



ACTION RESEARCH PROJECT REPORT

Piloting and knowledge co-creation on the nature-based solution to protect wave erosion in haor areas of Bangladesh



August 2024



Acknowledgment

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List of abbreviations

BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BDP	Bangladesh Delta Plan
BHWDB	Bangladesh Haor and Wetland Development Board
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
CPE	Center for People and Environ
DAE	Department of Agricultural Extension
DDM	Department of Disaster Management
DRRO	District Relief and Rehabilitation Office
FGD	Focus Group Discussion
GIS	Geographic Information System
HHS	Household Survey
IFRC	International Federation of Red Cross and Red Crescent Societies
KII	Key Informant Interview
NAP	National Adaptation Plan
NDWI	Normalized Difference Water Index
NGO	Non-Governmental Organization
NPDM	National Plan for Disaster Management
NbS	Nature-based Solutions
RHD	Roads and Highways Department
RS&GIS	Remote Sensing and Geographic Information Systems
UNB	United News of Bangladesh

Executive Summary

In the Tahirpur upazila of Sunamganj district, flash floods are frequent, threatening wave erosion for the people living on the mound of Haor. The quasi-experimental action research was conducted to develop nature-based solutions (NbS) for flood wave erosion protection and promote flood-resilient livelihoods during the monsoon. The study applied longitudinal data collection using a Household Survey (HHS), Focus Group Discussion (FGD), and Key Informant Interview (KII). RS&GIS was applied to monitor river trajectory changes beside the experimental field and track the erosion of the mound. The study also developed a longitudinal database of the inhabitants of the experimental mound to understand the flash floods and wave erosion vulnerability, food security, livelihood, and economic status of the treatment and control participants. The study finds that between 2003 and 2013, the Boulai riverbanks shifted 3.16 meters, and from 2014 to 2023, they shifted 2.9 meters toward the Puberbari area. Between 2003 and 2013 total of 0.033 hectares, and from 2013 to 2023 total of 0.30 hectares of land were eroded in Puber Bari. The majority of people have constant access to an adequate food supply during floods. Because of the application of the Nature-based solutions (NbS), in 2023, no erosion or river shifting in the experimental mound. The treatment participants also ensured food security through the production of value-added products from NbS during floods.

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1. Introduction

Bangladesh was placed fifth among 173 nations in the World Risk Report 2012 for its vulnerability to natural disasters and societal hazards (**Joarder & Miller, 2013**). Between July and September, when the monsoon is about to end, haors (huge bowl-shaped depressions and seasonal wetlands) continually overflow with water. The two worst climatic stresses that have a major impact on people's quality of life are flash floods (April-May) and drought (**UNDP, 2022; Prevention Web, 2022**). There are 373 haor/wetlands in the seven northeastern districts of the country, including Sunamganj, which cover around 859,000 hectares of land, according to the Master Plan of Haor Area adopted in 2012 (**Farid, 2019**). The number was 6,000 haors in 1999, about two-thirds of which are permanent and provide a significant source of fish (**Ali, 1999**). A study found that the Haor region is at risk from the impacts of climate change according to the Bangladesh Delta Plan (BDP) 2100 (**Farid, 2019**). Due to its geological location and geographic structure, particularly to flash floods, Sunamganj is one of the most disaster-prone and susceptible locations in the haor (**Rahaman et al, 2022; CARE, 2010**). In Sunamganj District, the water table frequently remained above the "danger levels" for flooding specified by the Bangladesh Water Development Board from 1988 to 2014. By exceeding danger thresholds for 60, 25, 43, and 18 days, respectively, in 1988, 1989, 1993, and 1996, floods, for instance, severely damaged rice and other crops (**BWDB 2014**). Sunamganj is an extremely susceptible district to flash floods, thunderstorms, and lightning, according to the Department of Disaster Management (DDM). Thunderstorms and hailstorms have been causing unprecedented disasters with rising damage and losses in the Haor region, according to the DRRO of Sunamganj (**Rahaman et al, 2022**). From early June, torrential rain and upstream water have completely submerged around 94 percent of the town of Sunamganj (**IFRC, 2022**). In the six haor districts, including Sunamganj, the flash flood of 2017 harmed 4,667,000 people

(DDM, 2017). According to the research, the production loss of crops decreased by an average of 27.6 kg per decimal and that of vegetables by 31.6 kg per decimal in the Sunamganj district **(CPE, 2022)**. The Haor people's way of life has been severely disrupted by numerous climate-related disasters, but Afal is the worst. It erodes soil, reducing the amount of livable land **(UNDP, 2022; Prevention Web, 2022)**. Sunamganj district includes Tahirpur Upazila, which is located in northeastern Bangladesh. There are 315.33 square kilometers in all. Tahirpur Upazila is situated between 91°02' East longitude and 91°19' East longitude, or 25°01' North latitude to 25°12' North latitude. In the west is Dahrmapasha upazila, in the east is Bishwambarpur, in the south is Jamalganj, and in the north is India. Tahirpur upazila covers about 86% of these haor regions. Flash floods very frequently happen within this area. It is shown by Tahirpur Upzila's union-level resilience status that people living in high-risk areas have poor resilience **(USAJ, 2018)**. In 2023, on June 15, the floods were catastrophic. All of the paddy and vegetable fields, as well as the roads in Tahirpur, were submerged **(Hossain, 2022)**. With the commencement of the rainy season, erosion by the Jadukata River along 50 villages in Tahirpur upazila has taken a dangerous turn **(Unb, 2011)**. Massive erosion occurs on the exposed surface of the hill after a flash flood **(Tajwar, 2019)**. Tahirpur, a sub-district of Sunamganj district, is one of the 11 upazilas out of a total of 69 upazilas in the haor districts that are not connected to the Roads and Highway Department (RHD) network **(BHWDB, 2012)**. Disasters like seasonal floods, flash floods, Nor'wester, and droughts happen frequently in the Tahirpur Upazila of the Sunamganj district. Every year during the monsoon, the village floods **(USAJ, 2018; Reliefweb, 2014)**. Tahirpur experienced flash flooding because of severe rains and upstream water from the Meghalayan hills. Its starting point is the Jadukata River **(Reliefweb, 2014)**.

2. Project Background

Flood and wave erosion are a significant threat to the haor people. Floods inundate the homestead, and wave erosion is responsible for bank erosion. During a flood, wave erosion increases in the haor, which causes the extinction of the living island of haor communities. A study finds that in the last flash flood of 2022, 3023 hectares of islands were eroded, and 932 households lost their homestead due to wave erosion. All of the men and women had to engage in the excavation and reconstruction of the island after the flood. As a result, most of the women suffer from health problems. After the successful solution, they will not be affected by floods and erosion, and the health problems of women will be reduced. Not only so, but also due to flood and erosion, homestead agricultural livestock and poultry rearing are restricted in the vulnerable islands of the haor. The project focused on disaster management, food and agriculture, livelihoods, employment generation, and health by developing a nature-based flood and erosion management mechanism and livelihood generation for the haor people.

3. Project objectives

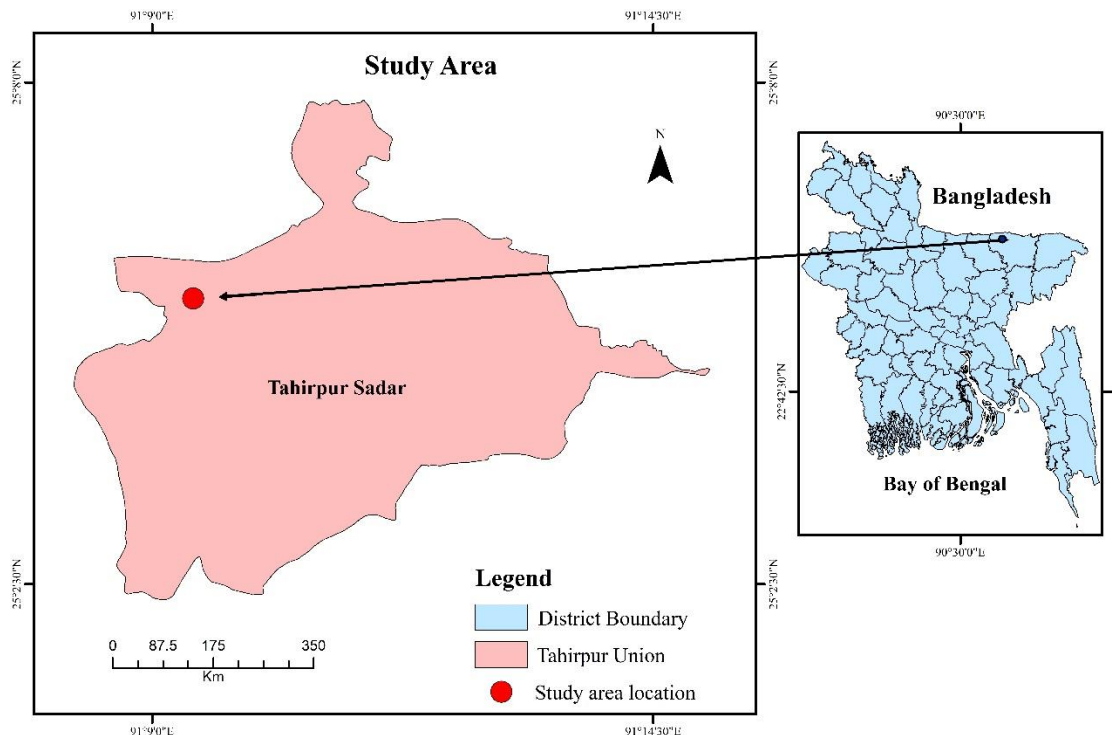
The action research was conducted to explore how Nature-based solutions can contribute to the protection of wave erosion and the livelihoods of the vulnerable people in the study area. The study aims to develop wave erosion protection measures through the introduction of nature-based solutions in the vulnerable areas. The specific objectives of the project are as follows:

1. Piloting and testing a nature-based solution to protect wave erosion in the haor.
2. To co-create knowledge on nature-based solution-oriented wave-erosion protection measures.
3. To develop a locally-led wave erosion protection measure management mechanism.
4. To sensitize policymakers on the nature-based wave erosion protection solution in the haor area.

4. Project area

Tahirpur Upazila is located in Sunamgonj district in the northeastern region of Bangladesh. The total area of this upazila is about 315.33 km². Tahirpur Upazila is located between 25°01' north latitude to 25°12' north latitude and 91°02' east longitude to 91°19' east longitude. It is surrounded by Dharmapasha upazila in the west, Bishwambarpur in the east, Jamalganj in the south, and India in the north (Islam et al., 2020). Among the seven unions of this upazila, Tahirpur Sadar Union is one of them (**Map 1**).

Map 1: Project area



5. Project Implementation Methodology

The indicative activities of the action research are

1. Selection of project area.

Methodology: CPE has selected a specific project area (wave erosion vulnerable islands in Sunamganj district) through the application of remote sensing and GIS, field validation, and

organizing a validation workshop with local-level stakeholders, including the local government engineering department, local government institutions, public administration, NGOs, etc.

2. Formation of a locally-led nature-based solution management committee

Methodology: In each island, one committee was formed, deploying members from the community (youth, women), local government institutions, grass-roots action organization (SWAPNO), NGOs, and government agencies.

3. Capacity building of the local-led nature-based solution management committee.

Methodology: A 3-day residential training was organized for the local-led nature-based solution management committee on plantation, management, scale-up, value chain development, and market linkage of end products of the solution.

4. Planting pati patha as a nature-based solution around the island to protect against wave erosion.

Methodology: Involving a local-led nature-based solution management committee, Pati Patha was planted around the island.

5. Monitoring wave erosion in the nature-based solution introduced islands.

Methodology: The CPE and SWAPNO personnel monitored and measured the wave erosion around the islands each week during the monsoon.

To comply with the project activities, the following methodology was also applied as participatory action research approach.

For the study, secondary information, relevant policies, and articles were collected from different pertinent institutions and sources. Long-term observational data on climate, livelihoods, and hazards were collected from the Bangladesh Meteorological Department (BMD), the Department of Agricultural Extension (DAE), and the Department of Disaster Management (DDM). Bangladesh Climate Change Strategy and Action Plan (BCCSAP), National Adaptation Plan

(NAP), National Plan for Disaster Management (NPDM, 2021 to 2025), Standing order on Disaster-2019, 8th Five-Year Plan of Bangladesh, Delta Plan, Haor Master, Water Policy, were also reviewed and analyzed. Primary information (qualitative and quantitative) was collected through **Participatory research using the** Household Survey (HHS), Focus Group Discussion (FGD), and Key Informant Interview (KII). Quasi-experimental longitudinal data generation approach was applied in the household survey data collection. A total of 375 household surveys were conducted for 9 months (March-November). Along with the household surveys, 12 FGDs with similar participants were conducted four times, and 9 Key Informant Interviews with similar personnel (Local Government, Department of Agriculture, Department of Disaster Management, Haor Board, Local Government Engineering Department, Bangladesh Water Development Board) were conducted.

Multi-temporal Landsat data were used to identify the shifting of the Boulai River using the NDWI (Normalized Difference Water Index) by remote sensing index to identify the presence of water bodies in satellite imagery. In ArcGIS, NDWI was calculated using raster data. Ensuring the imagery consists of two bands that were sensitive to water content, typically the near-infrared (NIR) and the green (G) bands. ArcGIS was applied to perform the calculations and generate a new raster layer representing the NDWI values.

NDWI formula:

$$NDWI = \frac{NIR - G}{NIR + G} \text{ ----- (i)}$$

The raster of consecutive times of the river was taken into consideration for the years 2013 and 2023. Then, from the raster area, the erosion and accretion areas were calculated in ArcGIS.

Erosion and accretion area calculation:

$$\text{Erosion} = (\text{New river NDWI raster} - \text{Unchanged NDWI raster}) \text{ ----- (ii)}$$

$$\text{Accretion} = (\text{Old river NDWI raster} - \text{Unchanged NDWI raster}) \text{ ----- (iii)}$$

Bank shifting in the specific location was calculated through selected cross-sections at regular intervals along the length of the river. Next, for each cross-section, the positions of the riverbanks were determined. This was done by measuring the distance from the water's edge to a specific reference. Then, using equations (ii) and (iii), the bank line shifts along the identified cross-sections were calculated. From the shifting in the time frame, the average shifting of the river position per year was calculated using the following formulas:

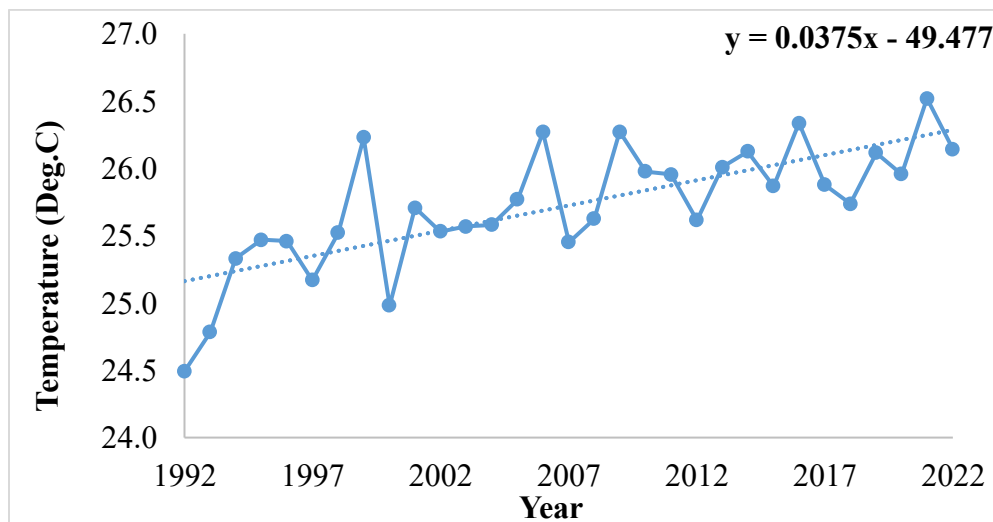
$$\text{Average Shifting per year} = \frac{\text{Average Shifting per Cross section}}{\text{Number of Year}} \text{ ----- (iv)}$$

6. Study findings

6.1. Climate of Tahirpur

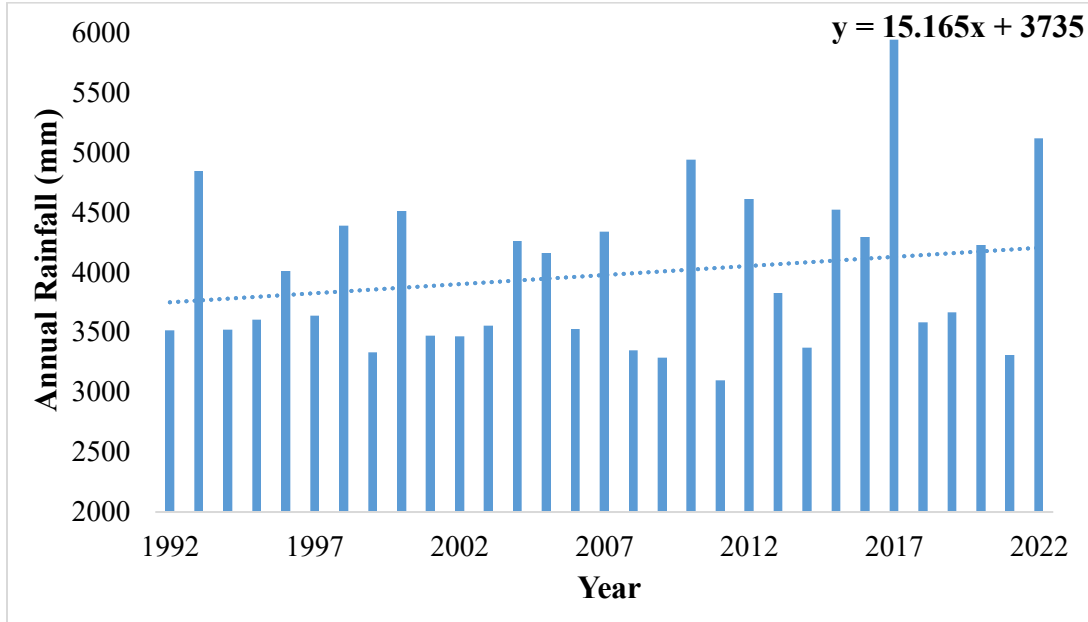
The average temperature in Tahirpur has increased from 1992 to 2022. The annual rainfall trend was also found with an increase in Tahirpur for the same period. The annual rainfall is following an increasing trend of 15.165 mm/year (**Figure 2**), and the average temperature is increasing by 0.0375 °C/year (**Figure 1**).

Figure 1: Average temperature of Tahirpur (Sylhet station) (1992-2022)



Source: BMD, 2023

Figure 2: Annual rainfall of Tahirpur (Sylhet station) (1992-2022)



Source: BMD, 2023

6.2. Climate-induced disaster in Tahirpur

Flooding is a common phenomenon in the haor areas, and almost every year, people experience seasonal and flash floods. The Haor areas are suitable for boro rice cultivation, but early flash floods often wash away standing crops, and people lose their harvest. Early floods, hailstorms, and drought are the main constraints to growing modern boro rice (**Kamruzzaman & Shaw, 2018**). Early flash floods in Haor areas result from climate change, which has a destructive impact on agricultural productivity, natural fish breeding, land use practices, lifestyles, and livelihoods (**Azizul & Kabir, 2022**). In the Haor Basin, Sunamganj is a flood-prone area, and natural catastrophes or calamities have the potential to harm crops every year (Abedin et al. 2019, CEGIS 2012a, Mia, 2021, Himu et al. 2020, Hoq et al. 2021, Ali et al. 2018, Islam et al. 2023). For about half of the year, the low ground is entirely flooded. To increase food security and the social safety net, it is essential to make sure that food grains remain accessible for domestic use throughout the

year (Islam et al. 2023). Because these regions were inundated almost every year, the Uttar Shreepur Union of Tahirpur Upazila in Sunamganj District was chosen to undertake the study to determine the causes of the flash flood, situation analysis during and after the storm, and diverse sectoral repercussions of the flash flood. (Khan et al.2021). High rainfall and water extent fluctuation frequently occur in the Sunamganj district of the Sylhet division. The northern half of Sunamganj receives 8000 mm of rainfall on average each year. As a result, Tanguar Harbor experiences more severe floods. The Haor region encounters drought conditions when the water level is low, however, this happens relatively seldom on average. Numerous natural disasters occur in the region as a result of climate change, high human density, and environmental degradation. But compared to other places, this region experiences flash floods more frequently. Tahirpur Upazila's monthly average precipitation from 2001 to 2018. Rainfall averaged 7.7 mm in January, 19.3 mm in February, 41.2 mm in March, 158 mm in April, 270.3 mm in May, 482.8 mm in June, and 512.1 mm in July, 6.8 mm in August (432.6 mm), September (300.6 mm), October (165 mm), November (32.1 mm), and December. The months of June and December had the highest and lowest rainfall totals, respectively. (Bagchi et al. 2020). The Haor regions and low-lying parts in the northeast have been submerged by 2017's heavy rainfalls and the onrush of water from the Indian Meghalaya hills upstream. Unusual flash floods and early floods in Sunamganj frequently result in substantial amounts of Boro crop damage in this area. When early flooding occurs, it is discovered that the damage percentage is larger in March (75%) and April (70%-90%) than it is in May (15%-40%). The Sunamganj district has been most severely impacted as a result of early-season flash floods in 2017. While 91,690 hectares of standing crops in Boro fields have sustained damage, around 102,436 hectares of agricultural land have sustained complete devastation. The prospective rice harvest was projected to have lost a total of 354,840 metric tons (MT) and a

corresponding BDT 10,645.2 million in economic terms. (Mondal et al. 2019). In the transitional period between the Chaitra and Boishakh months, when heavy rainfall and water flow from Meghalaya can cause unexpected and deadly flash floods, Tahirpur Upazila, located in the Sunamganj district and bordering Meghalaya, is particularly vulnerable to flash floods. The main cause of these flash floods is upstream high rainfall that occurs suddenly in Meghalaya, which sends a surge of water due to the Jadukata stream in the Badaghat area of Tahirpur Upazila (Tahirpur.sunamganj.gov.bd, 2019). Significant agricultural damage is caused by these flash floods in places like Matian Haor, Tanguar Haor, and Shonir Haor. The local population's ways of subsistence are adversely affected by the damage that these flash floods cause to infrastructure, homes, schools, and communication networks. As an illustration, the 2010 flash flood damaged 10,337 hectares of crops (totally damaged), damaged 2,613 hectares of crops (partially), partially affected 20 kilometers of highways, and eroded 16 kilometers of embankments (Tahirpur.sunamganj.gov.bd, 2019). The 2010 flash flood specifically affected 382 hectares of farmland in Tahirpur Sadar Upazila, 1,580 hectares of farmland (totally damaged), 3 kilometers of roads (partially affected), and 3.50 kilometers of embankments, all of which had a significant adverse impact on Boro crops. 1,293 farming families in the area were impacted by this, both directly and indirectly (Tajwar, 2019). In Tahirpur Sadar Upazila, a flash flood can damage 1,670 hectares of Boro crops (totally damaged) and 447 hectares of crops (partially damaged) if it were to happen again, because of too much rain and water from Meghalaya, as it did in 2010. In addition, it may have a partial influence on 6 kilometers of highways and 8 kilometers of embankments, which will directly and indirectly affect 1,315 farming families (Tajwar, 2019). Seasonal flooding that occurred in 2004 affected aman crops on 62 hectares of land, 682 dwellings, 14 km of (partial) road, 3.5 jobs, 6 educational institutions, 5 fisheries firms, 17 tube wells, 45 latrines, and 7 religious

institutions in Tahirpur Sadar union of Tahirpur upazila. However, a seasonal flood claimed the lives of 20 livestock. 1507 farming households are thereby impacted, both directly and indirectly (CDMP, 2014). In 2010, Kalboishakhi Jhar in Tahirpur Sadar union of Tahirpur Upazila, affected 20 latrines, 34 trees & plants, 5 hectares of boro crops (full), 4 hectares of boro crops (partial), 2 dwellings & homesteads (partial), and 5 hectares of boro crops (partial). 287 families experienced losses as a result, both directly and indirectly (CDMP, 2014). 18 domestic animals and 70 houses suffered damage in 2009. In 2010, damage to 37 hectares of crop fields (in full) and 28 hectares (in part), 20 dwellings (in part), 324 trees, 1 educational institution, 1 religious institution, and 74 latrines. In Kalbaishakhi Jhar, 35 dwellings were partially damaged in 2011, along with 17 domestic animals (CDMP, 2014) (Table 1).

Table 1: Loss and damage due to Disasters

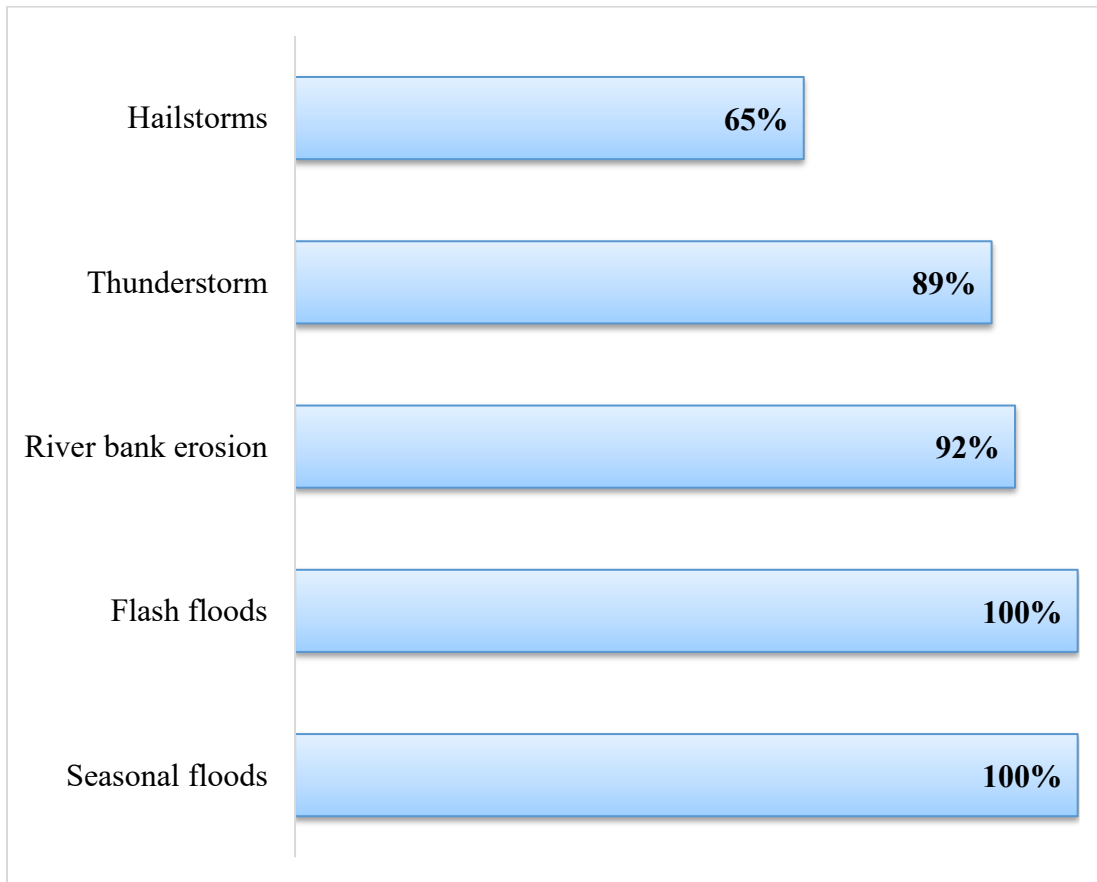
Disaster name	Year	Affected people	Asset loss	Reference
Nor'wester	1 April 2015	1 died	-	Karatoa, April 2
Nor 'wester and Thunderstorm	2 May 2015	1 died	-	Daily Star, May 3
Nor 'wester and Thunderstorm	7 May 2015	1 died and 4 were injured	-	Daily Star, May 8

Nor ‘wester and Thunderstorm	26 May 2015	9 injured	200 houses damaged	Daily Star, May 27
Thunderstorm	25 June 2015	3 died	-	The Ittefaq, June 27
Tornado	30 April 2017	-	259 houses were fully damaged, and 559 houses were partially damaged	NDRCC Report, May 01, 2017
Thunderstorm	4 May 2018	1 died	-	http://www.prothomalo.com , May 04, 2018
Thunderstorm	8 May 2018	1 died	-	http://www.prothomalo.com , May 08, 2018
Flash flood	10 July 2019	-	4100 families marooned	NDRCC Report, July 11, 2019
Thunderstorm	13 July 2019	2 died	-	NDRCC Report, July 13, 2019
Thunderstorm	14 July 2019	2 died	-	NDRCC Report, July 15, 2019
Flash flood	17 April 22	-	Crops on 2,000 hectares are at risk.	jagonews24.com 17-April 22

Flash flood	18 April 22	-	Hundreds of hectares of paddy fields submerged	prothomalo.com 18-April 22
Thunderstorm	19 May 2022	3 died and 10 were injured	-	jagonews24.com 19-May 22
Thunderstorm	23 March 2023	1 died	-	The Daily Jugantor
Thunderstorm	23 April 2023	1 died and 2 were injured	-	https://www.prothomalo.com/bangladesh/district/jy39k877e4
Thunderstorm	19 September 2023	3 died	-	https://thefinancialexpress.com.bd/national/lightning-strikes-kill-9-farmers-in-sunamganj-moulvibazar-sylhet

The recent trends of climate-induced extremes (flash floods, seasonal floods, river bank erosion, thunderstorms, and hailstorms) are common disasters in Tahirpur. According to all of the respondents in the study area, seasonal floods and even flash floods are common in Tahirpur. Also, they suffered from different climate-induced disasters, such as riverbank erosion, thunderstorms, and hailstorms, as mentioned by 92%, 89%, and 65% of respondents, respectively (**Figure 3**).

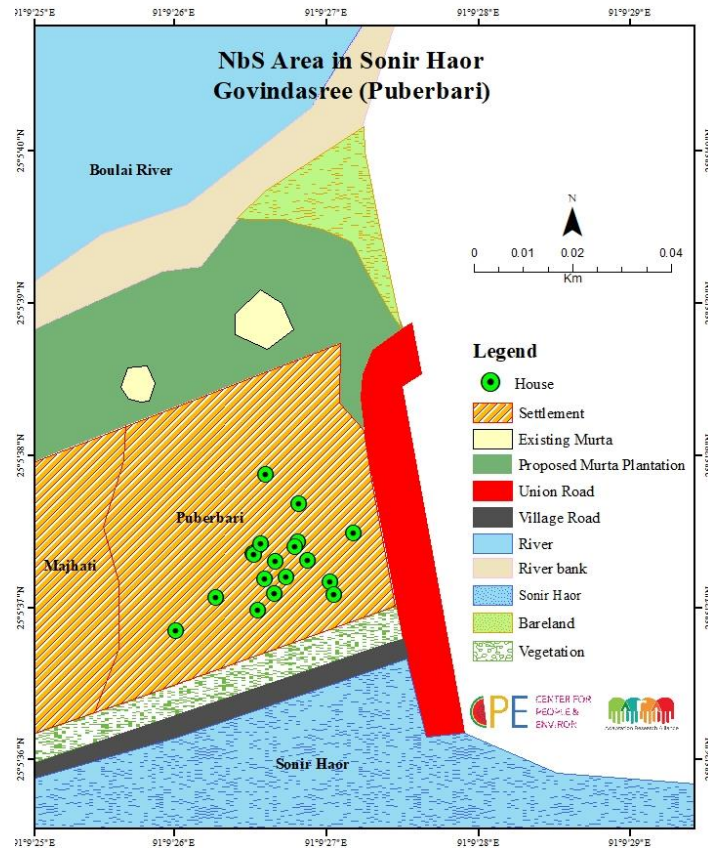
Figure 3: Disasters in the study area



6.3. Adaptation plan through NBS

In 2023, with the financial support of the Adaptation Research Alliance, the action research was implemented in the study area. There is most important livelihood resilient intervention and wave erosion protection measures were found to be the application of Murta plantation as a Nature-based solution (NbS). Based on the participatory research, the Murta has been planted by the location-specific planning (Map 2).

Map 2: Murta Plantation area



7. Comparison of riverbank erosion, shifting river, and livelihood scenario before and after NbS application

Flood and wave erosion are a significant threat to the haor people. Floods inundate the homestead, and wave erosion is responsible for bank erosion. During the flood, wave erosion increases in the haor, which causes the erosion of the island. Also, the communities of haor who live on the remote island don't have livelihood support. In this regard, the action research was undertaken to pilot and test a nature-based solution to protect wave erosion in the haor, co-create knowledge on nature-based solution-oriented wave-erosion protection measures, and also to develop a value chain through capacity building for the intangible commercial heritage product Shital Pati produced from Murta.

7.1. Riverbank erosion and river shifting

Due to floods and flash floods, wave erosion in the islands of Haor is a common scenario. Map 3 represents the river trajectory changes of the Boulai River along Puberbari over the years. Due to morphological issues and other hazards like Flash floods, intense, sudden rainfall causes erosion on the riverbank. As a result, changing river trajectory is a common scenario in these areas. Between 2003 and 2013 Boulai river banks shifted 3.16 meters, and from 2014 to 2023, it's shifted 2.9 meters in the Puberbari area (Table 2).

Map 3: River Trajectory

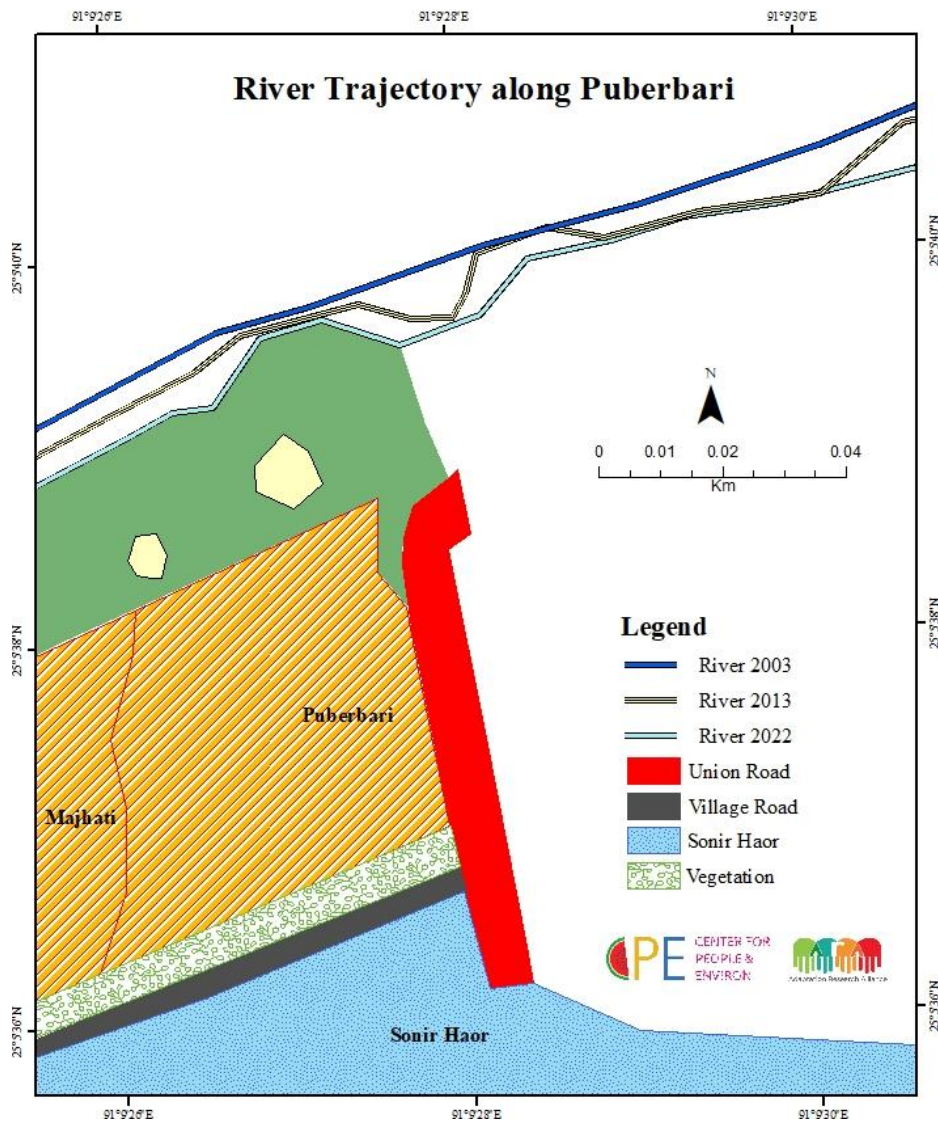


Table 2: Riverbank shift of Boulai River (2003-2022)

River Name	Year	Changes (Meter)	Change
Boulai River	2003-2013	3.16	
	2014-2022	2.90	0.26

Flash floods are the main cause of land erosion in Puberbari. Flash floods frequently occur in the haor region. According to the Department of Agricultural Extension (DAE), the Sunamganj district was the most severely damaged by the early flash flood in 2017 (Abedin et al., 2022). Between 2003 and 2013 total of 0.033 hectares and from 2013 to 2023 total of 0.30 hectares of land were eroded in Puber Bari (Map 4, Table 3).

Map 4: Land erosion map

Land Erosion Scenario in the Puberbari (2003-2022)

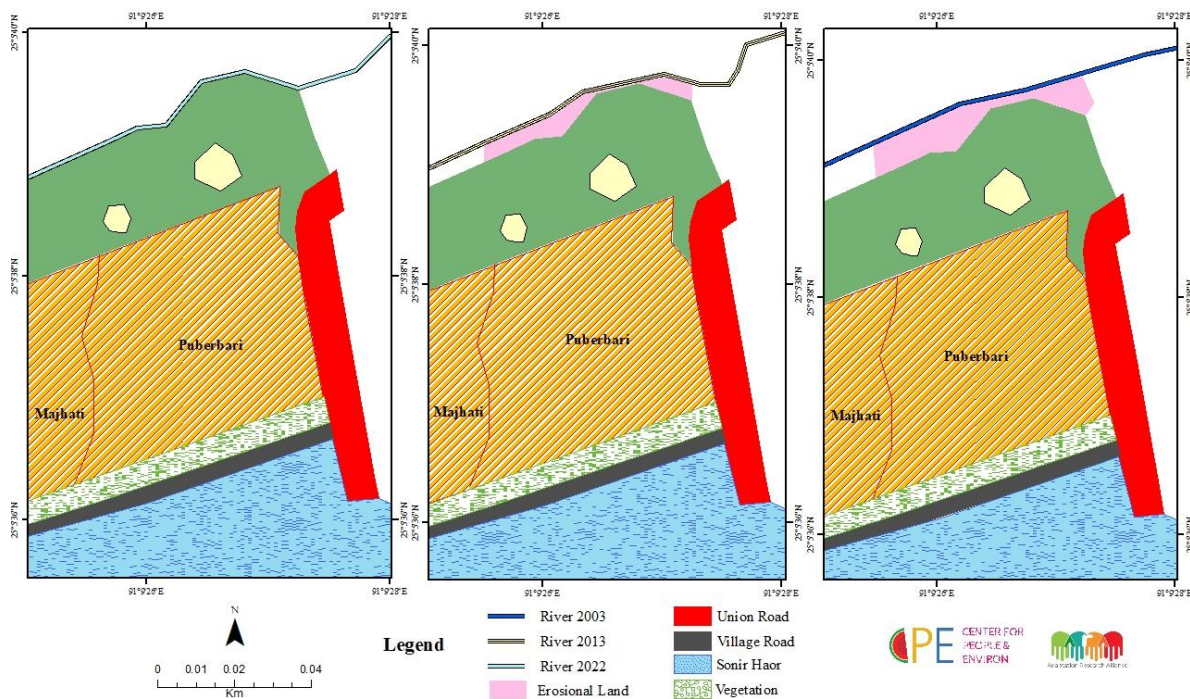


Table 3: Land erosion of Puber bari

Year	Total Area/hectares	Changes
2003	0.582	
2013	0.549	0.033

In 2013-2022, the Boulai River shifting was found to be 0.26 meters; however, by the application of Murta as NbS, the river shifting scenario has improved, and in 2022-2023, only 0.09 meters was shifted (Table 4)

Table 4: River shifting scenario

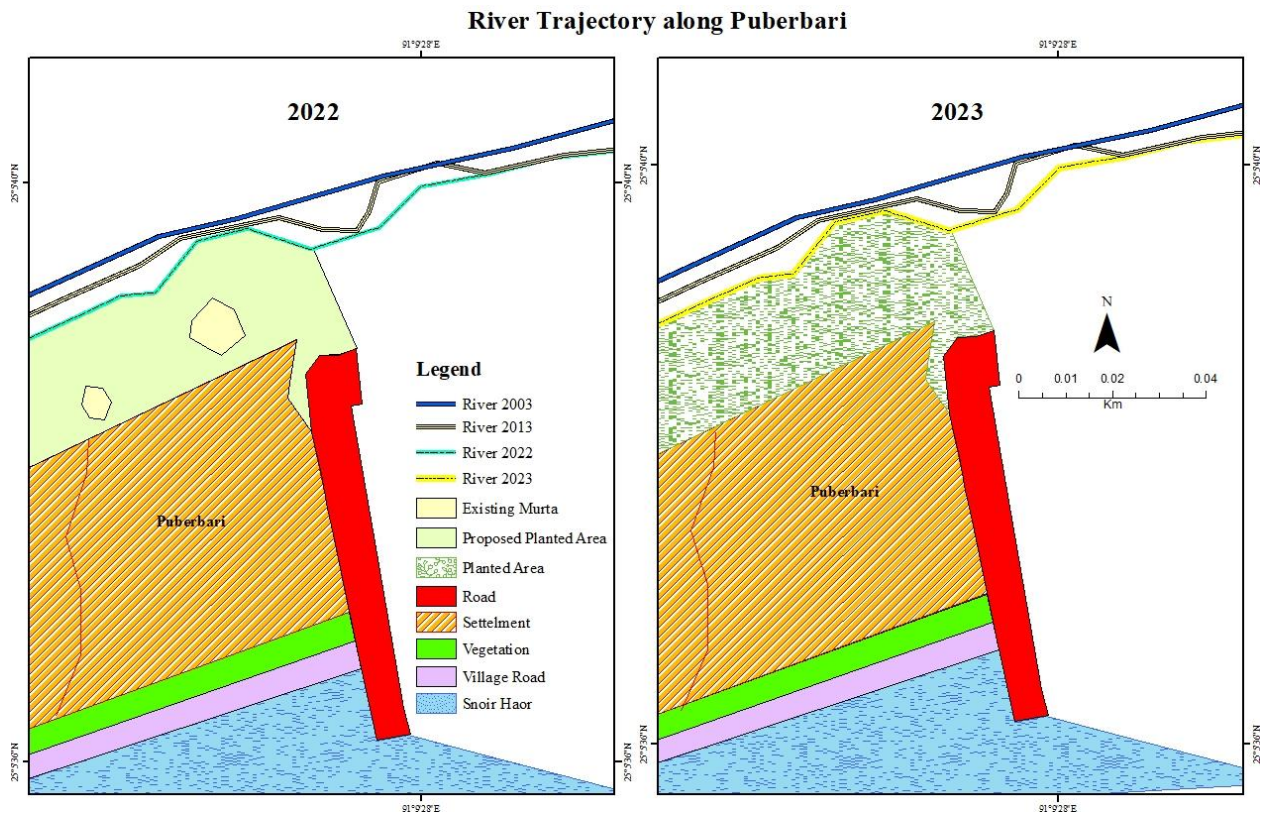
River Name	Year	Changes (Meter)	Change
Boulai	2003-2013	3.16	
	2013-2022	2.9	0.26
	2022-2023	2.81	0.09

Similarly, land erosion also improved. In 2003, there were 0.582062 Ha of land in the Haor; however, in 2023, it stands at 0.548758 Ha and decreased by 0.033 hectare due to erosion. In 2023, it stands at 0.518403 hectares and decreased by 0.033 hectares due to erosion (Table 5, Map 5). The application of NbS reduced erosion.

Table 5: Land erosion scenario in the study area

Year	Land area (Ha)	Changes
2003	0.582062	
2013	0.548758	0.033
2023	0.518403	0.030

Map 5: River trajectory and land erosion in the NbS location



7.2. Disaster-induced loss and damage

Due to floods and flash floods, and wave erosion, most of the community people suffer from loss and damage each year. **Table 6** demonstrates the amount of loss and damage suffered before and after NbS application across the project participants. The largest percentage, 88.46%, is accounted for by losses related to houses before Murta Application; however, this percentage decreased to 9.5% after Murta plantation, with an approximate average financial worth of 23,043.48 BDT per household before NbS, which decreased to BDT 15542 after NbS. Following with 15.4% from homestead farming in 2022, which reduced to only 2% after NbS. Losses from the poultry sector were 15.38%, or BDT 811.9 per household, before NbS; however, this reduced to 1.5%, or BDT 238.6, respectively, suggesting possible health and poultry farming issues. The percentages of livestock losses and fodder losses, which total 3,514 BDT and 10,000 BDT, respectively, and

represent 11.54% and 65.38% of total losses, indicate challenges with livestock management and access to animal feed. In both sectors, in terms of the percentage of households and the amount of taka for each household, have also been reduced due to NbS.

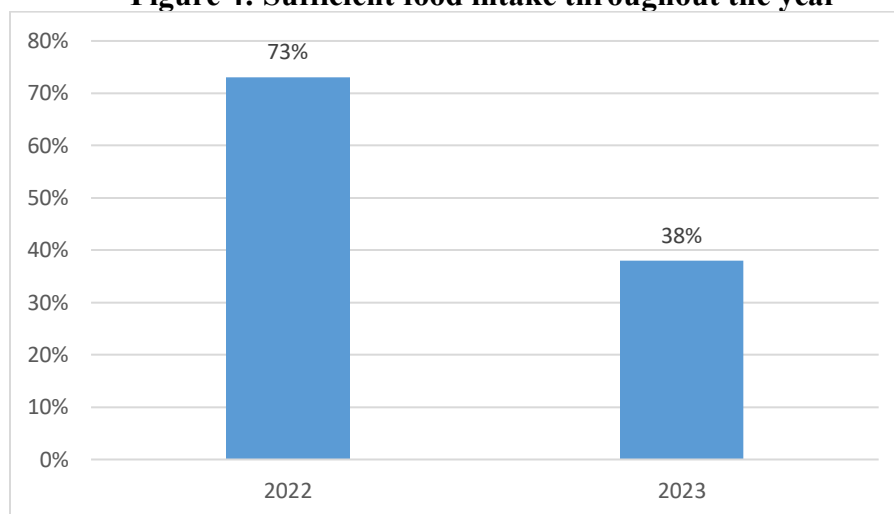
Table 6: Disaster loss and damage in the last year

Loss and damage sector	2022	2023	2022	2023
	Percentage		Average amount (BDT)	
House	88.46%	9.5%	23043.5	14542
Homestead farming	15.4%	2%	632.5	180
Poultry	15.4%	1.5%	811.9	238.6
Livestock	11.5%	3.8%	3514	1136.9
Fodders	65.4%	18%	10000	4050.5

7.3. Food security situation

Before the NbS application, a significant number of project participants (73%) did not have adequate food for all year, while 38% were insecure after the NbS application. said "no." This graph shows that the majority of people have constant access to an adequate food supply, but a significant minority still confronts food insecurity (Figure 4).

Figure 4: Sufficient food intake throughout the year



8. Conclusions

The study explored the resilient intervention needs of the poor, women, and youth in the contexts of current and emerging climate-induced disasters. They are more exposed and sensitive to multiple climate hazards, including floods, flash floods, and erratic rainfall. Focusing on wave erosion and resilient livelihoods, this study has captured the effectiveness of NbS measures to enhance community resilience regarding wave erosion protection and resilient livelihood promotion. The study also captures non-structural interventions, led by community members, which will be influential in enhancing community resilience, including awareness raising, household and community level preparedness, and response actions. To protect the Haor island from wave erosion, and also to generate resilient livelihoods, as well as income-generating activities, the Murta Plantation is an effective measure. Not only wave erosion protection and livelihood generation, but Murta can also restore intangible heritage products of Bangladesh, which have commercial, aesthetic, and carbon footprint value nationally and internationally.

Reference

- Abedin, M. A., Parvin, G. A., Habiba, U., Golam Kibria, M., Ahsan, R., Onitsuka, K., Rahman, M. M., Kobeasy, M. I., & Gaber, A. (2022). ICT uses, constraints, and challenges in flash flood risk management: A case study in north-eastern Haor areas of Bangladesh. <https://www.researchgate.net/publication/361644048>
- Azizul, M. B., & Kabir, M. H. (2022). Haor area people's adaptation strategies to climate change induced events in Kishoreganj, Bangladesh | WCSA. <https://doi.org/10.46473/WCSAJ27240606/04-05-2022-0002//full/html>
- Bagchi, R., Miah, M. A., Hazra, P., Hasan, R., Mondal, H. S., & Paul, S. K. (2020). Exploring the effect of rainfall variability and water extent in Tanguar Haor, Sunamganj. *Australian Journal of Engineering Innovation and Technology*, 2(4), 66–76.
- Brammer, H. (1990). Floods in Bangladesh: Geographical background to the 1987 and 1988 floods. *Geographical Journal*, 156(1), 12–22.
- CDMP. (2014). Sulla Upazila DM Plan_English version.pdf. ReliefWeb. <https://reliefweb.int/report/bangladesh/upazila-level-disaster-management-plan-development-tahirpur-upazila-district>
- Hossain, M. A. (2022, May 28). The flooding of Sunamganj. *The Business Standard*. <https://www.tbsnews.net/features/focus/flooding-sunamganj-428446>
- IFRC. (2022, June 28). Millions in Bangladesh impacted by one of the worst floods ever seen | IFRC. <https://www.ifrc.org/press-release/millions-bangladesh-impacted-one-worst-floodings-ever-seen>

- Islam, M. R., Babu, M. A. H., Uddin, M. J., Khatun, M. L., & Islam, M. S. (2020). Investigating the risk and resilience of flash floods in the Sunamgonj haor region of Bangladesh. <https://www.researchgate.net/publication/348967869>
- Islam, M. S., Hossain, M. N., Alam, M. D., & Chowdhury, M. T. A. (2023). Crops diversification, adequate and nutritious food: A challenge for rural communities in Sunamganj District. *Bangladesh Journal of Materials and Environmental Science*, 14(4), 449–461.
- Kamruzzaman, M., & Shaw, R. (2018). Flood and sustainable agriculture in the Haor basin of Bangladesh: A review paper. *Universal Journal of Agricultural Research*, 6. <https://doi.org/10.13189/ujar.2018.060106>
- Khan, M. J. U., Islam, A. K. M. S., Das, M. K., Mohammed, K., Bala, S. K., & Islam, G. M. T. (2019). Observed trends in climate extremes over Bangladesh from 1981 to 2010. *Climate Research*, 77, 45–61. <https://doi.org/10.3354/cr01539>
- Khan, M. S., Apu, M. R., Begum, S., & Billah, M. M. (2021). Sectoral impacts of flash floods in Tanguar Haor in Sunamganj of Bangladesh. *Asian Journal of Geographical Research*, 55–64.
- Mondal, S., Akter, L., Hiya, H. J., & Farukh, M. A. (2019). Effects of 2017 early flash flooding on agriculture in Haor areas of Sunamganj. *Journal of Environmental Science and Natural Resources*, 12(1–2), 117–125.
- NPDM (National Plan for Disaster Management). (2010). Disaster Management Bureau, Disaster Management & Relief Division, The People’s Republic of Bangladesh.
- Reliefweb. (2014, November 18). Upazila level Disaster Management Plan Development: Tahirpur Upazila, District-Sunamganj, August 2014 - Bangladesh | ReliefWeb.

<https://reliefweb.int/report/bangladesh/upazila-level-disaster-management-plan-development-tahirpur-upazila-district>

Tahirpur.sunamganj.gov.bd. (2019). Final DM Plan (Tahirpur) Eng pdf.

http://tahirpur.sunamganj.gov.bd/sites/default/files/files/tahirpur.sunamganj.gov.bd/page/6908b696_0757_11e7_a6c5_286ed488c766/Final%20DM%20Plan%20%28Tahirpur%29%20Eng%20pdf.pdf [Accessed June 26, 2019]

Tajwar, K. M. A. H. I. R. (2019). Causes and consequences of flash flood in the north-eastern part of Bangladesh: A case study on Tahirpur Upazila of Sunamganj District.

https://www.academia.edu/42615795/Causes_and_Consequences_of_Flash_Flood_in_the_North_Eastern_Part_of_Bangladesh_A_Case_Study_on_Tahirpur_Upazila_of_Sunamganj_District

Unb, H. (2011, August 7). Mindless sand lifting triggers serious erosion in Habiganj. The Daily Star. <https://www.thedailystar.net/news-detail-197576>