "structures which hinder the free flow of water in streams and rivers, or the waters so formed or accumulated behind or upstream of those structures." Dams are used for navigation, recreation, flood control, irrigation, conservation, and the generation of hydroelectric power. Even while dams disrupt the water's natural flow and harm river ecosystems, they are beneficial for controlling flooding. Small dams are unlikely to make much of a difference to the ecosystem. Low dams, sometimes called barrages, have been used to divert portions of stream flows into canals. (*Dams and Reservoirs | EBSCO*, n.d.)

2.1.2 Levees

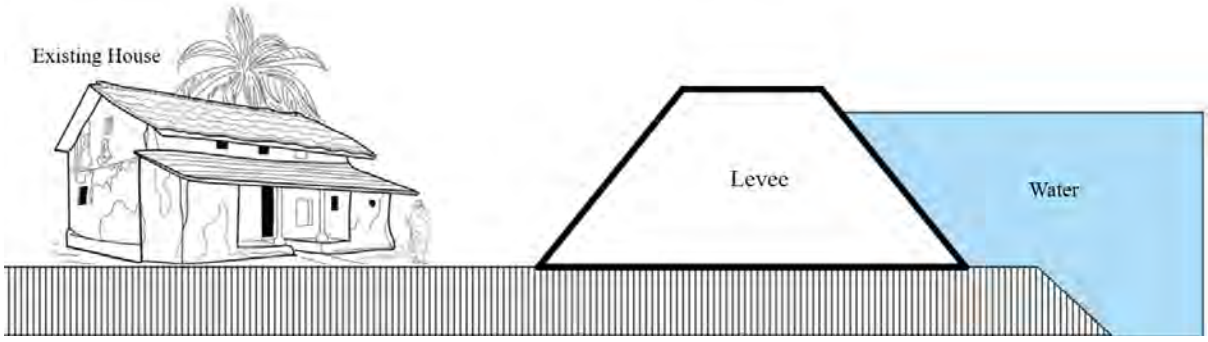


Fig-13: Flood water protection by levees (What Is Levee Seepage, n.d.)

In Wenger (2015), Flood levees are commonly used nowadays and have been used for a long time in many countries. There are a few reasons why this is the case. A physical barrier to water provides vulnerable communities with the comfort of knowing they have been 'protected' and with tangible evidence of 'protection'. Because the necessary investment is often beyond the capabilities of residents, it is also crucial that levee building be externalized to the larger community, either entirely or in part. For those who are affected, this may greatly increase the allure of structural mitigation. (Smith, 1998). Levees have huge significant acceptance among decision-makers as the only practical alternative or the lowest-cost mitigation strategy for existing development. (SCARM 2000; UNFCCC 2006; Liao 2014).

2.1.3 Channelization

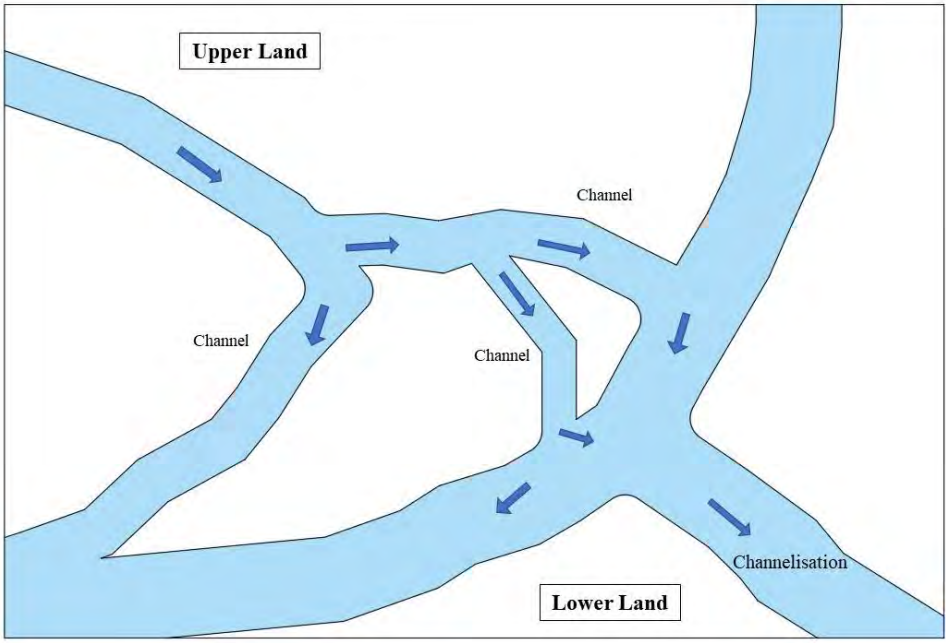


Fig-14: Channelization for diverted flood water (A Flood Toolbox, 2023)

Channelization is the removal of material from a channel to make a new channel, to divert a stream, or to straighten an existing channel. To minimize local flooding, floods are made to spread out less and move faster downstream (Emerson, 1971). The Army Corps of Engineers, private drainage districts, and, more recently, the Soil Conservation Service, have all used this method for many years. (Lea and Mattson,1974)

2.1.4 Detention and retention basins

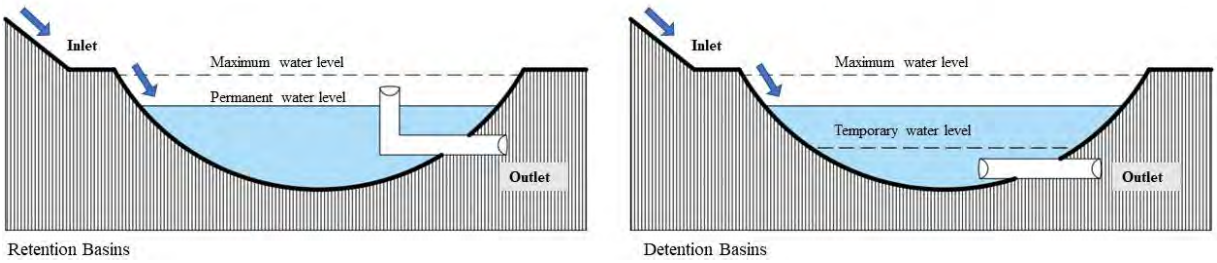


Fig-15: Retention and Detention basin. (*Retention & Detention Facilities*, n.d.)

Natural basins, or detention and retention basins, are designed to hold floodwater to reduce peak flooding downstream temporarily. Retention basins are like detention basins, except that the outflows of detention basins are not controlled. In other words, while water collects in retention basins, it slowly evaporates or seeps into the ground and is retained within the basins for a short time before being released through a natural or manufactured drainage channel.

Detention and retention basins come in all shapes and sizes, depending on the geography. Retention basins permanently store a body of water, while detention basins temporarily store water and then drain. Detention and Retention Basins can reduce downstream flood peaks by being triggered at the right point in a flood wave (Detention and Retention Basins, n.d. In recent years, conventional flood retention basins have gained steadily increasing attention from local and regional developers, planners, and politicians (Scholz, 2007).

According to Robinson (2010), the majority of retention basins, both man-made and natural, hold rainwater until it can be discharged without creating floods downstream. Other, less evident but equally important roles of certain catchments, like wetlands, include absorbing diffuse pollutants and allowing treated runoff to seep in, which helps replenish groundwater. As a result, we have a very diverse, conflicting, and complicated set of retention basins due to multiple and often conflicting purposes.

2.1.5 Flood wall

In the event of a flooding event, Avalanchecreative (2024), flood walls are designed to block and prevent flood waters from entering residential/industrial homes, commercial buildings, public infrastructure, and vulnerable communities. The need for adequate flood protection has never been greater if our inland and coastal communities and their ecosystems are not to suffer severely from the costly, dangerous, and destructive impact of floods.

Flood damage is unpredictable and, therefore, expensive, as are the subsequent flood repairs, but it is strongly advised that municipalities invest in proper flood protection measures, such as flood barriers, which are a much more cost-effective option. A good wall will prevent erosion from washing away the embankment and floodwater from overtopping and damaging your home. A permanent water retaining wall should be built if residents live in an area where there are often flood alerts. This will not only hold back floodwaters but can also prevent erosion. (Avalanchecreative, 2024) A water retaining wall may help protect property that backs onto a lake or river from flooding in the future. Water retaining walls can be permanently installed to prevent overflow for decades or temporarily protect from a particular flood condition. It can also help to avoid the erosion of the property over time.

A weak retaining wall may be able to withstand normal seasonal water overflow, but it may fail at a high-water level during a severe storm. This depends on the strength of the floods and the effectiveness of the retaining wall. A well-built, designed, and positioned retaining wall can hold back heavy waves. Water detention barriers are basically made of brick, concrete blocks, sandbags (Avalanchecreative, 2024).

Sandbag Wall:

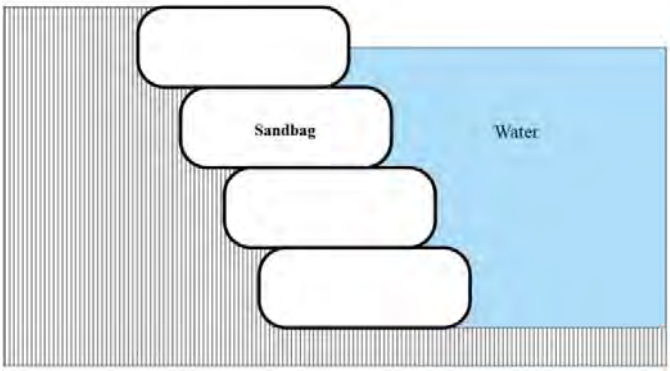


Fig-16: Retaining wall by filled sandbag (Kim & Inc, 2005)

In this context, the term "sandbag" is used for any bag containing any fill material. Fill material is any material that can be used to form walls in bags, including sand, gravel, soil, and dry mix concrete (which hardens after it is moistened and left to cure). (Kim & Inc, 2005)

To create long-lasting retaining wall constructions and preserve the integrity of the sandbag wall system, interconnecting elements are used to keep the sandbags within the wall courses together. The connecting elements are plates having projections on both sides that extend into adjoining sandbags both vertically and horizontally. (Kim and Inc, 2005) In order to stabilize the fill and connect the sandbag structure to the fill, pieces of geogrid can be attached to the connecting elements and extend into the fill material that the sandbags are supporting. The cost of constructing a sandbag retaining wall is lower and less labor-intensive if backfill and geogrid are used rather than excavating behind the wall face. It would be helpful if such barriers could withstand steep banks.

Concrete Block wall:

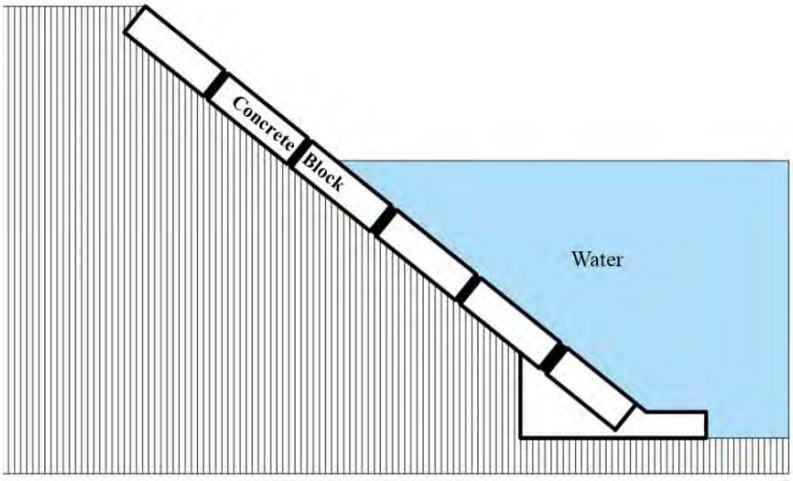


Fig-17: Concrete-constructed block wall (ELITE PRECAST CONCRETE, 2017)

Flood protection barriers can regulate, reduce, or prevent the harmful effects of water level rise. A perfect modular flood defense wall can be built with concrete interlocking construction blocks. The precast modules are stacked in a dry stack and piled up on top of each other without mortar. The blocks are interlocking because they have studs and recesses. Due to their bulk and the studs and recesses that hold them in place, they do not require any bonding medium such as mortar. (Flood Protection Constructed Using Precast Concrete Wall Blocks, 2025)

Precast concrete materials are often used to raise riverbanks, construct floodplain defenses, and create new barriers. These walls are a durable, relatively inexpensive, and easy construction alternative that does not require professional equipment. Modular flood retaining walls made of Sustainable Concrete Blocks are most suited to shoreline protection, sea walls, rivers & riverbanks, coastal and flood plain erosion management. (Flood Protection Made with Precast Concrete Wall Blocks, 2025) Additionally, the blocks are easy to install in any weather.

It is possible to build gravity-retaining buildings with a vertical or slanting face in front. This is accomplished by tilting the structure's base's upper surface open. It is emphasized that increasing the backward batter slope improves the Wall's durability. (ELITE PRECAST CONCRETE, 2017) In any case, this benefit must be balanced against the area required to construct the Wall.

Brick Wall:

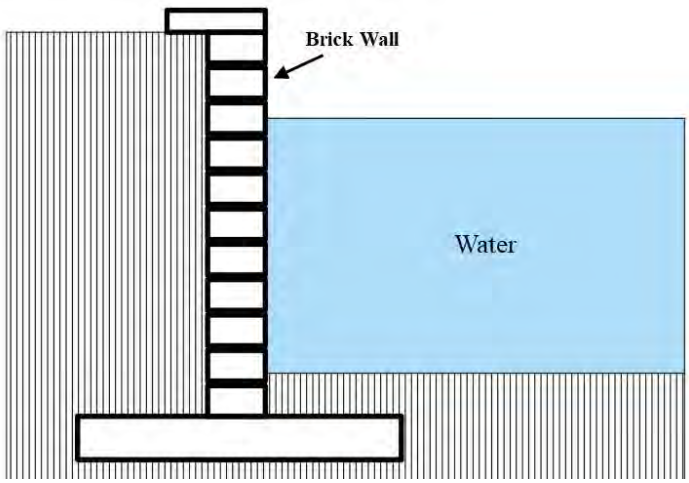
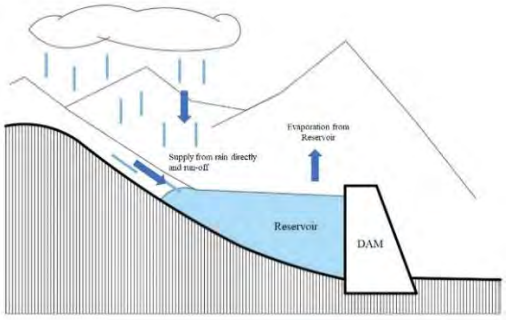
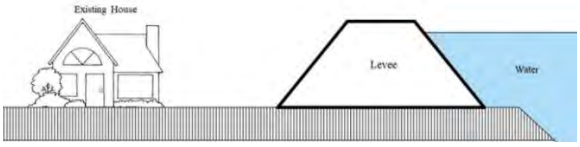
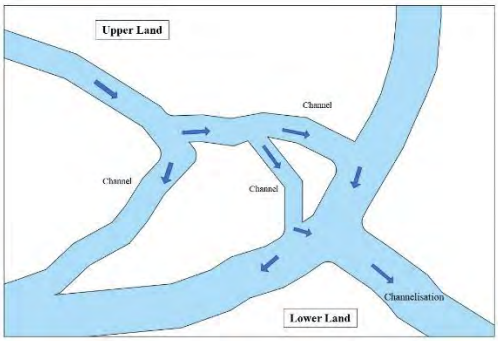
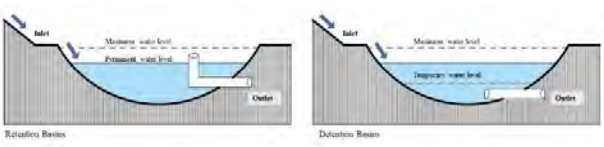


Fig-18: Brick protection wall (Flood Defense Walls to Protect Your Home from Water Damage, n.d.)

Brick veneer structures are physically capable of withstanding potential flood loads and should have quick, practical, efficient floodproofing methods available. If excessive water flow must be kept away from the wall, proper waterproofing measures should be taken.

Brick veneer walls are too porous. As a result, additional measures such as thick coatings, waterproof membranes, or tubular sealing are required for minimizing water ingress (Pace, 1978). Double-layer brick walls with an internal waterproofing layer were better than the single-layer walls because the water could penetrate the first layer but was stopped by the waterproofing layer. While coatings and sealants can be a valuable part of an effective brick flood protection system, they must be coupled with a combination of waterproofing materials and structural reinforcement. (Pace, 1978)

2.1.6 Summary Table of Active Structural Mitigation Type

No	Name	Description	Image
1.	Dams and Reservoirs	Water bodies created by the damming of water behind or upstream of such buildings and structures, which resist the waterflow in rivers and streams	
2.	Levees	The visible barrier is an additional measure of water exclusion that provides a level of comfort and actual physical protection for populations at risk.	
3.	Channel	Channelization is the process of either excavating a new channel into which a stream is diverted or straightening an existing one.	
4.	Detention and Retention basins	Retention basins are used to create a permanent pond, but Detention basins are only used to temporarily detain water before releasing it.	

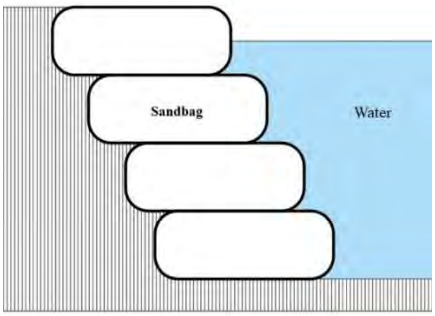
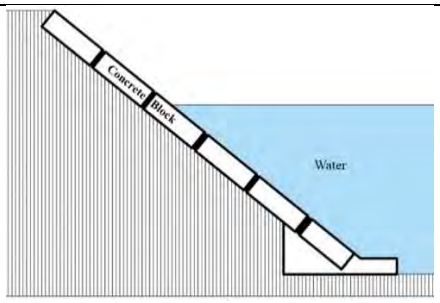
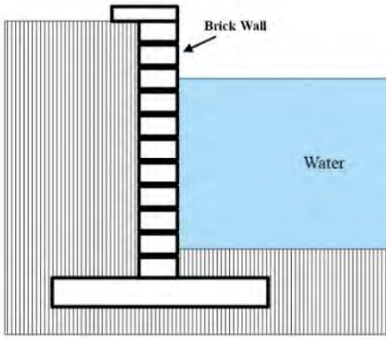
5.	Flood wall	Flood walls are built to divert and prevent flood waters from residential homes, commercial businesses, public infrastructure and at-risk populations.	
5.1	Sandbag Wall	Sandbag is any bag that is filled with a filling material. Fill material is the general term used when referencing any material that is used in bags to build walls, such as sand, gravel, soil, dry mix concrete.	
5.2	Concrete Block wall	Creating an excellent modular flood defense wall out of concrete interlocking construction blocks.	
5.3	Brick Wall	Brick-veneer structures are physically designed to support potential flood loads, and therefore quick, efficient, and practical floodproofing methods should be available.	

Table-1: Summary Table of Active Structural Mitigation Type

2.2 Structural Flood Mitigation Impact on The Environment

Yet, many structural floods control measures, such as sluice gates, levees, and embankments, harm natural hydrological processes, sediment transport, and wetland habitats. According to Rahman and Salehin (2013), these structures could prevent seasonal flooding, which dries out wetlands and destroys aquatic ecosystems. In coastal and deltaic areas, where tidal flow and groundwater dynamics have been altered through structural interventions, waterlogging and

soil salinization have emerged as significant environmental issues over time (Islam and Gnauck, 2011). However, these Endorsements are often perverse in that their short-term protection schemes encourage hazardous land use and settlement in high-risk floodplains, which potentially increases the long-term environmental susceptibility of the floodplains to environmental change (Warner et al., 2012).

2.3 Rural Livelihood

A livelihood is comprised of the activities, assets, and access that together form a person's or a settlement's basic standard of survival conditions (Ellis, 1998). A person's livelihood is what they have access to get the essentials of life, such as clothing, food, drink, and shelter. Therefore, at both the individual and family levels, a livelihood encompasses all activities related to food, water, shelter, clothing, and other essentials necessary to support human life. Most of the villagers of the village areas rely on mini-scale cultivation, fisheries, livestock growth, and non-agricultural pursuits for their livelihood.

Because of poverty and lack of necessities, the poor people have a difficult life. As a solution to the poverty problem and its eradication, Chambers and Conway (1992) proposed the concept of sustainable development.

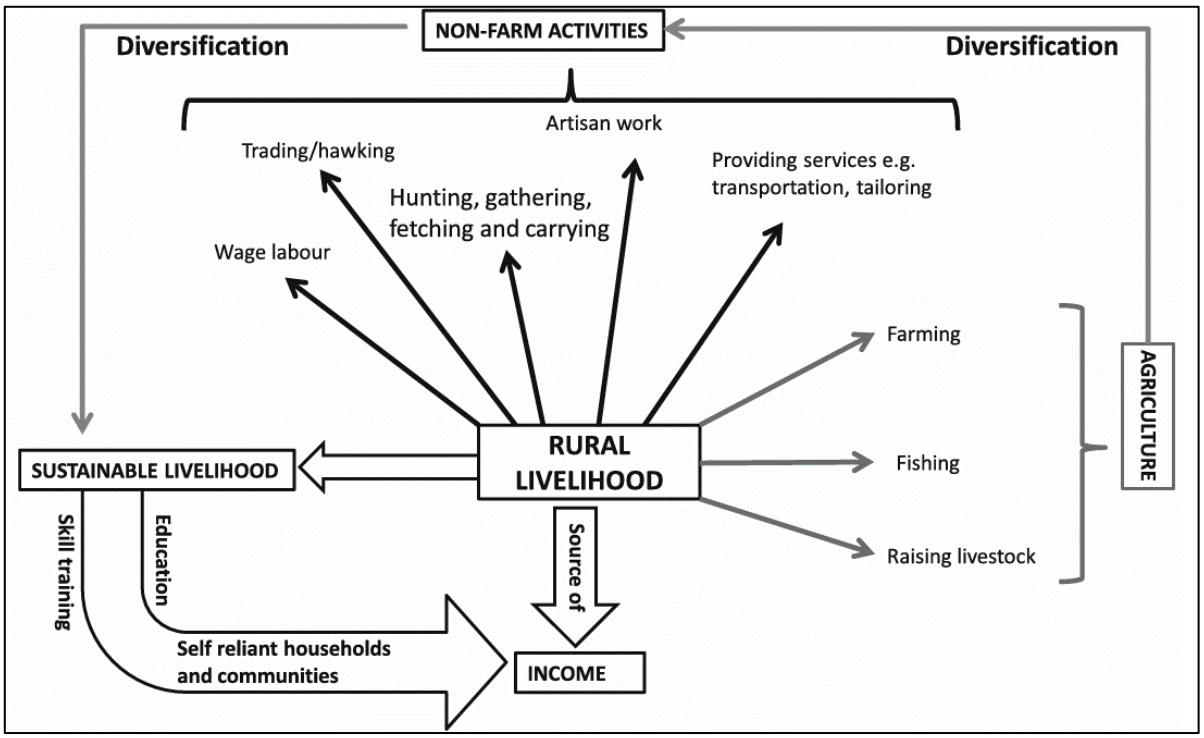


Fig-19: Rural livelihood (Mphande, 2016)

In Figure-19 of Mphande (2016), rural livelihoods are a source of revenue. Agriculture is a primary component of the complex system of rural living, but some people are varied into non-

agricultural activities to achieve a sustainable livelihood and increase household cash generation. Among the activities that come under the rubric of rural livelihood are agriculture, cultivation and animal keeping, including animal husbandry, shooting and collecting, pay labor, trade and hawking, craftsman work, including weaving and carving, transport driver and other work, bringing and bearing, bakery, and basketry.

2.3.1 Rural Diversification of Livelihoods

Age, education, access, family size, dependency ratio, opportunity of land and resources, availability and access of sprinkling facility, borrowing capacity, far from city, training, less electricity facilities and skill improvement, participation of social group, etc., are some of the factors influencing diversification (Khatun and Roy, 2012).

Family activities that family members perform to increase their social position and quality of living are described as diversification (Ellis, 1996). According to Khatun and Roy (2012), diversification may also attribute to the efforts attempted by an each or household to explore the new track to survive, ensuring increased cash and resilience against disaster, such as disease outbreaks and calamities.

2.3.2 Factors Influencing Rural Livelihood Diversification

How one's livelihood is treated depends on the variables that help ensure one's survival. According to Khatun and Roy (2012), there are several important determinants of livelihood diversification. Since older people often have less energy and may not be able to accept new responsibilities through education and skill training, age significantly influences one's ability to perform various jobs. Education increases access to information and credit and improves employment opportunities. Family size matters - smaller families are often able to fund development, while larger families must find multiple sources of income to support it. A high reliance ratio suggests that earners need to vary their ways of earning. The problem is, if there is a land shortage, then people will also need to work in non-agricultural jobs (Barbier & Hochard, 2014).

An asset creates opportunities that absence does not allow for investment and expansion. Irrigation access impacts yields, which in turn affect food security, ultimately influencing income. For example, collateral is not a limitation on investment, but credit availability is. The closer a town is to urban centers, the greater the opportunities are for accessing markets and employment, as well as for access to training that will enable one to work in high-income employment industries. (Ellis, 1996) Furthermore, social groupings serve as the vehicle for

financial access, knowledge, and capacity-building networks that ensure livelihood diversification and enhancement.

2.3.3 Obstacles to Diversification of Rural Livelihoods

Various obstacles that individuals or families face, some of which may be geographical or socio-economic, may limit their opportunities to diversify their livelihood. According to Mphande (2016), these challenges can significantly impact whether and how diversification occurs. Communities that are isolated from the rest of society due to poor roads, inadequate transportation, and limited permit to major work such as banking, healthcare, and knowledge have limited opportunities for economic growth (GIZ, 2013). If there is no money, real estate, or other collateral, it is difficult to find a loan or other source of income to secure that collateral. Extreme weather events can also be a significant stumbling block, as they can impact investment and make a new market seem to be of no significance.

As a result of the reduced access to credit, families are less willing to take financial risks in new business ventures. In addition to insufficient ideas about market opportunities, an insufficient amount of self-training, and a lack of potential skills for creating and effectively deploying products in markets, populations are constrained from diversifying their sources of income. Aside from hindering community development, communities are being deprived of the opportunity to diversify their economies due to inadequate infrastructure, limited markets, and subpar healthcare, education, and educational facilities. These interconnected barriers represent significant challenges that must be overcome before sustainable livelihood options can be achieved.

2.3.4 Impact of Natural Disasters on Rural Livelihoods

Natural disasters and epidemics are two issues that have plagued rural life. Poor people in rural areas bear a disproportionate share of these severe livelihood challenges. Floods, earthquakes, storms, fires, landslides, etc., are examples of natural disasters. The loss of life, property, and livelihoods due to natural disasters. Rural communities that rely upon land and other natural resources for their livelihoods lose their human capital in the event of a natural disaster. Crop, livestock, and other productive income losses result in people losing their economic capital. In addition, homes and properties get destroyed, leaving a community devastated and making it difficult for reconstruction to begin. Natural disasters can lead to poverty by destroying the resources on which a person relies for income and livelihood. (Mphande, 2016)

2.4 Framework of Sustainable Livelihood (SLF)

SLF is a valuable methodology of social science. In the mid-1980s, Robert Chambers wrote that information on the livelihood conditions of people is useful when recorded and analyzed by researchers. The Sustainable Livelihood Approach is based on the SLF, which is the method of analyzing the livelihoods of low-income people. SLF is essentially a tool of capturing livelihoods because it is too complicated to grasp the multiple and manifold livelihoods. The richness and diversity of characteristic and contributor research at the rude level requires qualitative and participatory research that is qualitative and participatory. (Development Study Group: Zurich, 2002)

SLF is a useful instrument towards understanding the feasibility of different livelihood regions. It has been used in social research to measure the livelihood situation of people or to learn the activities that generate livelihoods. According to Dasgupta (2015), SLF can help us to study where people currently dwell. Its holistic nature means that SLF can be useful in identifying longer-term solutions to eliminate mass poverty and can enable us to delve deeper into the causes of poverty.

SLF demanded a two-track strategy:

1. It is concerned with what impact the policies have on livelihoods.
2. It observes the role of better appreciation of livelihood in enhancing the formulation and execution of policies (Bhuyan, 2011).

2.4.1 The Approaches of SL

The current approach to development that is becoming popular is called sustainable livelihoods and is people centric. The term sustainable livelihood arose through the work of research institutes (Institute of Development Studies at the University of Sussex and the Overseas Development Institute, United Kingdom), non-governmental organizations like CARE and OXFAM and development organizations (DFTD, UNDP) based on the first UNDP Human Development Report from 1990 and the Brundtland Commission Report from 1987. (Anand, 2013)

2.4.2 Fundamental Concept of SLA

The strategy suggested by Kolmair, Gamper, and Juli (2002), focuses more on the utilization of resources than on any other aspect of placement. In this way, its perception is complete and pluralistic in nature, an adaptive and reactive framework to the formulation of long-term objectives. This puts the task of initiating and supporting the process squarely in the hands of

the most affected stakeholders. It also connects the macro and micro aspects of the governance chain, linking different components together and creating awareness of the necessity to make future livelihoods sustainable.

2.4.3 Sustainable Livelihood Framework Model of DFID

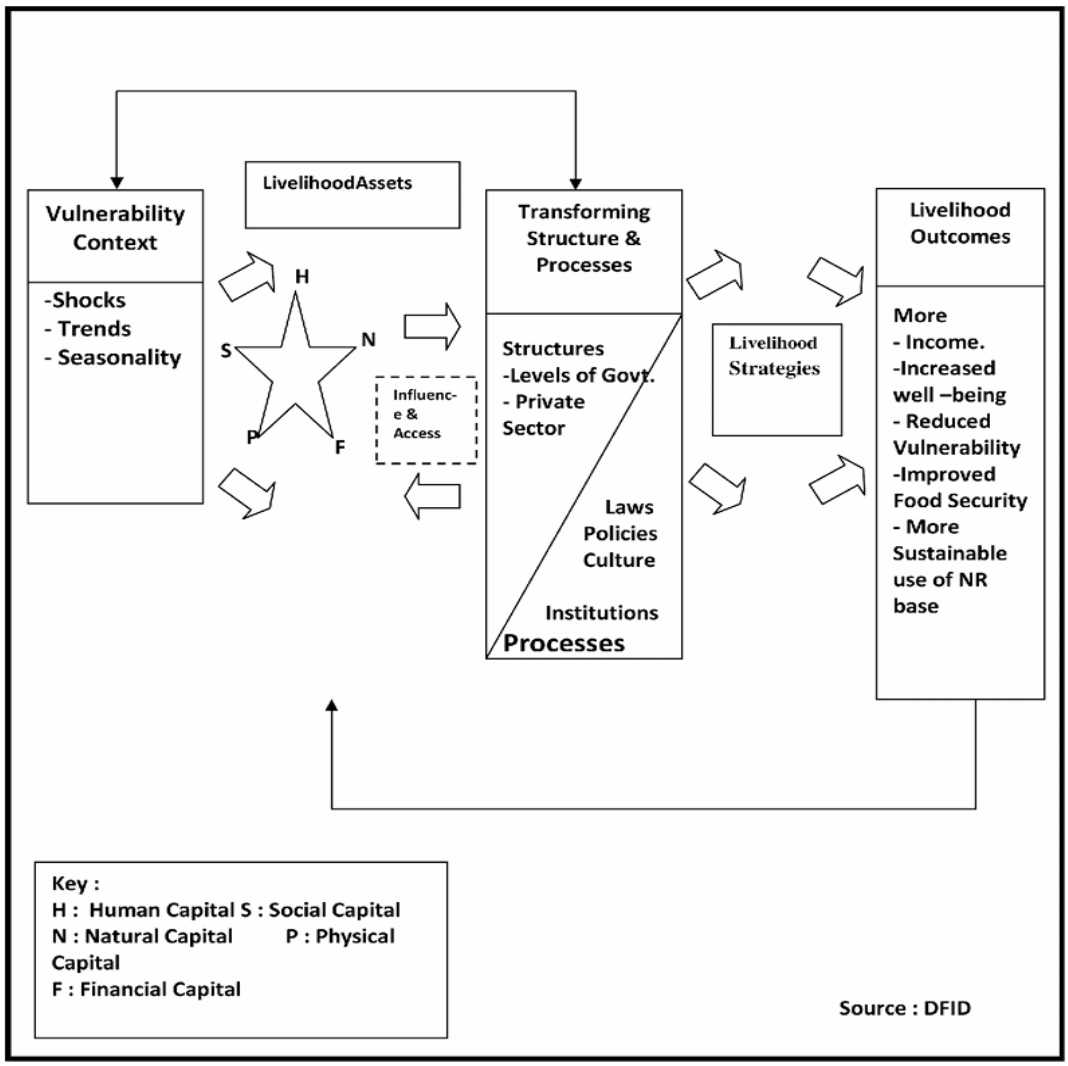


Figure-20: Sustainable Livelihood Framework DFID model (DFID, 2000)

Sustainable Livelihood Approach or SLA is a brainchild of Robert Chambers. According to the DFID Guidance Sheet, the sustainable livelihoods framework explains significant forces that influence how humans live and their overall relationships with others. It can be applied in designing new development projects and evaluating existing projects based on their contribution to sustainability.

DFID is explicit about the contribution of capital assets to livelihoods and the value of micro, macro, social, economic, and institutional sustainability. In the context of poverty eradication,

the UNDP has specifically highlighted the potential of technology (as supported by DFID, CARE, and the UNDP) to help people escape poverty. (Bhattachargee, 2009)

2.4.4 Crucial Elements of the DFID Framework

DFID (2000), defines the Sustainable Livelihoods Framework (SLF) as an integrated strategy that helps individuals develop and sustain their livelihoods when such livelihoods are at risk. The SLF provides some of the following services:

Vulnerability context:

Trends associated with issues that may complicate individual efforts to remain safe and healthy. According to the World Bank, well-being may decrease to a certain threshold due to external factors. This may include demographic, resource, or governance patterns; artificial or natural shocks, such as disease or death; or economic shocks, including crop failure or unemployment. Such a background encompasses changes in product and service availability, employment opportunities, and family and household dynamics, as well as global and regional conflicts.

Assets for livelihood:

In this way, therefore, Bebbington (1999) and DFID (2000) are mobilized by people to achieve their livelihood objectives. These forms of capital include environmental capital (soil, water, forests), human capital (health), skill and knowledge, the sufficiency to work, communal capital (connectivity and social understanding), as well as financial and physical capital (infrastructure, tools, equipment, savings, salaries, credit, and remittances).

Structures and processes:

The evolving structures and processes are embodied, among others, in the laws, rules, and cultural norms that determine access to opportunities and resources, as well as the public and commercial organizations that provide or offer services. The conditions dictate what livelihoods are created in an environment and how they are maintained across time.

Livelihood strategies:

People attempt to attain their objectives through livelihoods. According to Scoones (1998), these could involve either migration or diversification into multiple income-generating activities, or efforts to improve or enhance agricultural production in the resource- and opportunity-rich centers.

Livelihood outcomes:

These are the targeted goals. According to Sarma and Bhuyan (2020), the outcomes include better food security, more effective use of natural resources to create a sustainable production system, lower vulnerability due to increased assets, improved health and well-being resulting

from higher income, enhanced self-esteem, and increased social inclusion. Collectively, these concepts offer a rational explanation of how individuals assess opportunities and risks, enabling them to enhance their living standards.

2.5 Contextual Literature

2.5.1 Flood and Flash Flood

A flood happens when water comes over the surface of normally dry land. When the aquatic level in an existing waterway, river, stream, or drainage ditch rises, a normally dry area becomes submerged. Floods can occur over days or weeks - unlike flash floods. (NOAA, National Weather Service, n.d.)

Flash floods are defined as floods that are the result of excessive and/or heavy rainfall that occurs in a limited time frame, generally six hours or less, and are usually associated with torrents, which, after heavy rains, roar over riverbeds, city streets, or mountain valleys, wash everything before them. Alternatively, it can be minutes or hours later, particularly in areas where there is much rain. They can also happen during a time without rain, such as after a dam, when a levee breaks, or when water is released unexpectedly. (iAlert.com, n.d.)

2.5.2 Floodplains of Bangladesh

Two-thirds of Bangladesh's territory lies below five meters above sea level, making it one of the country’s most susceptible to floods globally (IFAD, 2011). In many areas of the country, floods are a regular occurrence, leading to massive destruction (Alam, 2000). In ordinary years, river floods impact between 25% and 30% of the nation; in exceptional years, rates may reach 68% (DMB, 2010). Floods are mainly due to heavy rainfall in the upper reaches of their watersheds (Alam, 2000), which include the great Himalayan range of India. Apart from the local monsoon rain, significant flooding resulting from rainstorms also dramatically increases the water level in rivers. Filling of riverbeds, erosion of riverbeds, and a decrease in the river channel's carrying capacity all make the problem worse. (MoEF, 2005)

2.5.3 Categories of Flood Damage

According to Jongman et al. (2012), there are four types of flood damage: direct tangible (bodily harm by link with water); indirect tangible (damage of revenue and output); direct intangible (death); and indirect intangible (trauma). The degree and intensity of flood activities, also known as hydrostatic and hydrodynamic actions, determine how much structural element degradation occurs. (Pistrika and Jonkman 2010; Kelman and Spence 2004)

2.5.4 Strategies for Flood Mitigation

Many mitigation techniques have been used to reduce various economic losses and protect human lives, property, and productions. Structural flood protection measures consist of large-scale flood infrastructures like protection walls and embankments, which are designed to block flooding in an intrinsically flood prone area (Schelfaut et al, 2011).

According to Alam (2000), Any flood mitigation strategy should have four main goals: minimizing flooding, preventing damage, saving lives, and protecting property. Each of the three fundamental strategies for lowering hazard vulnerability has several technological alternatives. There are essentially three strategies, 'protect', 'retreat' and 'accommodate'; these are described as follows:

1. The best way to reduce the threat of the event is to make it less likely to occur.
2. Minimize the threat of the event by reducing its potential impact.
3. Increasing the community's capacity to handle the event's consequences. (IPCC 1990: Report of the Coastal Zone Management Subgroup of the Response Strategies Working Group, no date)

2.5.5 Haor

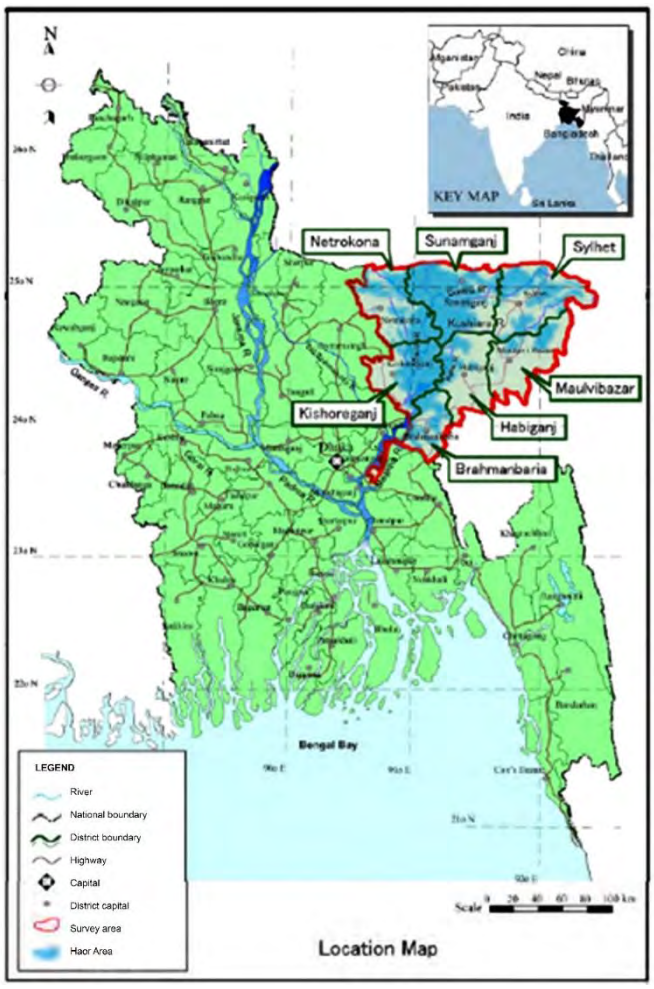


Figure-21: Haor area of Bangladesh (Geographical Coverage, n.d.)

The Meghna River, which has several branches and tributaries, is in the floodplains of the Haor region in north-eastern Bangladesh. (MoEF, 2005). The Indian and Eurasian plates colliding is causing this tectonic depression to deform vertically. (IFAD, 2011). It includes rivers, canals, streams, islands of settlements, fields that may be cultivated seasonally (called beel in the region), and permanent bodies of water (called haor). The whole Haor area, with the marshes and the periodically flooded areas (MoWR 2012), turns into a vast, almost continuous watery surface during each year, which has a depth of 1.8 - >3 metres (MoEF 2005). This is because of its low topography (Alam & Hasan, 2010) and protracted monsoon rains (June to September) with intense flash flooding (Salauddin & Islam, 2011). Although not having a clearly delineated territory, it spans an area of over 24,000 km2, or seventeen percent of the Bangladesh's land area (Alam & Hassan, 2010), and parts of 7 north-east districts in NE Bangladesh (Netrakona, Habiganj, Sylhet, Moulavibazar, Sunamganj, Brahmanbaria, and Kishoreganj) (MoWR, 2012). The Haor area has three seasons: summer, monsoon, and winter. It is in a subtropical monsoon climate. Summer (April - June), winter (December - January), and monsoon (June - September). In addition, temperatures in the area are relatively mild compared to the national average, with minimum temperatures of 26 °C and a high of 33 °C (IFAD, 2011). It also receives a median of 4130 mm annual rainfall, more than twice the national average (Salauddin & Islam, 2011).

2.5.6 Master Plan of Haor Area

The Bangladeshi government has taken the initiative and created a strategy for the Haor region in order to avert the flash flood and seasonal flood tragedy. As stated in the Haor Area Master Plan (2012),

Background

Haors are large bowl-shaped depressions with distinctive hydro-ecological features that are found across northeastern Bangladesh's flood-prone regions. They span 19,998 sq km and are inhabited by around 19.37 million people. There are 373 haors, or non-permanent wetlands, in the areas of Sunamganj, Sylhet, Habiganj, Maulvibazar, Netrakona, Kishoreganj, and Brahmanbaria. The combined size of these 373 Haors is 859,000 hectares, or around 43% of the Haor districts' total area. It has a diversity of aquatic ecosystems, added as huge tracts of cultivational plains that flood yearly, beels, waterways, and canals. The region's water supply comes from the Tripura Hills towards the south-east side and from the lower sides of Shillong Plateau in India, which stretch over the Indian border on the north side. In the Haor area, flash

floods are a serious calamity that endangers people's lives and means of subsistence by submerging the main productive sector of agriculture.

Integrated Water Resources Management (IWRM)

The Global Water Partnership (GWP) defines IWRM as "an approach which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant social welfare equitably without compromising the sustainability of vital ecosystems." This approach was followed in drawing up the Master Plan.

The Master Plan's duration

The master plan is a set of development projects for selected industries or argument for the upcoming twenty years (through FY 2031-32). The proposed development activities in;

- The short-term: 1-5 years (2012-13 through 2016-17)
- Medium term: 6-10 years (2017-18 through 2021-22)
- Long term: 11-20 years (2022-2023 through 2031-32)

It represents the allocation of funds and other assets. The strategy outlines the priorities for the programs of work aimed at holistic development.

Goal

To maximise resource utilisation and reduce poverty, the Master Plan's overarching goal is to accomplish long-term sustainability in the area via integrated planning and execution, including community and multi-organizational engagement. The goal is to provide circumstances for the creation of sustainable lives and the region's engagement in national development activities without degrading the Haor's environment. The development of a broad-based Master Plan is one of the tools for achieving this goal. This planned activity's goal aligns with the Government of Bangladesh's (GoB) Sixth Five-Year Strategy, Agenda 2021, and other pertinent policies. The following are the six national goals of the Haor Area Master Plan:

1. Development of the economy
2. Security of food
3. Good quality of life for the people
4. Reduction in poverty.
5. Safety and public health
6. Safeguarding of the natural elements

Objectives

The following are the goals of the Haor master plan:

- The comprehensive strategy intends to promote flow, preserve natural water bodies and safeguard the aquatic environment.
- To minimize flood risk and damage, maintain the wetlands that now exist in and around natural canals.
- Ensure fish and crop production, protect infrastructure and homesteads, and biodiversity.
- Coordinate and direct community and infrastructure growth in order to provide responsible wetland management.
- Establish integrated programs of action to ensure sustainable management and prevent resource degradation.
- Develop and recommend department- or agency-specific action plans, future action programs, and interventions that address an integrated approach; and
- Projects will be set within the needs of the stakeholder community for the development of the Haor area.

Areas of Development (DAs)

In line with IWRM principles, the development plan was approached by taking the concept of the concurrent development of 17 designated Development Areas. Note that implementation schedules will be unique to each project published by a given DA. Based on the connections among the DAs and priorities, coordinated timetables for completing these projects have been created. Development Areas (DAs) include cultivation, fishing, culture, domestic animal, tress, biodiversity and water area, logistics, clean water and gray water, knowledge, medical, tourism, factory, electricity and solar energy, and communal services. The priorities and timetables have also been developed, considering the development funding available to the GoB and the investment needs of the various DAs.

Policies

The Sixth Five-Year Plan, Perspective Plan Outline (Vision 2021), To determine the policy orientations for creating the Haor Area Master Plan, the BHWDB Policy as well as several national policies and initiatives have been carefully examined. Additionally, over the many years, Bangladesh has developed several national plans in various sectors, many of which

provide direction for the development of the Haor Area Master Plan. The national policies have been evaluated:

Policies about water (1999), agriculture (1999), fisheries (1998), livestock development (2007), safe water supply and sanitation (1998), forestry (1994), education (2010), health (2010), land transport policy (2004), energy (1996), tourism (2009), environment (1992), land use policy (2001), jute policy (2002), rural development policy (2001), industrial policy (2005), information and communication technology policy (2009), management policy (2009), and renewable energy policy (2008).

Strategics

Master Plan is an analytical and design-oriented approach that relies on a small number of key principles for meeting the goals of the development areas. This plan has been developed to maximize the benefits while minimizing disturbance to the habitat. It is of critical importance to our understanding of how to proactively build interventions in human and natural systems, as well as to understand their consequences for the ecosystem for which they are being built. Hence, a range of general and formative investment solutions have been identified to address those challenges and requirements.

The three most important national plans that were examined were Steps Towards Change, the National Strategy for Accelerated Poverty Reduction (2008), the Bangladesh National Conservation Strategy, and the Bangladesh Climate Change Strategy and Action Plan (2009). The following crucial plans have also been looked at in order to develop strategies for the Haor Area Master Plan: These include the following: Bangladesh's Sixth Five Year Plan 2011; the National Water Management Plan 2004; the North East Regional Water Management Plan (FAP6) 1993; the National Environment Management Action Plan 1995; the National Plan for Disaster Management 2008; the Biodiversity Strategy and Action Plan 2000; and the Summary Perspective Plan 2011.

2.5.7 Flood History of Sunamganj Haor

Flood in 2017:

Fig-22: Sunamganj Haor flood in 2017 (Monsoon Floods in Bangladesh - Situation Report 02, 2017)

This was especially true for the 2017 flash flood in Tanguar Haor. Early in April, following heavy rains in Meghalaya and the Barak basin, flood waters from northeastern India flowed over the border into Bangladesh's haor region. The rainy event started in the last week of March and lasted until the first week of April. Rain is expected on some Meghalayan stations, the Barak basin, and monitoring stations in the northeast of Bangladesh between March 29 and April 5. The other rainfall occurred from the end of week 3 until the middle of the last week of April. In addition, some Meghalayan stations, the Barak basin, and monitoring stations in northeast Bangladesh were also hit by rain from April 18 to April 27. April was wetter than average at all rainfall sites. Due to the high rainfall activity, the water level increased dramatically. Surma River water level for the Sunamganj section was raised by 2.12 m on March 27, 2017. Also, the river water level is 7.58 on 02/04/2017. From March 27 to April 2, 2017, the water rose 5.46 ft. ("ANNUAL FLOOD REPORT 2017," n.d.)

There are 1,31,285 hectares of damaged crops and 8,642.43 damaged houses in Sunamganj alone. More than 10,000 hectares of cropland were washed away after part of the dam at Tahirpur upazila broke. (Bangladesh: Floods in Northeast (Haor) Areas (April-May 2017) - Bangladesh, 2017)

The Surma river was 73 cm above the danger mark. Most of the affected population is totally underwater. Education at 893 elementary schools is suspended. 600 metric tons of rice are arranged for 19,100 affected families. (Bangladesh: Flood Situation, 2017)

Many farmers in Sunamganj lost their single harvest of the year. The main crop of this haor area is borebo paddy. This year, a total of 4.5 lakh hectares of haor were used for Boro rice cultivation, and it is estimated that about 1.41 lakh hectares were submerged. They did not harvest one kilogramme in 2017. While many villagers are running away from their houses to work physically in nearby towns, some have sold their cattle and other assets. (Roy, 2017)

Flood in 2022:

Fig-23: Floodwaters overflowing an embankment in Tahirpur upazila, Sunamganj in 2022. (Star, 2022)

After the first flash flood started making its mark, a second flood started inundating fields in a haor in Sunamganj. The BWDB reports increased water levels of 43 cm for Patlai, 40 cm for Surma, and 71 cm for Jadukata (Star, 2022). This is owing to the record-breaking rainfall that was reported from Cherrapunji in India from April 1 to April 6. (Shawn, 2022)

Since Tanguar Haor is linked to the Eastern Haspung Salt Marsh through several levees, water coming from the haor will also harm paddy in Tanguar Haor if the levees are breached and water moves from the haor into Tanguar Haor.

Now, all are involved in protecting the dykes. Farmers have spent the night on top of the levees to stop them from breaching. Around Tk 125 crore has been lost due to the submersion of 7,083 hectares of paddy fields in the region. In many low-lying Haor areas, the paddy would have to ripen for a few more weeks. (Star, 2022). It is a significant project, and the Government organization is looking forward to initiating a long-term solution for flash-flood reduction in Haor areas of Bangladesh. Flash flooding is a normal phenomenon for the Haor areas in the

rainy or monsoon season. As is the case every year, a devastating flood has destroyed paddy on 5,000 hectares in Sunamganj district, submerging a large area of the land. (Shawn, 2022) The government spent Tk 120 crore on constructing 520 km of levees in Sunamganj district in 2022 to prevent devastation. However, in the first round of flash floods, 4,900 hectares of the district were submerged as three levees failed. (Star, 2022)

Flood in 2023:

Fig-24: Flood in Sunamganj Haor in 2023. (UNB, 2023)

Due to continuous rains, In Sunamganj's Haor region, the river's water level rised, sources of BWDB said. At Sholghar point of Sunamganj, the Surma is flowing at 13 cm below the danger mark. The water level was seven centimeters below the danger level. Ten thousand homes were ruined, and thousands of people had to suffer greatly. (UNB, 2023)

2.5.8 Structural Flood Control in Haor Region

"Living with floods" is replacing "fighting with floods" as the paradigm of flood control (Katyal & Petrisor, 2012). While "living with floods" involves structural and the non-structural measures, "fighting with floods" is specifically only about structural measures.

Concrete and masonry ring band and municipal protection structures are commonly used as flood protection measures (Alam, 2000). But, despite concerns voiced by other researchers about structural flood mitigation measures, Anik and Khan (2012) argue that an efficient yet costly method of base ground erosion control in Haor, Bangladesh, is to construct walls for

wave protection (wall construction as a structural mitigation strategy) around the perimeter of artificially elevated, island-like platforms created by the government. Alam and Hasan (2010) investigated the traditional geotextile-based slope protection in comparison to LGED-supported cement concrete block (wave protection wall) slope protection in Haor area, aiming to save the ecosystem against wave attack. They concluded that the latter approach reduces the loss of life and property in a less costly (in terms of both monetary and environmental impact, as well as social consequences) manner.

2.5.9 Settlement Hazards in Haor

Monsoonal floods are the most significant threat to the Haor area, flooding the main producing sectors (fisheries and crops) and putting people's lives and livelihoods at risk. During the long monsoon season, the intense wave action of this vast water mass makes the area more vulnerable, threatening a huge quantity of houses in this area and even washing away the land. (IFAD, 2011).

Furthermore, it is estimated that down-thrusting under the Shillong mass is causing the basin area to subside at a rate of 2.1 cm/yr. Other studies, however, show a significantly lower sinking rate of 2-4 mm/year based on an investigation of sediment thickness (IFAD, 2011). Flooding issues are made worse by the basin region's sinking.

2.5.10 Livelihood in Haor Area

Haor area’s people are impoverished, with few employment options, especially during the seasonal floods (IFAD, 2011). Seasonal floods engulf most of the area and rich farmland for a period of six to seven months. Although floods limit the possibilities for rural industry and agricultural output, they are essential to preserving the biological equilibrium of the area and the ecosystem. Residents in Haor villages make most of their money from seasonal off-farm labor and year-round fishing along with seasonal farming. Local governments lease the water bodies for extended periods through "open tenders", making it very expensive for anyone but the elite to engage in fishing. The leases have forced many traditional fishermen to change their livelihoods. At the same time, those who still fish for a living must pay a fee or give up a percentage of their catch to be allowed to fish (IFAD, 2011). Since they no longer have the same income from such activities, many men frequent nearby small towns, cities, and the capital in search of short-term employment.

2.5.11 Tahirpur upazila

According to the Upazila Level Disaster Management Plan Development: Tahirpur Upazila, Bangladesh, (2014),

Tahirpur Upazila is in the Sylhet division, within the Haor-enclosed Sunamganj district. Indian Meghalaya lies to the northeast, Maddanagar Union lies to the northwest, Jamalganj Upazila lies in south side, Bishawmvarpur lies in east side, and Dharmapasha Upazila lies in west side. The distance between Sunamganj district and the city of Sylhet is 69 km, whereas the distance between Tahirpur upazila and Sunamganj district is 40 km. This upazila has 300.04 km of roads, 129 km of embankment, 5 rivers, and 14 canals. This upazila has a total size of 336.70 square kilometres. Loamy, sandy loamy, and buisues soil types are all present. Tahirpur Upazila has seven embankments, totaling 129 kilometers in length. Buses make up most of the homestead. Loamy and sandy loam soils, which are high in fertility, comprise agricultural land. Roads are naturally sandy and loamy, as are the shores of ponds and irrigation canals. Stones and sand are examples of mineral resources.

House

There are 20192 residences in the whole Tahirpur upazila. Of those, 1427 are being built, while 18765 are huts. Tahirpur Upazila has witnessed a wide range of residences. Huts, buildings, semi-brick homes, and tin homes are important types of these. Clay, tin, bamboo, ikar, and other materials are typically used to construct hut dwellings

Land and its usage

The entire area of Tahirpur Upazila is 25246 hectares. There are 24595 hectares of arable land and 650 hectares of uncultivated land among them. Of the arable land, 13455 hectares are used for one crop, 8986 hectares for two crops, and 2154 hectares for three crops. Additionally, the settlement occupies 6,114 hectares of the total land area. Tahirpur Upazila's primary crops are peanuts, mustard, pepper, wheat, potatoes, vegetables, and rice (Boro, Aus, and Aman).

Rainfall trend

Rainfall is hefty from May to September. Analysing the Tahirpur upazila's rainfall pattern reveals that the average daily rainfall remains constant. Rainfall averages 4100 mm per year in Upazila Tahirpur. This upazila typically receives 1000 mm of rainfall in the summer, 2600 mm during the rainy season, and 500 mm during the winter.

Water

The primary sources of drinking water in this upazila include ponds, beels, canals, rivers, and tube wells. There are 1,085 tube wells in this upazila. Among them are 737 active tube wells

and 348 dormant tube wells. 61.19% of people in Tahirpur Upazila get their groundwater via tube wells.

In Tahirpur Upazila, the underlying water level is often between 100 and 300 feet below the surface. seeing a shift in the subsurface water level. At one time, the water level was 70 to 200 feet below the surface.

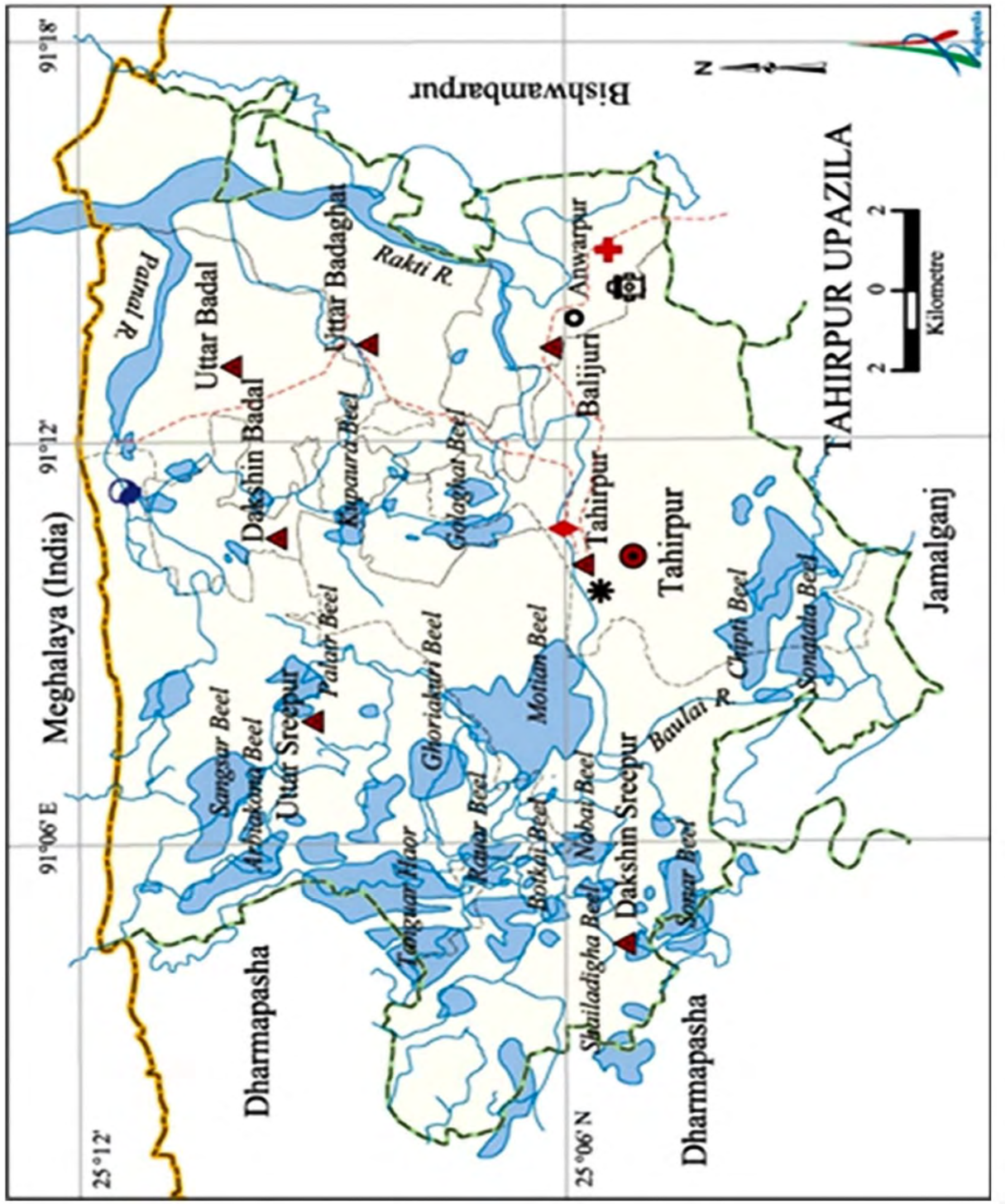


Fig-25: Tahirpur Upazila (*Tahirpur Upazila - Banglapedia*, n.d.)

Tahirpur Upazila has 23 haors. Of them, 6 haors in the upazila were named. The names of these are Gurmar Haor, Halir Haor, Matian Haor, Tanguar Haor, and Shonir Haor. Tahirpur Upazila comprises 2992 hectares of the 9727 hectares of Tanguar Haors.

Vulnerability, Hazard, and Disaster

Flash Flood:

Flash floods are the region's primary calamity. In addition, this upazila has experienced notable disasters, including Kalboishakhi Jhar, Drought, and periodic floods. Due to excessive rains and water from the upstream area, Tahirpur witnessed a flash flood. In the Tahirpur union of Tahirpur Sadar upazila, flash floods have harmed boro crops on 1,580 hectares of land (full) and 382 hectares of land (partial), as well as a 3.50 km embankment and a 3 km road. Consequently, at least 1293 farmers' families are impacted both directly and indirectly. A flash flood similar to the one that struck Tahirpur Union in 2010 could destroy 1,670 hectares of full and 447 hectares of partial boro crops, as well as a 6 km road and 8 kilometres of employment opportunities. The families' of 1315 farmers might be impacted.

Seasonal flood:

There is a lot of flooding in the Tahirpur area. Seasonal floods come to this area due to rain and upper areas' flood water from the March to June. The entire region is crowded during the rainy season. Every settlement then seems to be a floating water hyacinth (kachuri pana). The wind is causing the waves to rise higher and higher at this moment. Homes, bridges, culverts, cattle, educational and religious institutions, trees and plants, and embankments were all impacted. Cases of death also happen. The 2004 seasonal flood devastated 62 hectares of amon crops, 682 dwellings, a 14-kilometer road (partially), 3.5 jobs, 6 educational institutions, 5 fishing firms, 17 tube wells, 45 latrines, and 7 religious' institutions in the Tahirpur Sadar Union of Tahirpur Upazila. However, 20 animals perished in the periodic flood. The families' of 1507 farmers are impacted both directly and indirectly.

2.5.12 Tanguar Haor

The 9,727-hectare Tanguar Haor (TH) in Sunamgonj is situated along Tahirpur Road. 91° 01' to 91° 06' E and 25° 06' to 25° 11' N are the coordinates. The Surma, Baulai, and Jadukata Rivers have influenced this area. The governance of Tanguar Haor is split between the Tahirpur Upazila and the Dharmapasha, both of which are in the Sunamganj District of Sylhet. Approximately 31% of Tanguar Haor is allocated for agriculture, while around 50% is

comprised of water bodies. (Chowdhury, 2010) The Haor area is flooded by upstream water that moves northward during the monsoon.

The geography of Tanguar Haor is defined by five major core depressions: Rowar, Rupaboi, Bherberia, Tangua, and Leehchamara. These are surrounded by low-lying plains, rising topography, and finally the Indian Hills (Chowdhury, 2010). Thirty percent of the forty-four thin water canals that drop from Indian land into these beels have a year-round flow, while the other canals are only active during the monsoon season. Significant sediments are deposited into the beels and nearby upland regions (villages) by the water flows, including tiny canals and rivers, and they may be easily visible on satellite maps. [Figure-1: Tanguar Haor]

There are over fifty beels in Tanguar Haor. In certain areas, rivers are connected to extensive beels, and these beels are linked to one another, lending the region a unique character. The beels come together to form a single, large body of water during the monsoon season, which runs from April or May until October. The communities of Haor are isolated and in an island state. There are around 46 settlements in Tanguar Haor. (Raihan & Hossain, 2021)

2.5.13 Flood Effects on Tanguar Haor Livelihoods

Floods have an impact on people's salaries in addition to forcing them to change careers. Most of them switched to seasonal fishing during floods after previously working in agriculture and as day labourers, depending on the haor resources. (Abedin & Khatun, 2020) The kids also became seasonal fishers because of the flooding of local schools. Early flash floods destroy paddy crops, while post-monsoon flash floods pose a threat to vegetable production.

According to Abedin & Khatun (2020), before the flood, 35% of farmers, 11% of fishermen, 13% of day laborers, 2 % of teachers, and 8% of housewives worked, and most became jobless during the flood. During the flood, 31% of people became jobless, and only 4% of farmers, 9% of fishermen, and 11% of day laborers worked during flood time.

2.5.14 Tanguar Haor's Livelihood Calendar and Hazards

Abedin & Khatun (2020) stated floods in the early and monsoon seasons significantly disrupt farming activities such as seedbed preparation, planting, harvesting, fishing, and everyday labour. Hailstorms mostly harm crops grown for vegetables. Both drought and heavy rainfall create many problems, disrupting labour-intensive tasks, including soil excavation, fishing, and vegetable farming. Waterlogging and neither western-style seasonal storms have a detrimental impact on farming, agriculture, and vegetable output. Additionally, everyday tasks like stone

quarrying, boatman services, and product movement become challenging during floods and periods of excessive rainfall.

Local people's occupation depends on Crop cultivation in this there are separate fragmented work like preparing seedbed, planting, harvesting during dry season, during monsoon they depend on water-based economy like fishing, boating etc. and some people are also involved with day labor work. (Abedin & Khatun, 2020) This table shows the relationship between their occupations with natural disaster.

2.5.15 Flood Effects on Housing in Tanguar Haor

The immediate consequences of floods include the inundation of residences, the destruction and loss of physical assets, and the hazards linked to elevated water levels. According to (Abedin & Khatun, 2020), 53% of homes collapsed during floods, while the remaining 47% had significant damage that necessitated considerable repair costs. Approximately 34% of people impacted by recurring flash floods and residing in low-lying areas have shifted their residences, mostly to nearby elevated terrain. The remaining 66% either manage the flood or elevate the town above the typical reach of flash flood waters, unless during significant events.

2.5.16 Flood Wall Mitigation in Tanguar Haor

Villages are protected by protection walls against floodwater. The government organization LGED constructed protective walls using brick and concrete blocks. Locals built a sandbag mud wall around the structure to protect the village from floodwater. (Local Government Engineering Department, n.d.)

2.5.17 Protection wall

According to Zeeshan (2024), any vertical or sloping structure that must be in direct contact with water or has to bear the pressure of such water upon it is called a water wall. Retaining walls are essential for various construction projects that involve water management, coastal protection, or enhancing the durability of infrastructure. These can be made from steel, stone, or reinforced concrete.

The primary function of the wall in a water situation is to provide structural support and to prevent erosive and/or displacement effects of the materials caused by water flow, tidal action, or hydrostatic pressure. In addition to protecting buildings, roads, and other critical infrastructures that lie next to or in bodies of water, these walls are used as barriers to control water flow and prevent flooding. Walls are used in water construction to hold soil or other

materials when there are changes in the ground level. These walls are beneficial in areas with hilly terrain or near bodies of water, as they help manage water runoff and prevent landslides. Walls are often used to hold the land together on waterfront estates, to prevent erosion and provide a stable base for other buildings. Some of the materials that are generally used to build waterfront retaining walls include concrete blocks, brick, stone, and reinforced concrete.

2.5.18 Problems with the construction of a wall of protection

According to Zeeshan (2024), building a wall on water has its own challenges, and they need to be addressed so that the wall can be practical and useful over the long term. Some of these challenges include.

Hydrostatic pressure: Hydrostatic pressure is the force which water exerts on an object it has submerged. There is pressure build-up with the depth of water. The increase of water height increases the water hydrostatic pressure, which is a serious problem to water walls. Engineers are required to develop walls that can hold this sustained pressure to avoid fracture, wall movement, and collapsing.

Erosion and Corrosion: A wall which is exposed to water or waves can be eroded by the water. It may wear or corrode away, weakening the wall structure, over time with concrete and steel, such as. To prevent this deterioration, it is important to choose the material and treat it properly.

Soil Stability and foundation design: any wall constructed in water should have a foundation that is capable of resisting soil movement due to the passage of waves or water. Wall foundations should be strong enough not to tilt or settle in their place. Soil stability is particularly critical in loose or soft soils where the base of the structure can easily be eroded by water.

Environmental factors: Environmental factors that may affect the structural performance of a wall in water include tides, storms and waves. Powerful storms and huge waves can move and damage smaller buildings; therefore, it should be constructed in such a way that it is not damaged by their strong forces. This means that storm surges, seismic activity, and the increase in sea levels due to climate change are all factors that need to be considered during the design of the wall.

Seepage and Leakage: The other common problem with water barriers is the seepage. Water that gets through either the wall or the bottom can ruin the structure as well as the purpose of the building. The common solutions to this are an impermeable lining and appropriate methods of sealing, to ensure that there is no intrusion in water.

These are the problems that mostly increase when trying to construct a protection wall. Moreover, there are a lot of other issues that must be encountered.

2.5.19 Durability of the Protection wall in water

Concrete block

In Southgate (2025), Concrete blocks can be used in various environments and provide sufficient durability throughout the structure's lifetime due to their strong resistance to moisture. Standard concrete blocks can allow water to pass through in certain situations, despite offering some water resistance. Capillary action, in which water passes through the tiny pores in the concrete blocks, is the source of this. Several variables, including the type of block, its composition, and the building style, influence its resistance to water. All kinds of aggregate concrete blocks can offer considerable resistance to moisture intrusion, and blocks with a compressive strength of 7.3 N/mm² are considered frost- and moisture-resistant everywhere, including beneath the damp-proof course.

Efflorescence is a typical symptom associated with dampness. The surface of a brick wall or concrete block is covered with this white, chalky powder. It could appear fuzzy up close or like crystals growing on the blocks. This occurs when water seeps through the surface, dissolving the lime and causing it to begin leaking out, where it accumulates on the surface. Although it is typically a cosmetic concern, it should be rectified, especially if the wall is to undergo any surface treatments. (Southgate, 2025)

Water penetration can also be affected by the thickness of the concrete blocks. The minimum grade required to offer sufficient resistance to moisture and freezing danger is blocks with a compressive strength of 7.3N/mm2. In less protected areas, blocks with a lower compressive strength, such as 3.6 N/mm², can be utilized. (Southgate, 2025) Dense blocks, like those found in the linarite series, work very well. This is because fewer porous aggregates were used.

Suitably, several treatments are available to enhance the walls' functionality. One option is to apply render; pre-mixed types provide uniform quality and color consistency. In severe situations, consider coating the walls. Another popular option for moisture protection is bitumen wall coatings. Reducing moisture intrusion may also be aided with brick facade creams, sealers, and water-repellent coatings. By filling the pores on the surface of concrete masonry units, these treatments prevent water from penetrating and instead cause it to flow off. (Southgate, 2025)

Brick wall:

Although brick walls themselves are quite durable, they are not resistant to water damage and are vulnerable when exposed to moisture or cold temperatures for long periods of time. Groundwater can work its way into the brickwork, leading to structural damage, mold growth, and moisture accumulation.

Bricks have been used in areas with relatively mild environmental conditions; they do not need to support large loads or withstand extreme temperatures or weather changes. Of course, some bricks will end up being used in situations where they will be stretched to their limits. Engineering bricks may be necessary in more serious cases (such as recurring cold or prolonged exposure to moisture). Such one-way blocks are often used to construct important infrastructure, such as sewers or tunnels. (Nj-Totalsurf, 2023) The Engineering bricks are suitable for use in foundation applications due to their smooth external surface and core perforations, which allow for integration with steel bars or mortar to produce a high compressive strength.

When a brick is laid incorrectly, or it is the wrong kind of brick for the local climate, the result can be that it will deteriorate, and its structural strength will be lost. However, some bricks are very sensitive to a reduction in saturation caused by moisture or direct contact with water. If there is not enough, the brick can suck water from the surrounding mortar, which will cause cracks in the mortar; if there is too much, it may cause dilution, which will weaken the bond between the brick and the mortar. (Nj-Totalsurf, 2023)

Over time, decay, cracking, crazing, and spalling can occur due to the presence of moisture. In addition, water intrusion provides the moisture needed for mold growth on vulnerable wall elements. Some recommendations for protecting brick walls include ensuring there is enough cavity space. Weeps help water get out and air get in, which provides an additional layer of protection. Parapets and walls should be capped. (Caulfield, 2010)

Sandbag:

Sandbags are made mostly from burlap and woven polypropylene. Woven polypropylene is ideal for long-term flood defense, as it is highly resistant to water and extremely durable. Burlap is a more traditional, biodegradable option that is less durable than other materials. Consumers like these empty sandbags because they hit a balance between performance and cost.

How long sandbags last in water depends on the material they are made from and the conditions they are exposed to. Burlap sandbags are cheap and biodegradable, but they do not last long

and will degrade in 6 to 12 months, particularly when exposed to moisture and sunlight. However, if they are UV-protected and heavy-duty, then they are more resilient to breaking down than other types of sandbags. They can be exposed to water and UV rays for two to three years or more. (Gambell, 2024)

Polypropylene may also be used, as may PVC. PVC sandbags add an extra layer of protection and are most useful when the level of floodwater is expected to increase rapidly. They are used to build temporary flood barriers around rivers or car storage areas to create a tight and secure barrier. Not as easy to quickly stack as other types, but durable and practical in an emergency, and they cannot be bent. (King, 2025)

Chapter Three
Methodology

3.1 Research Process

This study used mixed-methodology approach. Three villages, Nichodropur, Solaimanpur, and Anondonagar, were selected to conduct the field study in Tanguar Haor.

For this study, the study population was selected from water-edge houses that have protective walls around their properties, as they are vulnerable to both erosion and flooding. These houses were most impacted by the flood and, as such, should experience the largest benefit from the flood protection wall.

Quantitative: A Survey questionnaire with mostly closed-ended questions collected numerical data on the impact of structural flood mitigation on respondents' livelihoods, enabling statistical tests to compare key indicators across the three settlements.

Qualitative: Qualitative interviews were conducted with the water edge household community members to gather in-depth information on potential threats and experiences through focus group discussions (FGD) and Key Informant Interviews (KII) with relevant organizer officers to gain their knowledge and experiences. This reveals the quality of their lives, culture, and livelihood, as well as some numerical data.

3.2 Methods

3.2.1 Primary Data

The Quantitative Method

Questionnaire Survey:

For this Quantitative sample, Purposive sampling was selected. In these three villages, peripheral settlements close to the water's edge with a protective wall were selected because these houses are affected by both erosion and floodwater. The protection wall has the most impact on these houses.

These water edge houses with a protection wall were used as the population size. The population size is known and small. In this case, if the questionnaire sample size is funded from (How to Calculate Sample Size Using a Sample Size Formula, n.d.).

Sample size = [{Z^2 x P(P-1)}/E2] / [1+(Z^2 x P(P-1)/ E^2 x N)]

Where N = population size, Z = z-score, E = margin of error, and P = standard deviation. The Z-score is 1.96 for the computations based on a 95% confidence level. The standard deviation

is taken to be constant at 50%, and the margin of error is set at 5%. From the equation and matrix.

	Nichodropur	Solaimanpur	Anondonagar
Sample Size	33	22	17
Population size (Total House or Settlement No.)	35	23	17

(*Sample Size Calculator*, n.d.)

Table-2: Sample Size calculation

Since there is little difference between the sample size and the population size.

So, for this study, the large number was taken as a sample size which is the whole population size.

where Nichodropur, Solaimanpur, and Anondonagar have 35, 23, and 17 water edge houses with a protection wall.

The Qualitative Method

FGDs, KII, and direct observation gather primary data. First, the participant receives a detailed explanation of the study's objectives. Then, a semi-structured interview is conducted with them. The interview uses open-ended questions, allowing participants to express their experiences fully.

Focus Group Discussion (FGD):

FGD was conducted with 6 people to encourage active participation and diverse perspectives. The questions were open-ended to encourage contributors to share their understanding, opinions, and suggestions about their experiences with the impact of structural mitigation on their livelihood, particularly regarding the level of property damage, economic effects, and social relationships.

Key Informant Interview (KII):

Key informants were selected from experts, including their opinions, ideas, and experiences on the impact of structural flood mitigation, as well as local Government and NGO officers who were directly involved in this process.

Organization name	Key informants	Number of KII
Local Government Engineering Department (LGED)	Engineer	01
Bangladesh Water Development Board (BWDB)	Engineer	01
BRAC	Officer	01

Table- 3: Key informants

For the KII, three people have been selected. Two of them are government engineers, and one is an officer from a BRAC NGO. All of whom work on flood protection and the quality of life of people during and after floods.

Direct Observation

Direct observation was used to collect data and note precise user behaviour patterns regarding the impact of the protection wall.

3.2.2 Secondary Data:

Literature Review

From the literature review, it was found that the Tangaor Haor settlement condition, villagers' livelihood, and the DFID and Rural Housing Livelihood Framework were examined. This was used to create links and validate the livelihoods of the people in the three villages.

Satellite Image Analysis

The impact of floodwaters and erosion on the villages has been analyzed by reviewing and marking satellite images from different periods.

3.3 Data processing and analysis

Quantitative data was gathered, analyzed, and recorded in an Excel data sheet for analysis. All data were numerically presented here. Data tables, graphs, and charts are created with a specific point of view for the comparison.

Qualitative data was analyzed by collecting data from FGDs, KIIs, and direct observations of their current condition and experiences with properties, damage, and social and financial conditions and to understand the previous condition, secondary data was used, which was collected from literature and satellite image analysis.

3.4. Data Validation of Findings

At the end, a triangulation analysis was conducted to validate the findings, incorporating the results from the questionnaire, KII, and FGD, observation, satellite image analysis and all points that can be obtained from primary data and secondary data for validation were validified by creating a link based on the DFID and Mphande (2016), rural housing's livelihood framework, or relevant points.

3.5 Research Framework

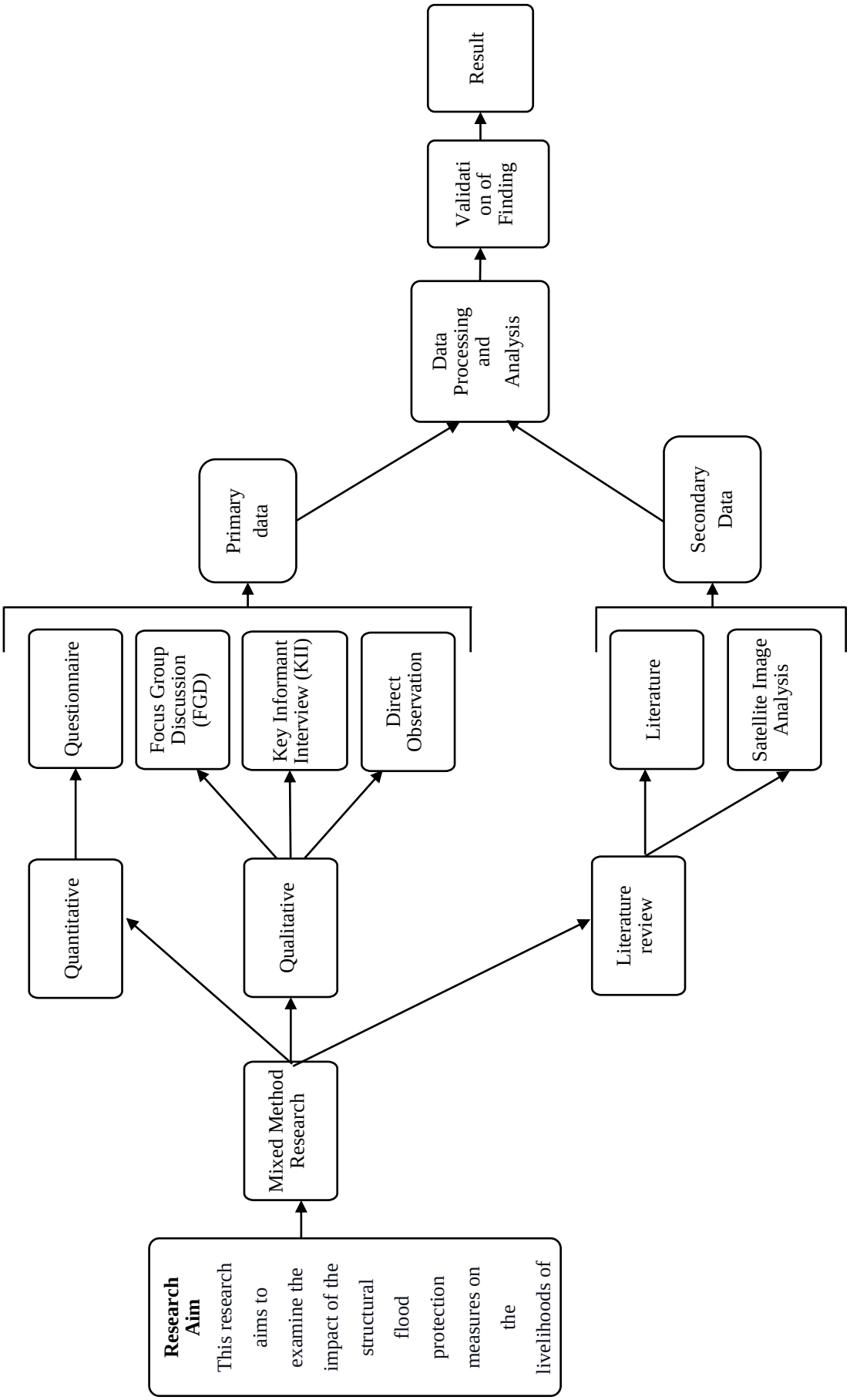


Fig-26: Research Framework

Chapter Four
Survey Findings

This chapter compares the impacts of structural flood mitigation measures on the Livelihoods of Nichodropur, Solaimanpur, and Anondonagar, three villages. Based on the questionnaire with closed-ended questions collected, numerical data. KII, FGD, direct observation and satellite image analysis revealed the quality of livelihood.

The questionnaire, Key Informant Interviews, Focus Group Discussions, Observation, and Satellite Image Analysis findings were used to form a triangulation and justify the result.

4.1 Findings from the Questionnaire

4.1.1 Settlement and Infrastructure:

Does your home still get damaged by floodwater and erosion after the protection wall?

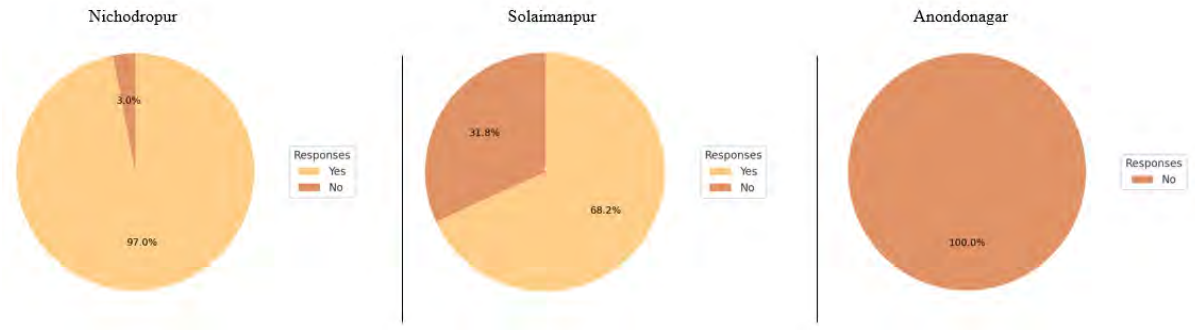


Fig-27: Comparative analysis between three villages: Does flood damage homes?

All Anondonagar's respondents said their homes are safe during floods because of their strong and durable protection walls. Their protection wall can protect their house from floodwater. In Solaimanpur, 68.2% of respondents reported that their houses were safe, while the remaining 31.8% experienced damage to their homes. Nichodropur's protection wall is fragile, so 97% of the responder's houses have been damaged by floodwater.

Does floodwater still submerge your home after the protection wall was built?

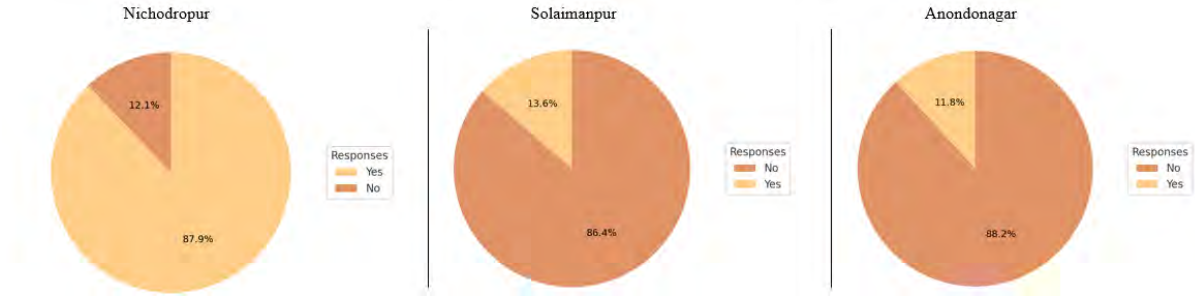


Fig-28: Comparative analysis between three villages: Homes submerged after the embankment

In Anondonagar and Solaimanpur, 88.2% and 86.4% of responders said their houses did not submerge during the flood, and 11.8% and 13.6% said their home portions were submerged with floodwater. Despite having a protection wall in Nichodropur, 87.9% of people's houses were submerged in floodwater.

Were you able to build a new house after the protection wall was constructed?

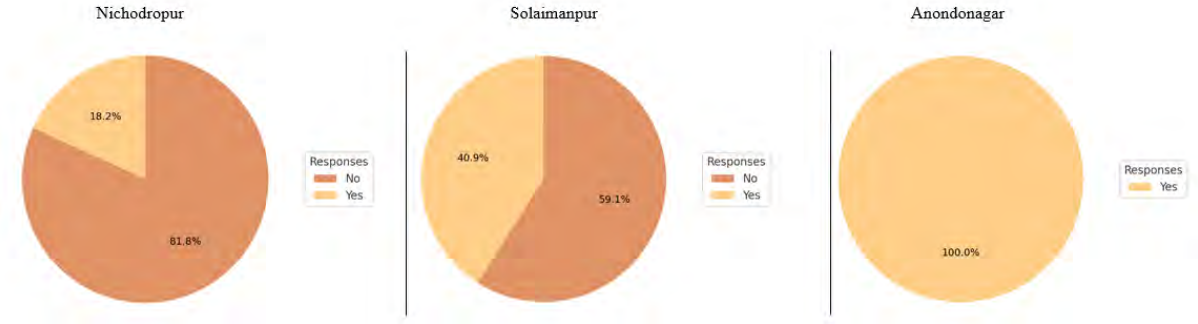


Fig-29: Comparative analysis between three villages: Were you able to build a new house after the dam was built

After the protection wall, Anondonagar and Solaimanpur, 100% and 40.9% of the responders can build their new houses. Instead, in Nichodropur, only 18.2% of respondents can build new homes, while the rest, 81.8%, always rebuild or repair their old homes.

How well has the protection wall worked to keep and protect livestock?

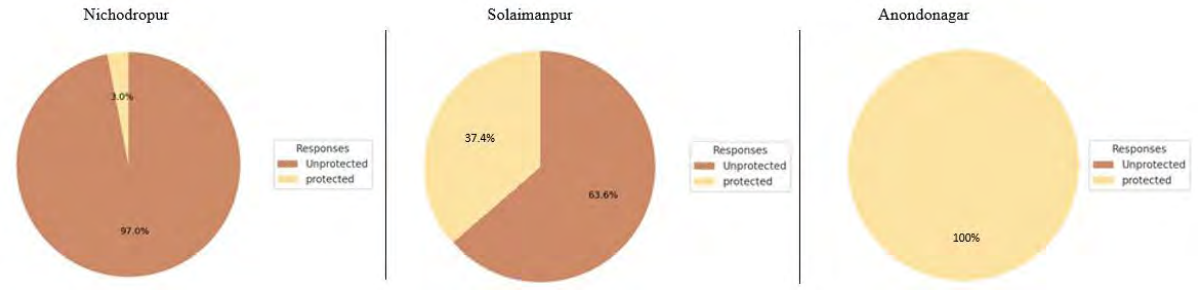


Fig-30: Comparative analysis between three villages: Is the protective wall capable of protecting livestock

According to Anondonagar's responder, they are happy to be involved in cattle breeding. All the responders said their cattle were safe behind the protection wall. 63.6% of the respondents from Solaimanpur stated that their cattle are protected from floods, whereas in Nishchintapur, only 3% of the respondents reported that their cattle are safe, while 97% stated that their cattle are not safe.

4.1.2 Financial Capacity

During flood season, is income generation disrupted due to maintaining the protection wall?

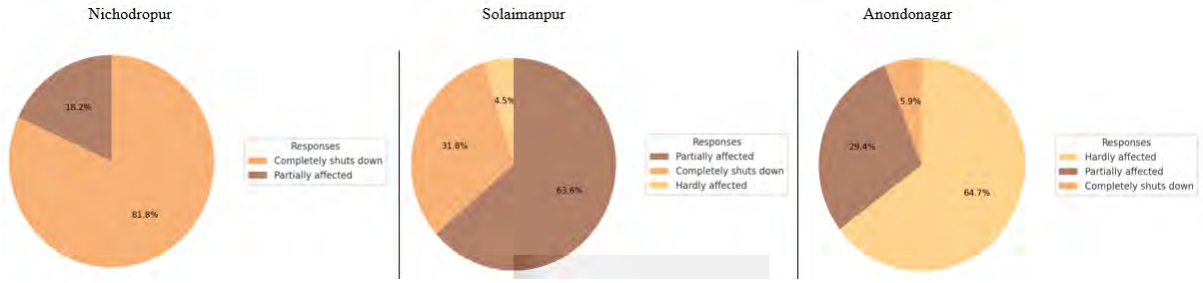


Fig-31: Comparative analysis between three villages: Is the income disruption during flood

In Anondonagar, most people 64.7% can continue their income, 29.5% of incomes are partially affected during flood time, and only 5.9% of people have their income affected. Because their brick protection wall is so durable, they do not need to bother with it. In Solaimanpur, 63.6% of the respondents were partially affected, and 31.8% of their income was stopped during the flood. Only 4.5% of people could generate their income. But Nichodropur's protection wall is so fragile, so they need to stay in their home to protect this dam and their properties. That's why 81.8% of responder's income completely stops.

How frequently do you need to pay for repairs to the protection wall?

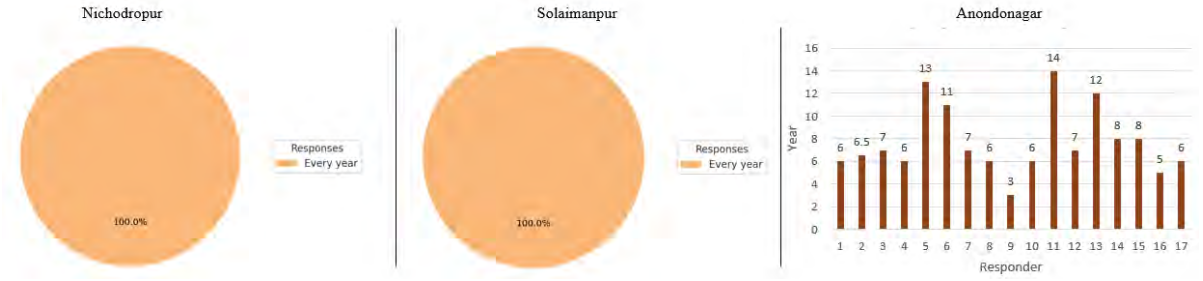


Fig-32: Comparative analysis between three villages: How often do you need to spend money on protection wall repair

According to Anondonagar's responder, they do not repair or spend money on repairing the protection wall. They must repair it after a long year gap. In response, the lowest year gap is 3 years, and most people spend money on repairs every 5 to 8 years. Even some responders spend money after 10 to 14 years. On the other hand, Solaimanpur and Nishchintapur responders spend money every year to repair the protection wall.

How much Yearly Expenses Percentage of income on the protection wall?

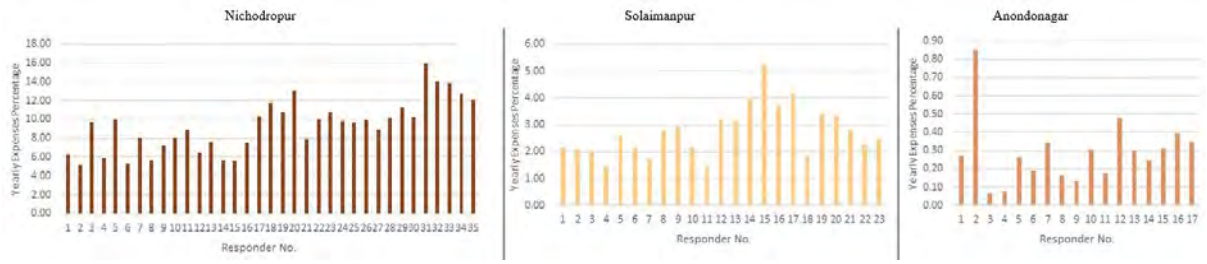


Fig-33: Comparative analysis between three villages: Yearly Expenses Percentage of income on the protection wall

According to Anondonagar's responder, they spend less than 1% money of their yearly income on the protection wall. So, they can save their money, and this saved money can be invested in other life-improvement sectors. In Solaimanpur, most people spend 2-3% of their yearly income. Only two responders spend more than 4% of their money on the protection wall. Nishchintapur: The graph indicates that most responders allocate 6 to 10% of their annual income to protection wall repair. Even nine respondents out of 33 spend more than 10% of their annual income. This makes them economically weak, which in turn leads to a poor lifestyle.

4.1.3 Social Bondage

Condition of neighbourhood bondage after the protection wall was built?

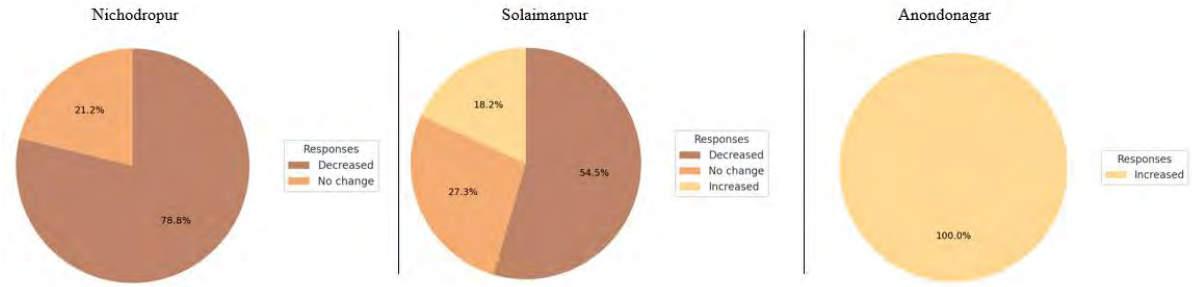


Fig-34: Comparative analysis between three villages: The impact of protection walls on social understanding

This diagram shows the impact of social relationships with neighbours based on the protection wall.

The diagram shows that Anondonagar has a better social understanding between neighbours, with 100% of people reporting an increase in their social understanding. Instead, in Solaimanpur, people reported that 18.2% experienced an increase, 27.3% saw no change, and 54.5% reported a decrease. But in Nichodropur, there is a lot of social unrest among them regarding the dam. Their social understanding decreased by 78.8%, and 21.2% are in neutral condition.

4.1.4 Benefits from structural measures

What good things have the structural measures done for you?

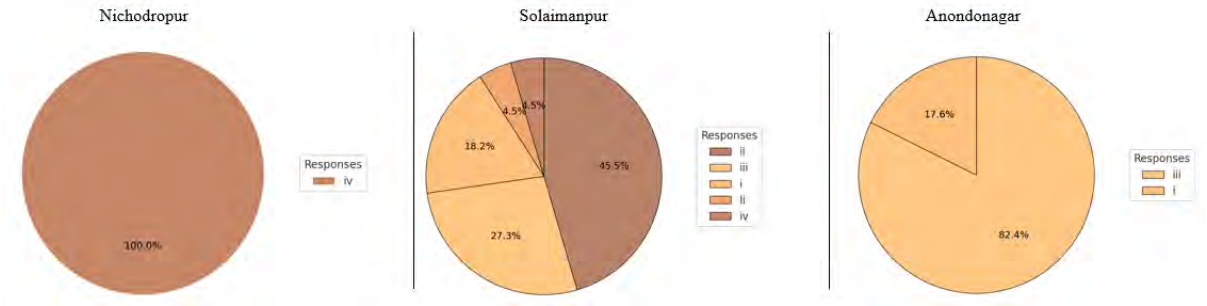


Fig-35: Comparative analysis between three villages: What benefits have you received due to the structural measures

Anondonagar's 17.6% responders selected option (i), which indicates they have a safe home, and 82.4% selected option (iii), which means they have a safe home, an Earning source, and safe cattle shed. In Solaimanpur, 45.5% selected (ii) new earning source and, 18.2% selected safe home(i), 27.3% selected number (iii), which is almost all safe home, earning source, and safe cattle shed. And both 4.5% said 'safe cattle shed' and 'nothing.' All Nichodropur's responder select number (iv), which is none. Despite their dam, they have not found a safe house, secure cattle shed, or anything new to earn money.

4.2 Findings from the FGD

4.2.1. Nichodropur

There is no positive impact on our lives after the Earth-filled sack protection wall. Every year, this protection wall is damaged by floodwater. Even after breaking the protection wall in our home, the cattle shed was also submerged by floodwater. When the flood level is low, this wall protects us, but when the water level rises, and the water wave force becomes strong, this wall cannot protect our home. At that moment, it is challenging for us to survive with broken homes, and saving lives becomes even more difficult.

This wall is not effective. We always must stay by the dam. We must stand guard here to protect the dam. During this time, we cannot move from here to earn. Our earnings were stopped at that time.

After the flood, we rebuilt this protection wall and the home and cattle shed through our savings. Once or twice is okay, but we rebuild our protection wall, home, and cattle shed every year, which hurts us financially.

Fig-36: Damaged earth-filled sack protection wall

Fig-37: Earth-filled sack protection wall

Evey year water edge household need to repair these sandbags after flood. Also, when we repair this most of the time, it creates a quarrel between neighbors.

This wall is not durable enough to withstand floods, which is a significant limitation of this wall. To repair the wall and our properties, we incur a significant expense. We hope, Government organizations or NGOs will help us and will build a permanent protection wall so our lives and properties will be safe.

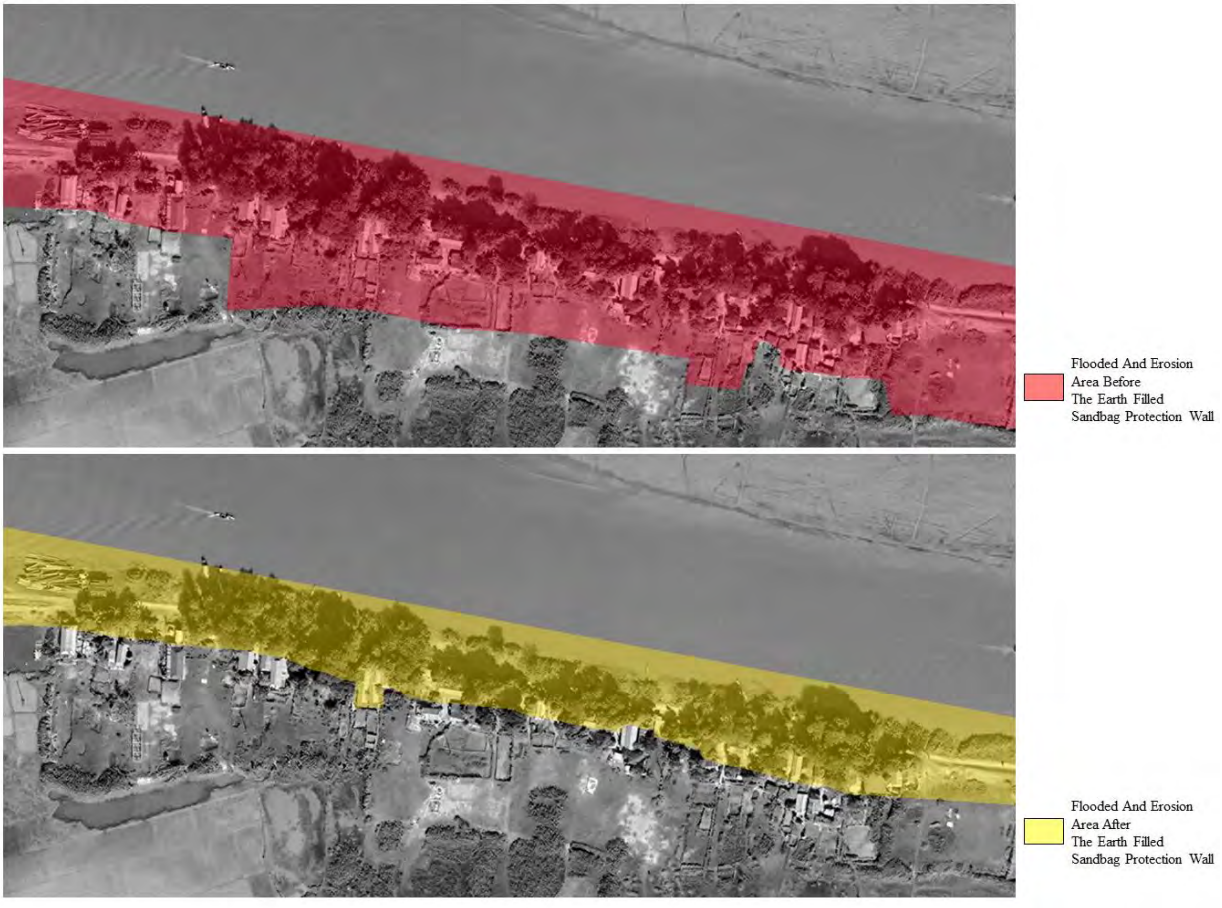


Fig-38: Flood and erosion affected area before and after the earth-filled sandbag protection wall

Before the sandbag protection wall, almost half of the village faced floodwater and erosion. Mostly, the water edge houses are most affected by floodwater and erosion, which is marked by red color.

After building a protection wall with earth-filled sandbags, the area of erosion and flooding has decreased, marked by a yellow color. But the water edge houses still suffered damage from floodwater and erosion, affecting their properties, households, cattle sheds, and the economy.

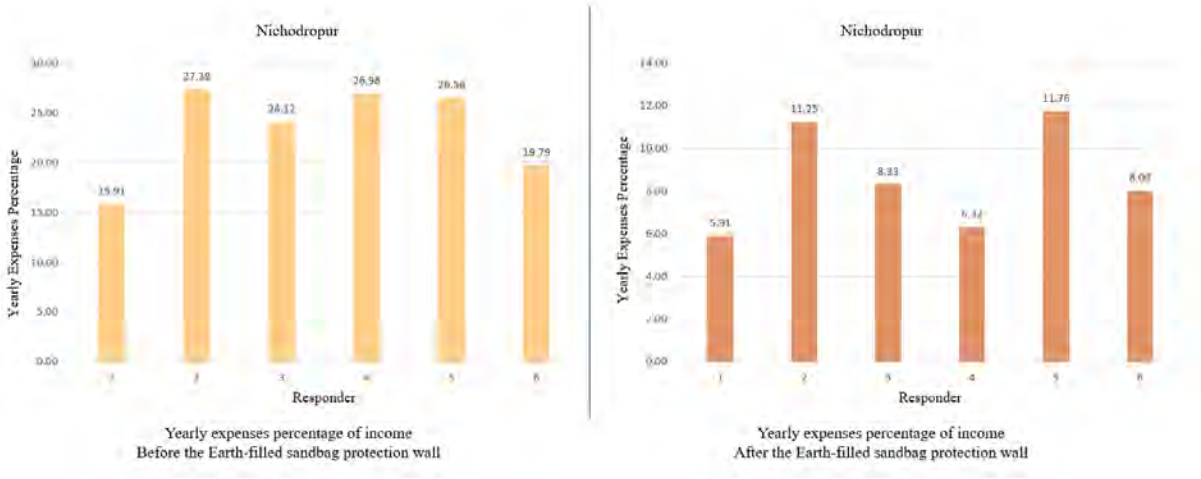


Fig-39: Yearly expenses percentage of income before and after the earth-filled sandbag protection wall

From the graph before the protection wall, households need to spend around 20% to 30% of their yearly income to repair their properties and other things to return to their previous life. After installing the sandbag protection wall, they need to spend around 10% to 12% of their yearly income to repair their properties. The 10-12% spent on repairs every year is too high for them, directly impacting their livelihood and growth.

[NB: Image of FGD in Nichodropur in Appendix D- Image 1]

4.2.2. Solaimanpur

Our homes and homeland are mostly safe after the Concrete block wall was built by LGED in 2017. But a few houses or homes still face damage. Few homes are still submerged, and floodwater is stuck in their inner and outer yards.

This protection wall saved our properties moderately because when the floodwater wave force increases, the block is displaced from some places, and the soil in those places' collapses. It impacts our homes. Sometimes, the home's portion broke, and some portions were submerged by floodwater.

This block Repair is costly for us and has an impact on our economy. Every year, we need to use mortar in the gap between two blocks. This mortar is made of cement and sand. There is no economic assistance from the government and NGOs. So, it directly hampers our economy. During this protection wall, we are moderately safe from flood water. The wall was safe in our home, cattle shed. For this, we have a wharf, which serves as our recreation space, and it helps us build our social understanding. On the block wall, we have fewer issues with our neighbors.

Fig-40**:** Blocks displaced by floodwater

Fig-41: Protection wall by concrete blocks

This protection wall is good but not the best or good enough. Repairing this block is not easy, as it has considerable weight, which is harmful to our bodies and requires extra carrying costs. Sometimes, our children's and domestic animals' legs get stuck between the gaps in the blocks. We need a stable protection wall. If it is a block-based protection wall, then we need a stable and strong block-based protection wall or brick wall protection wall, which is more stable.

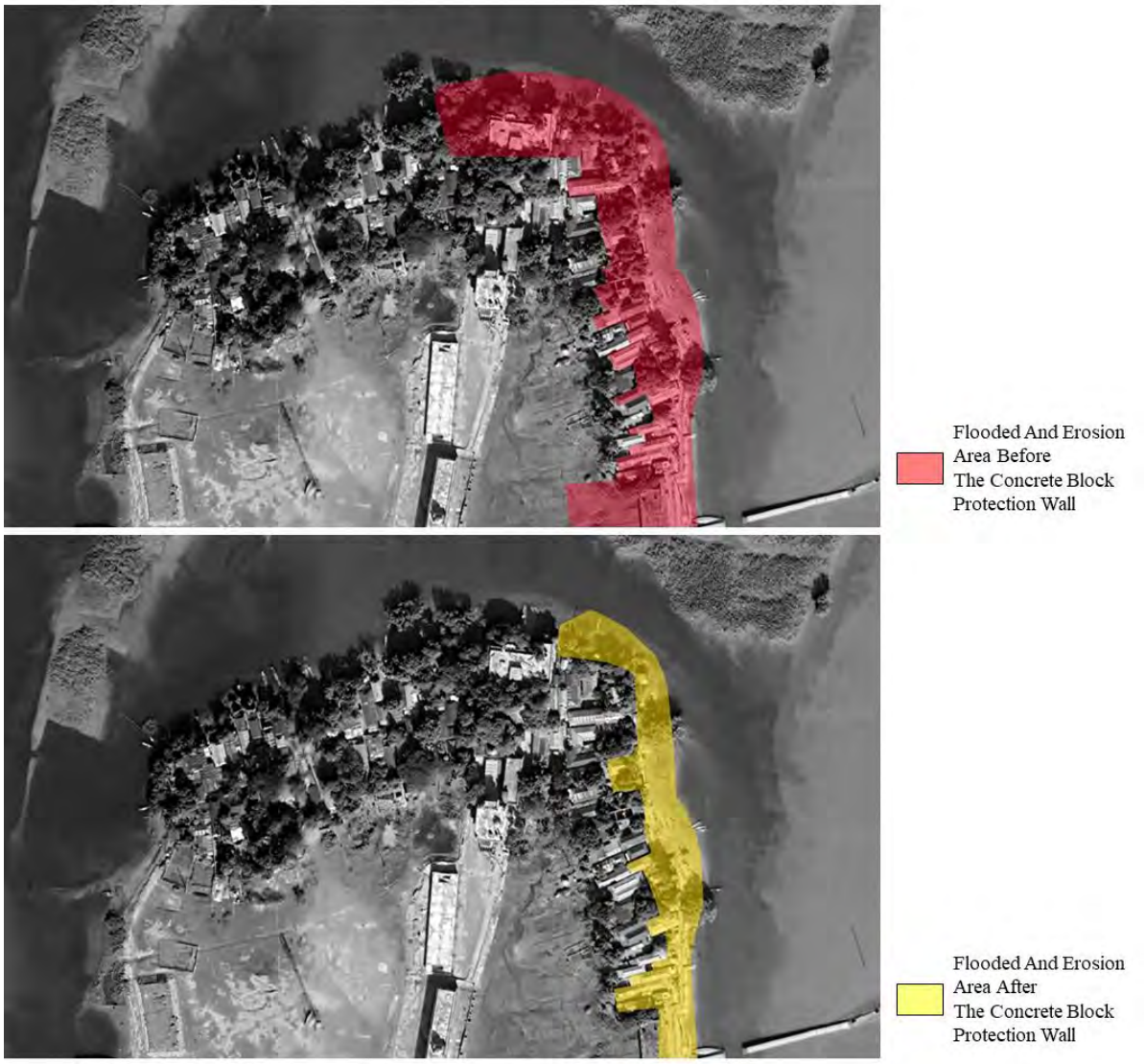


Fig-42: Flood and erosion affected area before and after the concrete block protection wall

Before the concrete block protection wall, almost one-third of the village faced floodwater and erosion. Mostly, the water edge houses are most affected by floodwater and erosion, which is marked by red color. At that time, the water edge household lost their house, cattle shed and fell into an economic crisis. After the flood, they need to rebuild or repair their properties.

Following the construction of a protection wall in 2017 using concrete blocks by LGED, the area of erosion and flooding has decreased, as indicated by a yellow color. A few water-edge houses that remain suffered damage from floodwater and erosion. The floodwater's force displaced the concrete blocks, leading to erosion and affecting the properties, households, and cattle sheds. In contrast, most water edge houses are now safe and are experiencing a positive impact on their livelihoods following the installation of the protection wall.

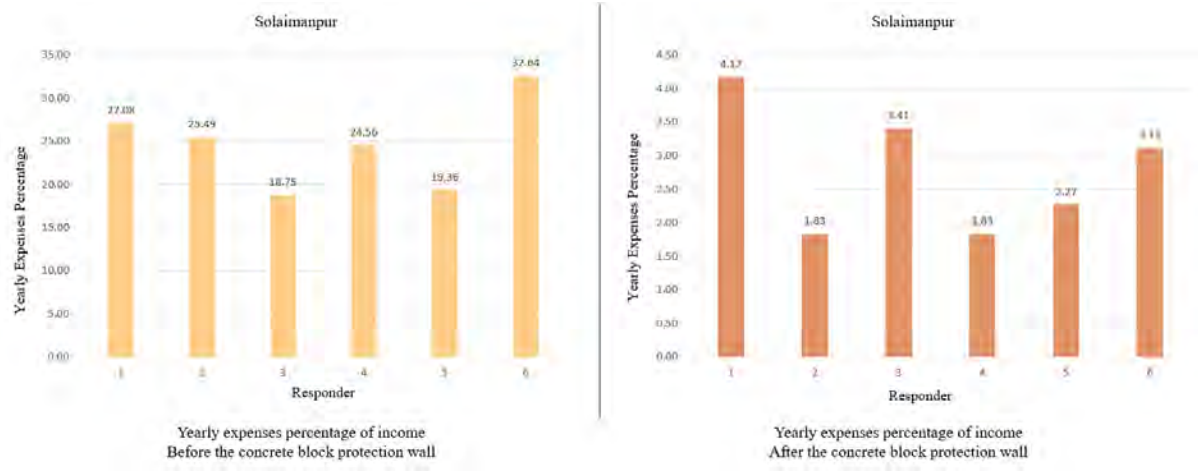


Fig-43: Yearly expenses percentage of income before and after the concrete block protection wall

From the graph, before the protection wall, households need to spend around 25% to 30% of their yearly income to repair their properties and other things to return to their previous livelihood. After building the concrete block protection wall, they need to spend around 3% to 5% of their yearly income to repair their properties. This percentage difference reveals the improvement in their livelihood before and after the protection wall.

[NB: Image of FGD in Solaimanpur in Appendix D- Image 2]

4.2.3. Anondonagar

We can live in peace in this village because there is a brick protection wall. When we do not have this protective wall every year, our houses are damaged. After this Protection wall, our House, Cattle shed, and other properties are entirely safe so far from the flood. In 2010-2011, LGED constructed this protection wall, which required minimal maintenance. If needed, it takes a minimum of 5-8 years, so you do not need much money to repair this.

This Brick wall serves as a protective wall and is very effective and durable, protecting our properties from floodwater. This wall provides all living facilities with very low maintenance. Even during flood season, villagers can go outside the village to earn a living.

This Protection wall gives us a safe home, a safe courtyard for vegetation, safe cattle shed, a safe toilet and kitchen, and a good understanding with neighbors. It also helps us to save money. We can save money and invest it in our lives because there is no additional cost to protect this wall and no cost to rebuild houses, cattle sheds, and other properties over a long period.

During the flood, everyone can go home inside the village, and movement can also be possible outside the village. So far, no one needs to stay here or worry about the property's damage.

Fig-44: Brick protection wall of Anondonagar

But the flood water level last year was too high compared to other years. After 14 years, the water level crosses the wall height. Therefore, a few houses need to raise the wall height as well.

We are pleased with this type of protection wall, but it would be great if the wall height could be increased.

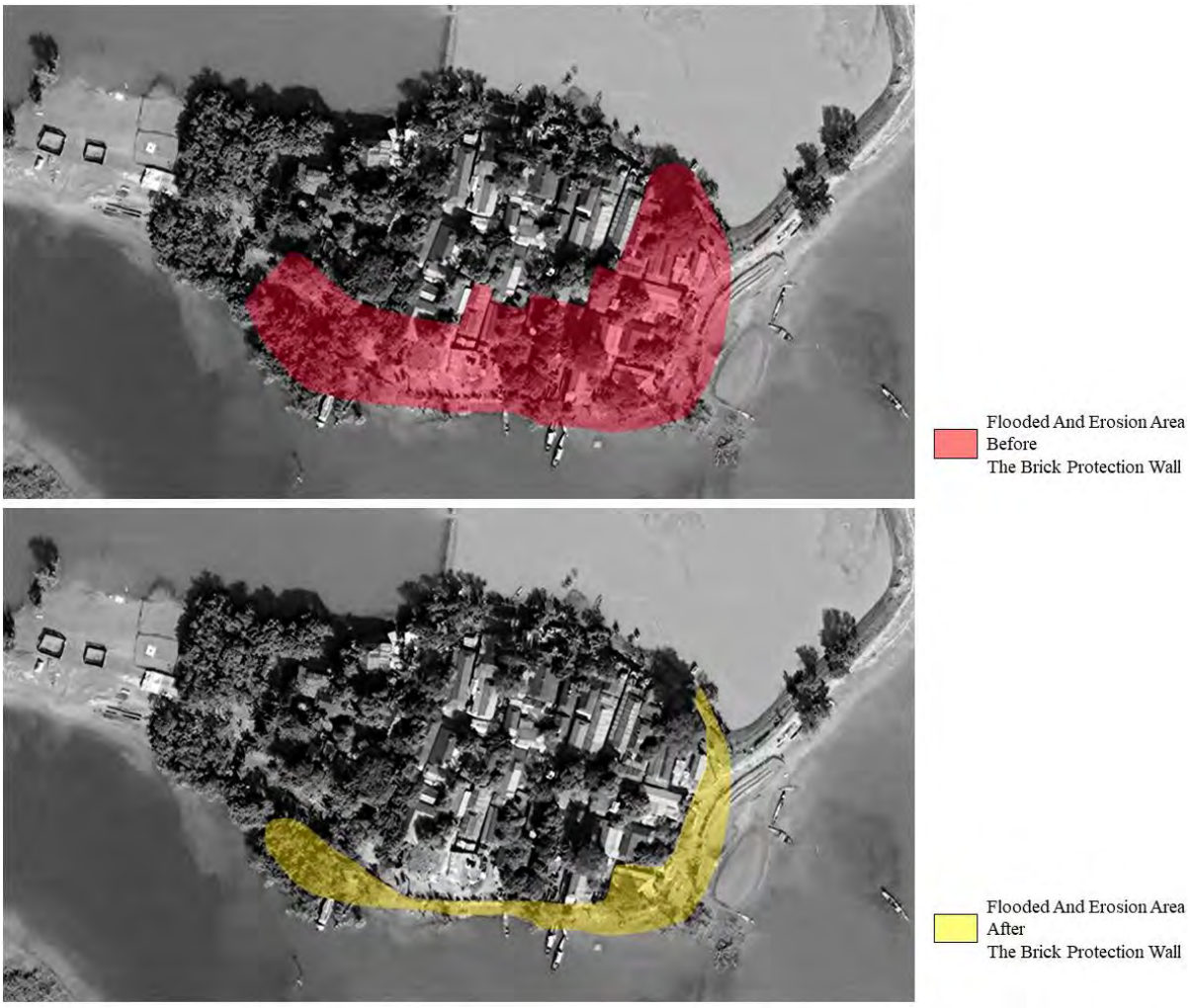


Fig-45: Flood and erosion affected area before and after the brick protection wall

Before the brick protection wall, almost half of the village faced floodwater and erosion. Mostly, the water edge houses are most affected by floodwater and erosion, which is marked by red color. At that time, the water edge household lost their house, cattle shed and fell into an economic crisis. After the flood, they need to rebuild or repair their house, cattle shed, and other properties.

LGED built this brick protection wall in 2010-2011. Following the construction of protection, the area of erosion and flooding has decreased drastically, as indicated by a yellow color. All water-edge houses are safe from damage from floodwater and erosion. The floodwater's force did not break the brick wall; this wall prevented the properties, households, and cattle sheds from being affected by erosion and floodwater. With this protection wall, the water edge household's livelihood improves.

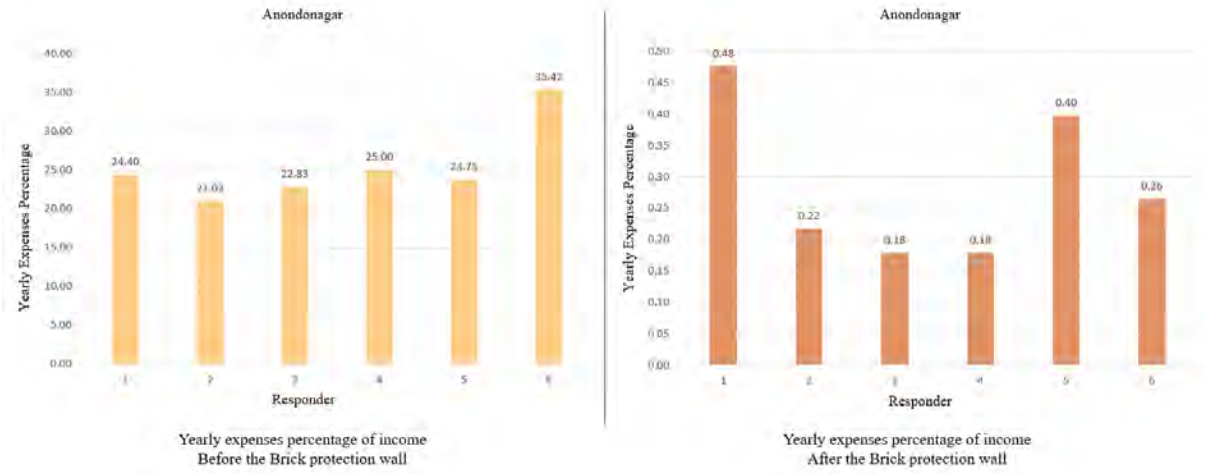


Fig-46: Yearly expenses percentage of income before and after the brick protection wall

According to the graph, before the brick protection wall, households needed to spend over 20% of their yearly income to repair their properties and other things to return to their previous livelihood. After building the brick protection wall, they need to spend less than 1% of their yearly income to repair their properties. This percentage difference reveals the improvement in their livelihood before and after the protection wall.

It helped them financially when they didn't have to pay to fix the house, cattle shed, protection wall, and other properties. They can spend money to build a new house, buy new domestic animals, and start a new business, ultimately improving their livelihood.

[NB: Image of FGD in Anondonagar in Appendix D- Image 3]

4.3 Findings from the KII

4.3.1 KII Person -1

Engineer. Anwar Hossain, Senior Assistant Engineer of LGED, has been working in Tangoar Haor for 8 years. He said, according to the question.

A protection wall is needed. Otherwise, each village would have been affected by floodwater, and their houses would have been flooded. So, it is very effective from floodwater. If this protection wall were not present, they would have to rebuild their houses every year. The sustainable brick dams and concrete blocks prevent any damage. Due to the presence of the dam, brick, and concrete, they do not have to rebuild their houses every year. They spend the money saved on other aspects of life. If the blocks get damaged, they fix them, spending a little money.

Having a protection wall is beneficial for the village, but it is not possible for the government to build a dam for each village. Unhealthy competition arises among villagers regarding the construction of the protection wall. Water flow and soil determine the type of protection wall necessary. Encountered numerous soil-related issues during the construction of the protection wall, but considering the speed of water flow, water height, and soil state, built a protection wall to prevent damage and reduce the suffering of the villagers.

A permanent and substantial protection wall for every village is needed. So, the villagers' properties are protected. Collaboration between the government and NGOs can improve the lives of the people.

[NB: Image of KII with Anwar Hossain in Appendix D- Image 4]

4.3.2 KII Person -2

Monir Hossain has been working in this Haor area for 2 years as a Sub-Assistant Engineer of BWDB. He spoke. "The Haor protection embankment protects crops, and village protective walls protect the houses and buildings from floodwater. This protection wall is much needed for flood protection, and this wall is very effective."

In Tangoar Haor, three types of protection walls are observed in the village: brick walls, concrete blocks, and sandbags. Among these, they enjoy the protection of brick walls and concrete blocks, and do not suffer much damage or spend much on repairs, but people suffer a lot when sandbags are used. Depending on the type of protection wall, the people of the village where the cost of repairing the wall is less are using this money to improve their quality of life.

The time window for protection wall repairs is tiny; depending on water levels, repairs are possible from January to May. Constructing the protection wall should consider the speed of flow and height of water to protect the lives and property of people.

The government should take up these projects to develop the standard of living of these people. It will protect their houses and belongings. The government can enhance the villagers' living standards by undertaking major projects, such as protection walls and embankment construction, which will protect their homes and assets from flooding and improve their quality of life.

[NB: Image of KII with Monir Hossain in Appendix D- Image 5]

4.3.3 KII Person -3

Adib Mia, an Office Assistant at BRAC, has 15 years of experience working in Tanguar Haor. According to him.

The locals need the dams. The village protective walls are very effective. Without this, the locals suffer damage to property and belongings. It's effective for the villagers.

Three types of walls are observed among the village protective walls: brick walls, concrete blocks, and sandbags. The village of Anandanagar is in a comparatively better state, as it does not require much repair due to the brick wall, allowing them to spend money on their family and cattle.

The stronger dams provide more financial safety to the locals. The locals from Anandanagar no longer take loans from BRAC to repair dams but rather invest in cattle and business almost the same scenario for Solaimanpur. But Nichodropur's people's lifestyles are downward. BRAC aids or loans to the villagers. Anandanagar and Solaimanpur took money for improvement, but Nichodropur's people faced numerous difficulties. They came to our office and claimed lots of money for repairing the Protection wall, house, and other properties.

BRAC gives loans for development in their lives, but the people of Nichodropur take loans every year for repairs. But since they cannot do it properly and cannot maintain it, they take loans every year and the loans become a burden for them. It has become challenging for us to raise the standard of living for the residents of this community.

Constructing permanent dams while considering population size and earning capability would significantly improve the lives of the people. Permanent dams that will protect lives and property, allowing the people to spend money on improvements to their lives. Village protective walls provided by the government can offer people safety, while training and aid from NGOs can help them improve their lives.

[NB: Image of KII with Adib Mia in Appendix D- Image 6]

4.4 Satellite Image Analysis

4.4.1 Nichodropur

Fig-47: Satellite image analysis of Nichodropur area (Source: Google Earth Pro)

From the satellite images, damage levels can be traced in images taken every November and December, when floodwaters recede slightly. Settlement started in this kanda from 2013. After that, they built an earth-filled sandbag protection wall to protect their village and properties. But, in 2016, 2017, and 2023, the image traced out the flood damage. The earth-filled sandbag protection wall is not sufficient to protect the village and villagers' properties from erosion and floodwater.

4.4.2 Solaimanpur

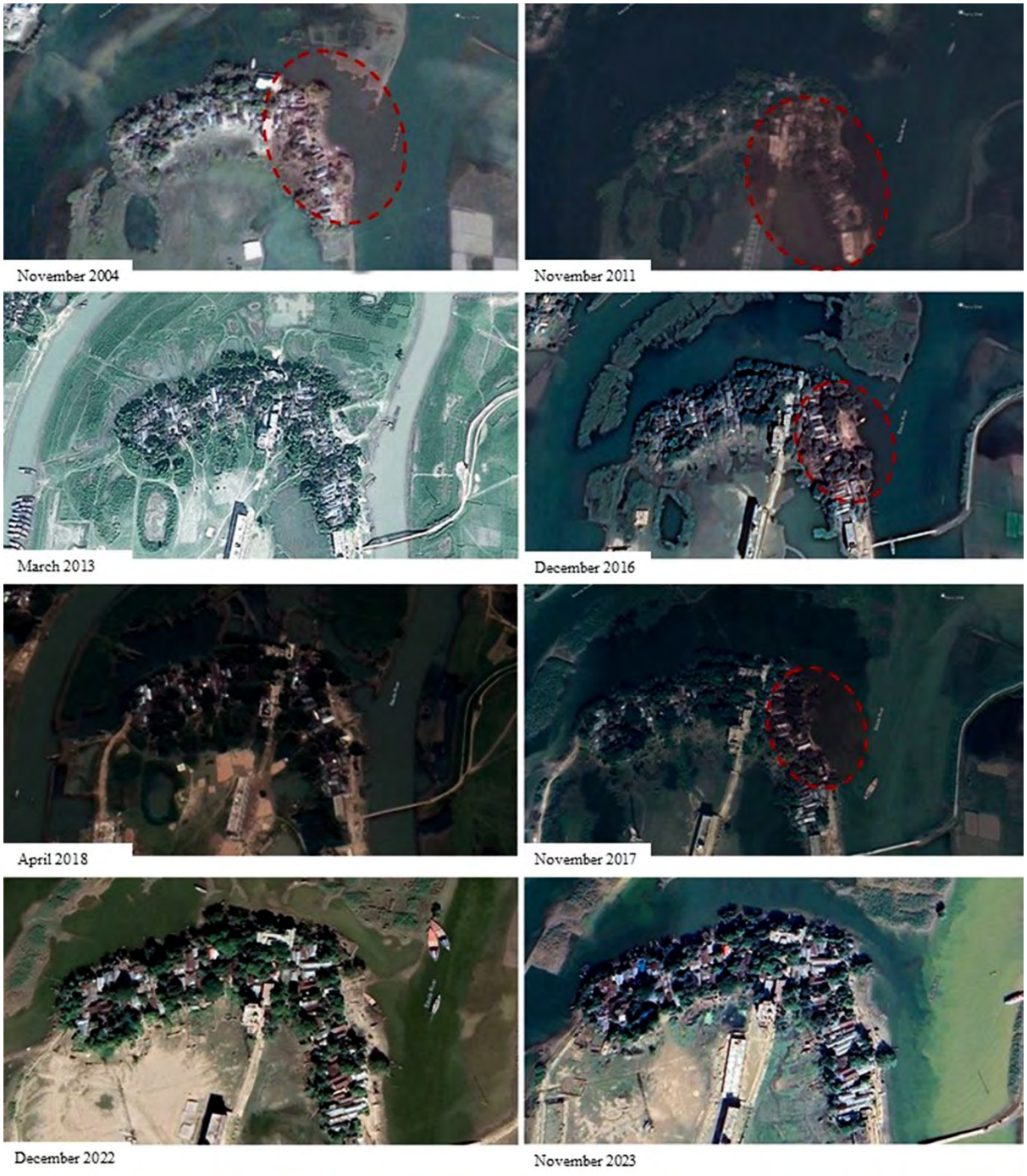


Fig-48: Satellite image analysis of Solaimanpur area (Source: Google Earth Pro)

March and April are the dry season, and after that, June to September is the seasonal flood time. After September, the floodwaters begin to recede. In 2004, 2011, 2016, and 2017, images of November and December show the damage level, and in 2017, LGED, a government organization, started to build a concrete block protection wall to protect the village. After 2017, there is no massive trace of floodwater damage or erosion impact.

4.4.3 Anondonagar

Fig-49: Satellite image analysis of Anondonagar area (Source: Google Earth Pro)

In 2004, an image showed floodwater and erosion traces in Anondonagar village. Following this, in 2010, LGED constructed a brick protection wall for the village, which has proven durable against floodwater waves. So that there is no trace of further erosion or floodwater in subsequent years.

4.5 Data Validation

For data validation based on the DFID and Rural Housing's Livelihood Framework, a triangulation analysis was conducted between the questionnaire survey, FGD, KII, Observations, and Satellite Image Analysis.

4.5.1 Nichodropur:

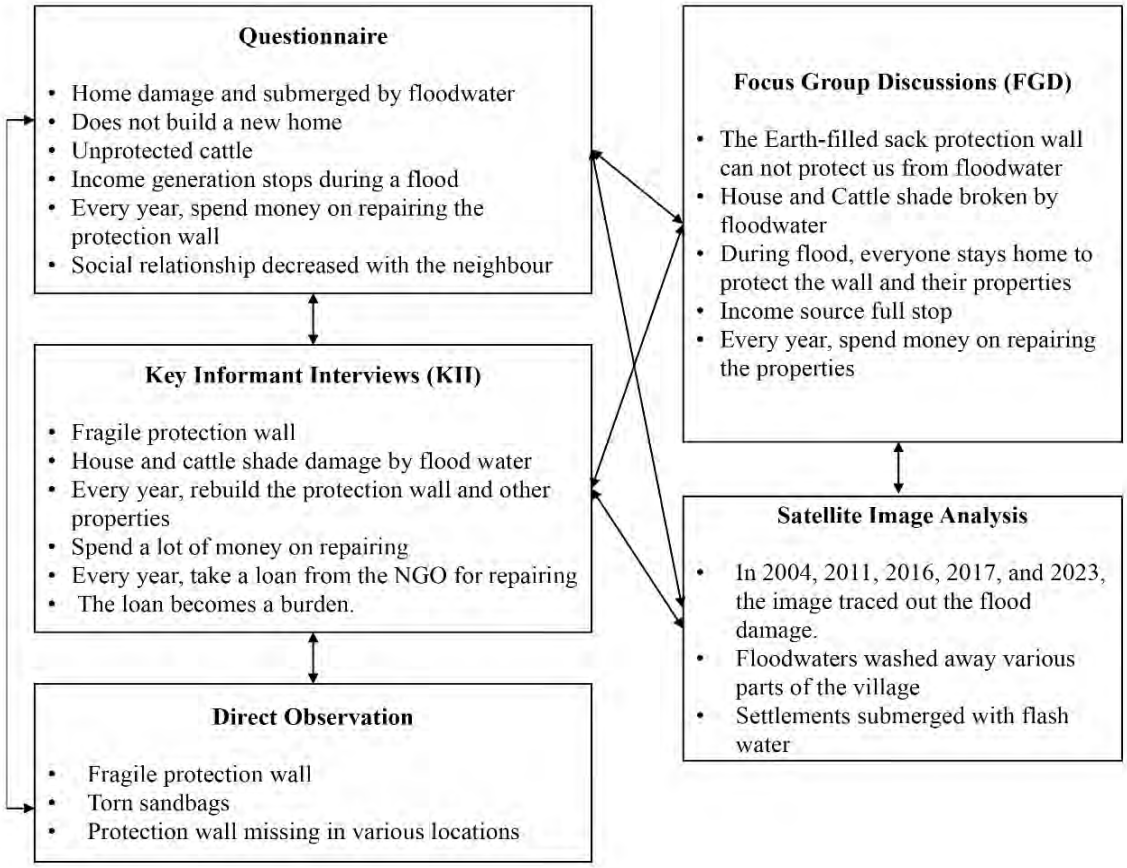


Fig-50: Data Validation between Questionnaire survey, FGD, KII, Observation, and Satellite Image Analysis of Nichodropur.

According to the crucial elements of the DFID framework to achieve the livelihood for a person include natural, human and social and economic capital where environmental capital is earth, water, and forests, human capital are skill, knowledge, and the capacity to work, social capital is social networking and social interactions and financial capital is infrastructure, savings.

Also, in Mphande (2016), the rural housing livelihood framework reveals that rural villagers' livelihoods are primarily dependent on agricultural work, livestock farming, and fishing, with some individuals branching out into non-farm pursuits to achieve a sustainable way of life and improve household income.

But according to the data validation analysis, Nichodropur's people struggle. Their protection wall is so fragile that their house and other properties are not safe. For floods, they lost their

properties and livestock, and during the flood, they were unable to move for any income. In the flood, agricultural farming, fishing, and labour jobs are all stopped. They must spend a lot of money repairing the protection wall and other properties. For the repair, they take loans, which pushed them to a low-quality lifestyle. Additionally, during the repair time, they get into a fight with their neighbours.

In this condition, this triangle analysis does not support the DFID and rural housing's livelihood framework, and according to this condition, Nichodropur villagers live in a poor livelihood condition.

4.5.2. Solaimanpur:

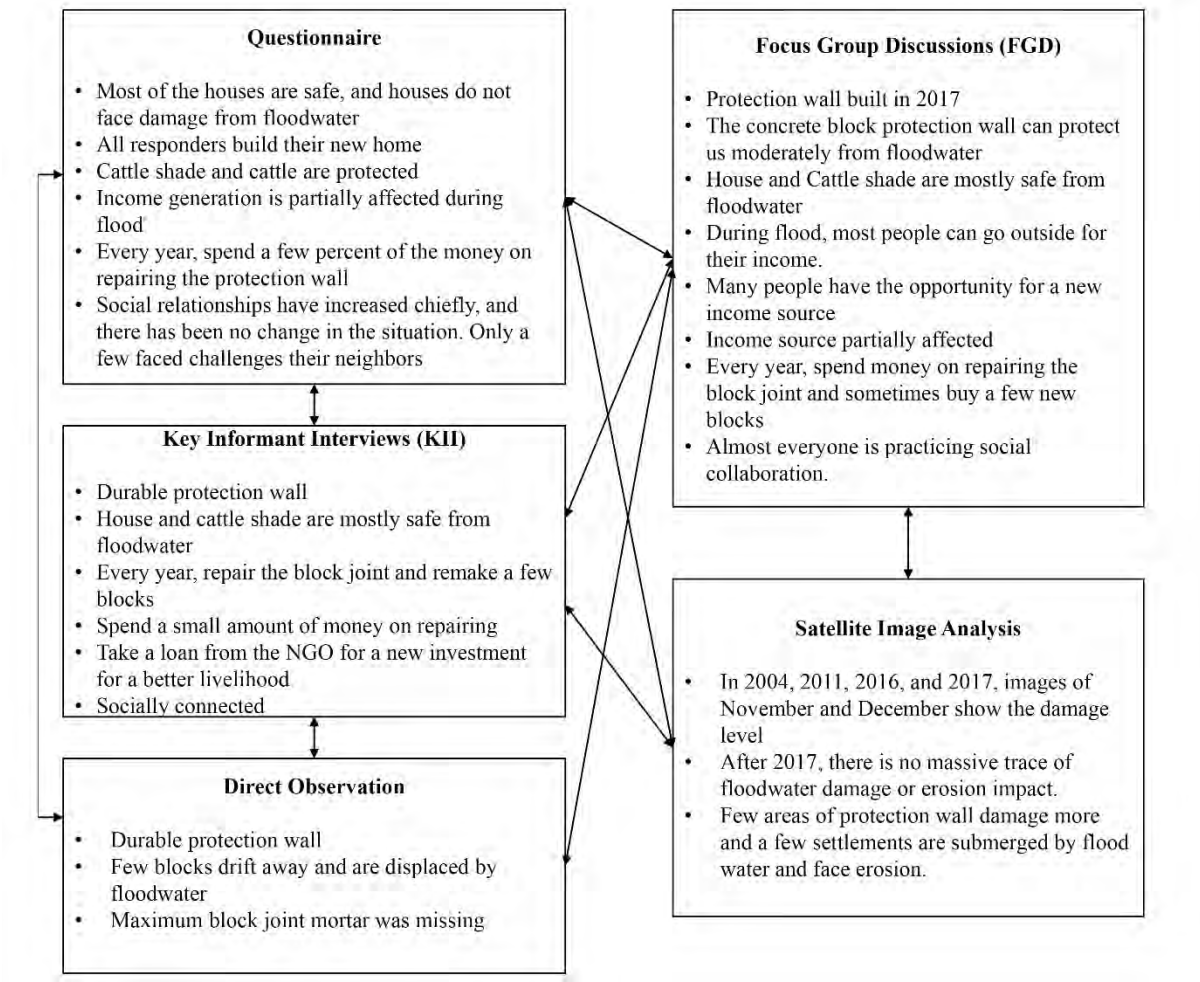


Fig-51: Data Validation between Questionnaire survey, FGD, KII, Observation, and Satellite Image Analysis of Solaimanpur.

Environmental capital includes earth, water, and forests; human capital, which includes education, expertise, community capital, which includes communal networking and communal interactions; and financial capital, which includes infrastructure and savings, are all essential components of the DFID framework for achieving a person's standard livelihood.

Additionally, according to Mphande (2016), the rural housing livelihood framework, the main ways of earning for rural people are agriculture, livestock farming, and fishing. However, some people choose to pursue non-farm activities to improve household income and live a sustainable livelihood.

From the data validation analysis, for the concrete block wall, their houses are mostly safe, but a few houses are submerged in floodwater. Cattle sheds are moderately safe from flood water. Their income is partially affected during a flood, but before the flood, they need to repair their wall block joint. For this, they spend a small amount of money each year. Otherwise, the people's lives and properties are safe, and they can save money and improve their livelihood. This condition supports the moderate DFID and rural housing livelihood framework, which leads to a good livelihood for the villagers of Solaimanpur.

4.5.3. Anondonagar:

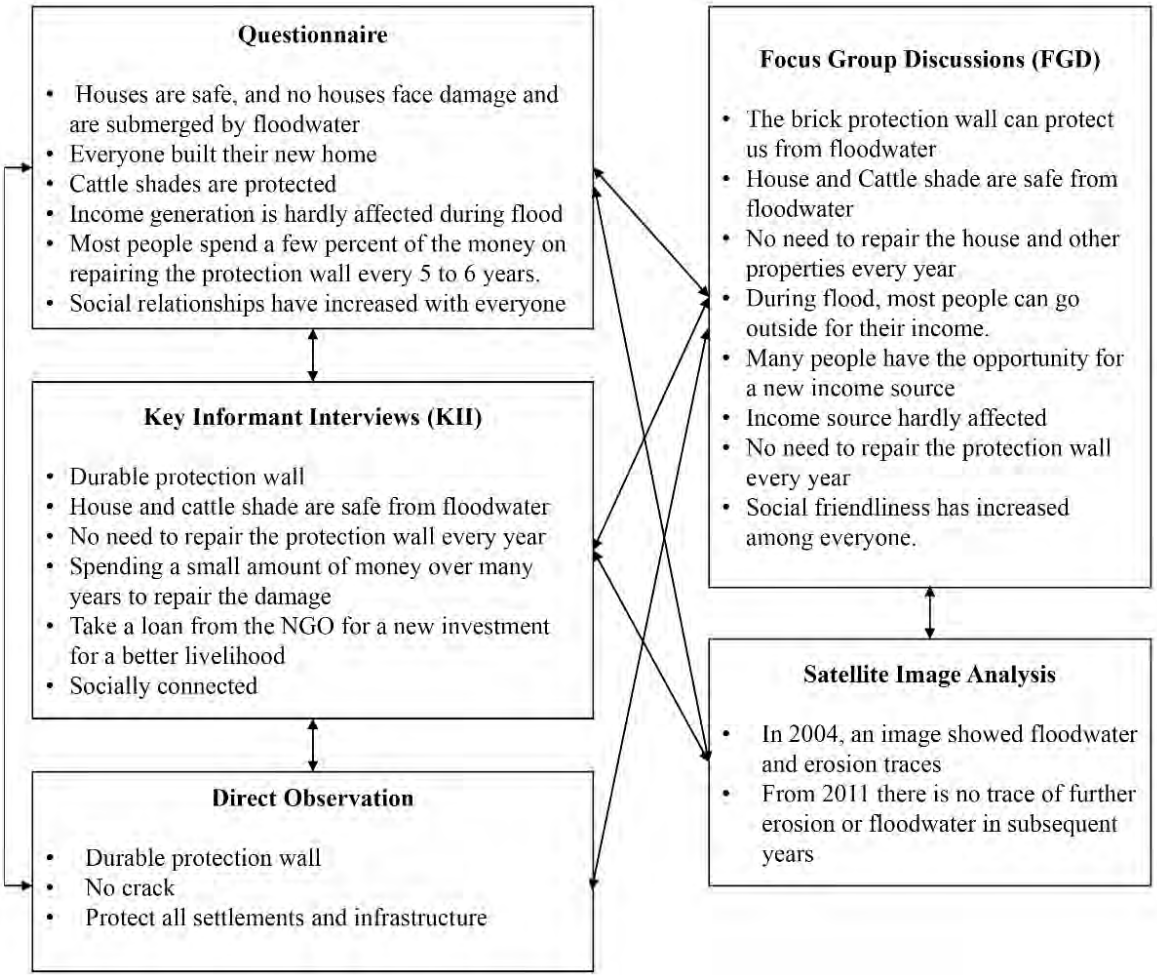


Fig-52: Data Validation between Questionnaire survey, FGD, KII, Observation, and Satellite Image Analysis of Anondonagar.

Land, water, and forests are examples of natural capital; skills, knowledge, and the ability to work are examples of human capital; social networking and social interactions are examples of social capital; and infrastructure and savings are examples of financial capital. These are the primary DFID framework components required to support a person's livelihood.

According to Mphande (2016), in the rural housing livelihood framework, the primary ways of earning for rural people are agriculture, livestock farming, and fishing. However, some people choose to pursue non-farm activities to improve household income and live a sustainable lifestyle.

From the data validation analysis, Anondonagar's protection wall is so durable. The protection wall has a less damaging impact on floodwater. People live a good quality of life because they have a safe house, cattle shed, and other properties. Their house and cattle shed did not submerge in floodwater. They do not need to spend money on repairing walls and other properties every year. So, they can save money, which can be used to build a new home. They take out loans for new investments, which enables them to maintain a good quality of life. It has also been reflected in their social life. They have a good understanding of each other.

This condition supports the DFID and rural housing livelihood framework, enabling Anondonagar villagers to lead a good livelihood and perform a vital part in earning a better one in future.

Chapter Five
Discussion

5.1 Discussion

This research compares three villages. Evaluating the impact of livelihoods on the protection wall. Anondonagar has a brick protection wall, Solaimanpur has a concrete block wall, and Nichodropur has an earth-filled sack wall.

From the results, Nichodropur's people on earth filed a sack wall, which is not a durable protection wall against floodwater. It becomes too fragile when floodwater wave velocity increases, and this protection wall breaks down easily. So, floodwater easily enters the village and destroys their houses and cattle sheds. Sometimes, flood water also carries away domestic animals. During this time, they cannot go outside their village to generate income. They should stay home and try to protect their house and protection walls. After the flood, they need to repair and rebuild their protection wall, house, and cattle shed. For repairs, they need money, and they either use their savings or take loans from NGOs. This hinders their economic development, rendering them financially weak. During the repair, they get into a conflict and fight with their neighbours. As a result, their standard of living declines, and an unhealthy environment prevails.

Solaimanpur's environment is much better than Nichodropur's. Solaimanpur has a concrete block wall, which is more durable and protects people from floods. Most homes are safe; they do not face any damage from flooding. Only a few homes are submerged in floodwater. But they did not face any significant damage. The cattle shed is also protected. During the flood, their income was partially affected. It did not significantly impact their lives because their properties were safe, so they did not bother repairing them. They need to repair the block joint. Otherwise, these blocks can be displaced, which can cause the land to shift and harm the home. So, they repair the joint, but it takes only a percentage of their yearly income. That is why they can improve their lifestyle by saving money and having a friendly understanding with their neighbours.

Anondonagar's people are happy with their Brick wall. It is very durable, allowing this protection wall to provide safety. This protection wall protects the houses, cattle shed, and other properties from floodwater. During the flood, they did not need to stay here to protect their properties, so they could go outside and earn money from their job. After the flood, they did not need to repair their properties, so the money they had saved was not spent on repairs.

Additionally, they do not need to repair their protection wall every year, so they do not incur significant expenses for it. That is why all people can build their new homes with the savings they have, and some of them take a loan from an NGO for a new business or investment purpose. Through this, they can live in peace and create a beautiful environment by building good relations with their neighbors.

In Bangladesh, brick is a common material and available in all village markets, and it is not a very expensive material, but it is not very durable in water and gets salty due to water salinity. Concrete blocks are durable and strong, but not widely available in all markets, and they are so heavy that they incur a significant cost for transportation. The earth-filled sandbag is not durable in water, but this PVC sandbag is cheap, and soil is also available and found everywhere.

Integrated Water Resources Management (IWRM) coordinates integrated improvement and directorate of rainwater, terrain, territory, soil, and relevant assets or reserves to equitably minimise the ensuing financial and social benefits without disturbing the sustainability of crucial ecosystems. According to IWRM framework in these three villages.

Anondonagar has a proper water management system, no land loss, and its settlements and livestock are safe without compromising sustainability and the ecosystem.

Solaimanpur has a moderate level of water management system, but sometimes, concrete blocks are displaced, creating a chance of land loss and an unprotected situation for properties and livestock. These blocks, which are merged with water bodies, can disturb the ecosystem and disrupt sustainable livelihoods.

In Nichodropur, water management is in horrible condition. Every year, their villages are submerged in floodwater and affected by erosion, causing land loss and depletion of other resources. This erosion destroys trees and other natural elements. To prevent this, they also cut down trees and sell their assets, which hampers the natural balance and generates income, but ultimately pushes them into unsustainable livelihoods and impacts the ecosystem.

5.2. Comparison Matrix

5.2.1 Settlement and Infrastructure

Nichodropur’s water-edge house suffers from flood damage every year. Floodwater breaks and submerges their house, cattle shed, and other infrastructure, and they also lost their house land due to erosion.

Solaimanpur's concrete block protection wall protects the moderately well-off villagers' houses and other properties; most of the houses are safe from erosion and floodwater submergence.

The villagers' houses in Anondonagar are safe from floodwater and erosion because they have a brick protection wall.

5.2.2 Financial Capacity

Nichodropur's villagers need to rebuild or repair their houses, and the protection wall every year, which makes them financially weak. And during a flood, all their income sources are completely stopped because they are busy protecting their land, house, and protection wall from the flood.

Mostly, people in Solaimanpur do not need to rebuild their houses and protection walls. If they need to repair, they can either repair the concrete block joint or buy new blocks, which require a little money each year. And during the flood, their income was partially affected.

Anondonagar's villagers have a sound economic condition because they do not need to repair or rebuild their properties or the protection wall. To prevent flooding, villagers can create home gardens to grow a variety of vegetables and explore the Haor area to find new income-generating sources.

5.2.3 Social Bondage

Nichodropur's people almost got into a fight with their neighbours over the reconstruction of the protection wall and the land demarcation.

Solaimanpur people use the wharf of the protection wall as a meeting point and recreational space. During their free time, they gather at the wharf and discuss and tell stories about various topics.

In Anondonagar, villagers also use their wharf as a recreational space, and they do not have any land demarcation issues for erosion. So, a good relationship prevails between their neighbours, and it creates a strong bond between them.

Criteria	Village Name		
	Nichodropur	Solaimanpur	Anondonagar
Settlement & Infrastructure	• Houses & cattle sheds flooded every year • Frequent damage & erosion • Loss of land due to erosion	• Concrete block wall protects houses • Most homes are safe from erosion & flood	• Brick wall fully protects houses & properties • No flood or erosion damage
Financial Capacity	• Annual rebuilding needed • Financially weak • No income during floods	• Minor repairs required (block joints) • Partial income loss during floods	• No repair costs • Stable economy • Engage in gardening & new income sources
Social Bondage	• Frequent conflicts over wall rebuilding & land disputes	• Wharf used as social & recreational space	• Strong community bond • No land issues • Peaceful environment

Table 4: Comparison Matrix

Table no-4 is the comparison matrix table in three villages with Settlement & Infrastructure, Financial Capacity and Social Bondage.

5.3. Recommendation

After the discussion phase, this paper recommends.

- To succeed in protecting the village from erosion and floodwater, innovations must be included in the protection wall's design to increase its sustainability and durability.
- If concrete blocks are used in the future, new techniques must be employed to ensure the block joints can withstand flood water, prevent displacement, and minimize damage from both floodwater and erosion.
- Earth-filled sandbag technology in a protection wall is a temporary process. In villages where protection walls have been built with sacks, they must be replaced very quickly, and permanent protection walls must be built.
- With this knowledge, government, private, and NGO organizations can take new steps to improve the technology of protection walls, making them more durable, or developing new types of protection walls.
- Policymakers should implement this idea or guide the policies to secure the existing protection walls to ensure the villages' livelihood remains safe from erosion and floodwater.

Chapter Six
Conclusion

6.1. Conclusion

In Tanguar Haor's when floodwater comes, every village is submerged in floodwater and erosion and faces damage during this time. To prevent this, the government organization LGDE provides many types of protection walls for villages. LGED provides a concrete block wall and a brick wall as a protection wall. Without protection walls, villagers face damage to their homes, cattle sheds, and other property every year. They must repair it every year, so this damage directly impacts their economy and creates a disrespectful understanding with neighbours. These damages, repairs, and economic impacts directly affect villagers' livelihoods. Although the government cannot ensure a protection wall for all villages. They built a low-quality protection wall.

This study investigated how the three different kinds of protection walls affected the villagers' livelihood. Anondonagar has a brick protection wall, Solaimanpur has a concrete block wall, and Nichodropur has an earth-filed sack wall. According to the results and discussion, the people of Anondonagar are leading a healthy lifestyle. Their protection wall saved their house, cattle shed, and other properties, and they do not need to repair their properties and protection wall every year, which gives them a better livelihood than others. Solaimanpur's people have a moderate level of livelihood. Most of their properties are safe from floodwater, but they need to spend a little money on repairing the protection wall. This repair cost and flood impact their savings partially, but after all of this, they can also build a new house and improve their life. On the other side, Nichodropur has an earth-filed sack wall. Every year, they faced damage. During floods, their house, cattle sheds, and other properties were submerged by floodwater, and the water force was breaking their home and other properties. Every year, they must repair this with a high percentage of their yearly income. They take loans from NGOs, which becomes a greater burden for them. This condition directly negatively impacts their livelihood, leading to poor conditions.

This understanding will be helpful for policymakers in guiding current policies or creating new policies on protection walls. Through this knowledge, the government will understand the importance of repairing existing protection walls to increase their durability and the potential of new technologies for villagers' livelihood. Private and NGO organizations will also be able to take new steps to enhance the livelihoods and living standards of people, and the biggest

vulnerable and impoverished individuals in the village will also see an improvement in their livelihoods.

This research also contributes to academia, enabling researchers to explore this topic from another perspective and create a new scope to work on protection wall types, wall durability, and villagers' livelihood in using different matrices, which will help the Tanguar Haor people's livelihood.

The study compared three villages: Anondonagar (brick wall), Solaimanpur (concrete block wall), and Nichodropur (earth-filled sack wall). Where, Anondonagar's brick wall proved most effective, ensuring better livelihoods. Solaimanpur had moderate protection with some repair costs. Nichodropur suffered the most, facing repeated damage, high repair costs, and a loan burden.

This knowledge will help the researchers, policymakers, government organizations, and NGOs to understand the impacts of structural flood mitigation (protection wall) on the Tanguar Haor people’s livelihood.

6.2. Limitation

The study was conducted in Nichodropur, Solaimanpur, and Anondonagar, with a sample size selected from the houses along the waterside of these three villages. If the number of villages could be increased and the sample size comprised the entire village, more accurate results would be obtained.

6.3. Future scope

This study aims to determine which type of protection wall is more effective for villagers' livelihoods but there is a future opportunity to explore the reasons why protection walls are not working effectively and how to improve them, making them more durable and suitable for various types of protection walls. Additionally, the impact of these walls on the environment can also be determined. Through this, their livelihoods will improve, and they will be protected from flood damage.

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Appendix A

Questionnaire Survey

Title: Impacts of Structural Flood Mitigation Measures on Livelihood: Comparative Study of Three Settlements in Tanguar Haor, Sunamganj, Bangladesh.

1. Information about you

Name: Name of the Village:

Age: Gender: ☐ Male ☐ Female

2. Source of Income and Livelihood

2.1. What is the major way your family makes money?

- Farming
- Fishing
- Day work
- Work
- Other: _____

2.2. How much money do you make each month?

3. Flood Mitigation Measures

3.1. Did you visit this village before or after the protection wall was built?

- Before
- After

3.2. What kind of protection wall does your community have?

- Concrete block
- Brick wall
- Earth-filled sandbag

3.3. What good things have the structural measures done for you?

a) Safe house
b) Source of income
c) iii.Protection of livestock
d) None

(1) a (2) b (3) a, b, and c (4) d

3.4. Do you think the protection wall protects your settlement?

- Yes
- No

3.5. Does your home still get damaged by floodwater and erosion after the protection wall?

- Yes
- No

3.6. Does floodwater still submerge in your home after the protection wall was built?

- Yes
- No

3.7. Were you able to build a new house after the protection wall was constructed?

- Yes
- No

3.8. How well has the protection wall worked to keep and protect livestock?

- Protected
- Not protected

3.9. During flood season, is income generation disrupted due to maintaining the protection wall?

- Completely shut down
- Partially affected
- Hardly affected

3.10. How frequently do you need to pay for repairs to the protection wall?

- Once a year
- Once every 1 to 5 years
- Every 5 to 10 years

3.11. Do you get money from the government or NGOs to fix the protection wall?

- Yes
- No

3.12. How much does it cost to fix the protection wall?

3.13. How has building protection walls affected your savings?

- Increased
- Decreased
- No change

3.14. Condition of neighbourhood bondage after the protection wall was built.

- Increased
- Decreased
- No change

3.15. How well do you think this protection wall works?

- Very effective
- Effective
- Not effective

3.16. Do you believe these steps are enough to make sure people can make a living?

- Yes
- No

Appendix B

Focus Group Discussion (FGD)

Title: Impacts of Structural Flood Mitigation Measures on Livelihood: Comparative Study of Three Settlements in Tanguar Haor, Sunamganj, Bangladesh.

Village Name:

Participants Information:

1	Name:			
	Age:	Gender:	☐ Male	☐ Female
	Occupation			
2	Name:			
	Age:	Gender:	☐ Male	☐ Female
	Occupation			
3	Name:			
	Age:	Gender:	☐ Male	☐ Female
	Occupation			

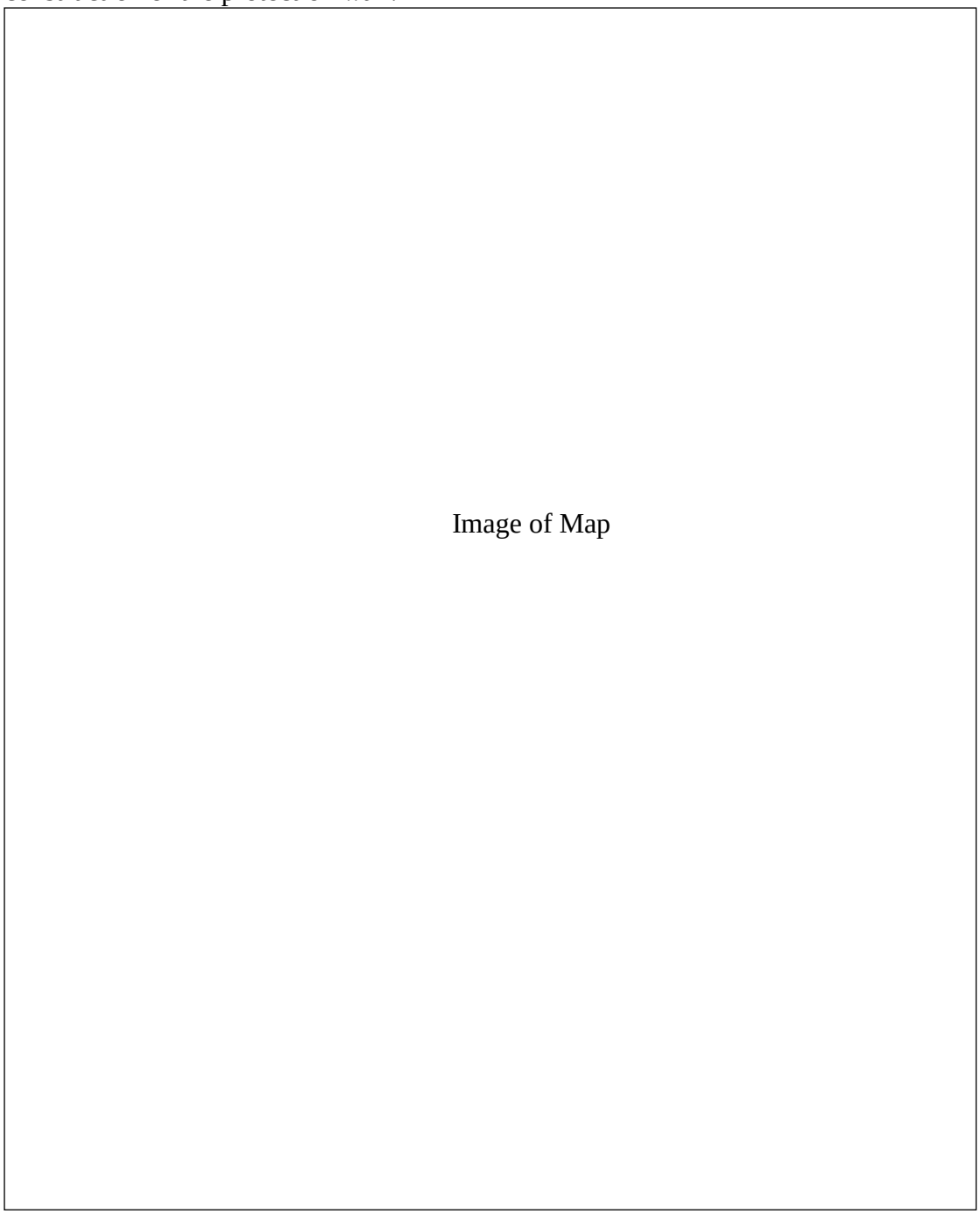
4	Name:			
	Age:	Gender:	☐ Male	☐ Female
	Occupation			
5	Name:			
	Age:	Gender:	☐ Male	☐ Female
	Occupation			
6	Name:			
	Age:	Gender:	☐ Male	☐ Female
	Occupation			

1. **Question:**
   - What kind of changes have occurred in your life due to the construction of embankments (flood control structures)?
   - How effective do you think this embankment construction has been?
   - What benefits have you received from these structural measures?
   - Do you think these measures are sufficient to ensure sustainable livelihoods?
   - Do you have any complaints or limitations regarding the structural flood mitigation measures?
   - What kinds of developments or changes would you like to see in the future?
2. **Monthly Income and yearly expenses on damage repair before and after the protection wall.**

No.	Monthly income	Yearly expenses on repair	No.	Monthly income	Yearly expenses on repair
1			4		
2			5		
3			6		

3. Demarcation of Flood and erosion areas on the map

Three maps are provided for three different villages, marked according to the pertinent shown to trace the floodwater and erosion position to understand the situation before and after the construction of the protection wall.



Appendix C

Key Informant Interview (KII)

Title: Impacts of Structural Flood Mitigation Measures on Livelihood: Comparative Study of Three Settlements in Tanguar Haor, Sunamganj, Bangladesh.

1. Basic Information About the Person Being Interviewed

Name: Age:

Designation: Contact:

Name of the organization:

Work experience in TH:

2. Questions About Structural Flood Mitigation Measures

2.1. Do you believe that this area needs protection walls to stop floods? Why?

2.2. How would you rate how well these structures work?

- Very effective
- effective
- Not effective

2.3. What kinds of improvements do you think these steps have made to people's lives or living conditions?

3. Effects on society and the economy

3.1. Do you think the structural measures have impacted on the income or job opportunities of individuals in the area? More, less, or the same (please explain)

3.2. Have there been any problems or difficulties in carrying out these kinds of projects? (Lack of local involvement, problems with upkeep, destruction from nature)

4. Suggestions for policies and plans

4.1. What do you believe has to be done to make these buildings last longer?

4.2. What changes would you like to see in the way floods are managed in this region in the future?

4.3. What do you think the most essential function for the government or NGOs would be in this case for their livelihoods?

Appendix D

Image: 1

FGD in Nichodropur

Image: 2

FGD in Solaimanpur

Image: 3

FGD in Anondonagar

Image: 4_ KII-1

Name: Anwar Hossain
Age: 44
Designation: Senior Assistant Engineer
Organization: Local Government Engineering Department (LGED)
Working in Tangoar Haor: 8 years.
Contact: anwar421@gmail.com

Image: 5 _KII-2

Name: Monir Hossain
Age: 40
Designation: Sub-Assistant Engineer
Organization: Bangladesh Water Development Board (BWDB)
Working in Tangoar Haor: 2 years.
Contact: hossenm507@gmail.com

Image: 6_ KII-3

Name: Adib Mia
Age: 37
Designation: Office Assistant
Organization: BRAC
Working in Tangoar Haor: 15 years.
Contact: 01949446292