CLIMATE RISK ASSESSMENT AND IDENTIFICATION OF CLIMATE-SMART LIVELIHOOD OPTIONS IN TEKNAF

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List of abbreviations and acronyms

8FYP	8th Five-Year Plan
AFOLU	Agriculture, Forestry, and Other Land Use
AI	Artificial Intelligence
AR6	Sixth Assessment Report
AWD	Alternate Wetting and Drying
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BCCRF	Bangladesh Climate Change Resilience Fund
BDRCS	Bangladesh Red Crescent Society
BDT	Bangladeshi Taka
BDRS	Bangladesh Disaster-related Statistics
BIWTA	Bangladesh Inland Water Transport Authority
BMD	Bangladesh Meteorological Department
BRC	British Red Cross
BSCSIC	Bangladesh Small and Cottage Industries Corporation
CBA	Cost-Benefit Analysis
CPE	Center for People & Environ
CSA	Climate-Smart Agriculture
CRPARP	Climate Resilient Participatory Afforestation and Reforestation Project
CZP	Coastal Zone Policy
DAE	Department of Agricultural Extension
DDM	Department of Disaster Management
DEM	Digital Elevation Model
DFID	Department for International Development
DLS	Department of Livestock Services
DRR	Disaster Risk Reduction
DRRO	District Relief and Rehabilitation Officer
EC	Electric Conductivity
EEZ	Environmental Endangered Zone
ESM	Earth System Model
EX-ACT	EX-Ante Carbon-balance Tool
FDA	Functional Discriminant Analysis
FGD	Focus Group Discussion
FIP	Forest Investment Plan
FMP	Forestry Master Plan
GCRI	Global Climate Risk Index
GDP	Gross Domestic Product
GHG	Green House Gas
GIS	Geographic Information System
GLM	Generalized Linear Model
GoB	Government of Bangladesh
GPS	Global Positioning System
HHS	Household Survey
HYV	High Yielding Variety
IBFCR	Inclusive Budgeting and Financing for Climate Resilience
ILMM	Integrated Livestock Manure Management

INM	Integrated Nutrient Management
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
KII	Key Informant Interview
LSD	Lumpy Skin Diseases
MHRM	Multi-Hazard Risk Maps
MPI	Max Planck Institute
MSL	Mean Sea Level
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NDC	Nationally Determined Contribution
NDVI	Normalized Difference Vegetation Index
NGO	Non-Government Organization
NIRAPAD	Network for Information, Response, and Preparedness Activities on Disaster
NLEP	National Livestock Extension Policy
NPDM	National Plan for Disaster Management
OECD	Organization for Economic Co-operation and Development
PSF	Pond Sand Filter
PWD	Person With Disability
REDD+	Reducing Emissions from Deforestation and Forest Degradation Plus
RO	Reverse Osmosis
RS	Remote Sensing
SLCP	Short-Lived Climate Pollutants
SNA	Social Network Analysis
SOD	Standing Order on Disaster
SRDI	Soil Resource Development Institute
SVM	Support Vector Machine
UDMC	Union Disaster Management Committee
V2R	Vulnerability to Resilience
WARPO	Water Resources Planning Organization
WDMC	Ward Disaster Management Committee

Executive Summary

Historically, Bangladesh has faced various hydro-meteorological threats including cyclones, floods, salinity intrusion, storm surges, erosion, and drought. The changing climatic pattern also increases the effects of climate-induced sudden and slow-onset disasters. The geographical location, climate, and topography of Cox's Bazar create a unique environment where local communities are exposed to multiple natural hazards and experience recurring extreme weather events. As a result, the livelihoods of the people of Cox's Bazar are under threat. The study was conducted in Teknaf Upazila (Sub-district) under Cox's Bazar district to develop climate-smart and disaster-resilient economically viable livelihood options for the climate-vulnerable area. The study has adopted a multidisciplinary methodology to explore the climatic vulnerability and resilient livelihoods of the study area. The study has reviewed secondary information, relevant policies, and articles collected from the Bangladesh Meteorological Department (BMD), the Department of Agricultural Extension (DAE), and the Department of Disaster Management (DDM). Under this study, IPCC Sixth Assessment Report (AR6), Bangladesh Climate Change Strategy and Action Plan (BCCSAP), National Adaptation Plan (NAP), Mujib Climate Prosperity Plan, Nationally Determined Contribution (NDC), National Plan for Disaster Management (NPDM, 2021 to 2025), Standing order on Disaster -2019, 8th Five-Year Plan of Bangladesh, Delta Plan, Integrated Coastal Zone Management Plan, Southern Agricultural Master Plan, Agriculture Policy, Water Policy, Forest Policy, OECD Building Resilience Systems were reviewed and analyzed. Primary information (qualitative and quantitative) was collected through Participatory research using Household Survey (HHS), Focus Group Discussion (FGD), and Key Informant Interview (KII). A total of 402 households were surveyed randomly. The study also conducted a total of 12 FGDs with men, women, persons with disabilities, and market actors (input sellers and buyers) to understand the existing climate vulnerability, capacity, and resources to deal with shocks, capacity, and resource needs, access to services, access to market and finance, etc. From local to national levels, the study has captured opinions from different institutions by conducting 16 KIIs. Multi-hazard risk assessment, Local climatic scenario generation, climate projection, soil and surface and underground water salinity measurement, Cost-benefit analysis of Climate-Smart Agriculture (CSA), GHG-Smart CSA identification, Sustainable and Resilient Livelihoods Identification, and Analytical Framework were applied in the study.

The study finds that the rising temperature scenario in Teknaf is higher, and the decreasing rainfall trend is lower than in Cox's Bazar district. Similarly, the wind speed increasing trend is slightly higher in Teknaf than in Cox's Bazar district average. The studied unions are highly vulnerable to rising temperatures, increasing wind speed, and decreasing rainfall trends. In all three studied unions, cyclones, heatwaves, seashore breaks, and agricultural drought increased in the last five years. The Sabrang union is highly disaster-vulnerable due to floods, strong wind, tidal inundation, riverbank erosion, thunderstorms, heat waves, cold waves, cyclones, and seashores. On the contrary, Hnila and Whykong are identified as a moderate risk of floods, flash floods, landslides, cyclones, tidal inundation, etc.

Due to the increasing trend of climate-induced disasters, farmers of Whykong and Sabrang are highly affected. In Sabrang, the people who depend on boat hawking for their livelihoods are also highly vulnerable. In all three unions, the number of day laborers and fishermen is high. The study also demonstrates climate-induced calamities, including heatwaves, groundwater

depletion, salinity, waterlogging, and heavy rainfall that severely damaged agriculture, homestead farming, livestock, poultry, etc. As a result, the livelihood-changing scenario is almost high in all three studied unions. Consequently, many locals including farmers, fishermen, and boat hawkers are changing their profession to ensure their livelihood.

Agricultural land loss is a common scenario in all unions because of salinity intrusion, water logging, riverbank erosion, drought, and conversion of agricultural land into residences and other development purposes. The agricultural land of Whykong is decreasing rapidly which is exerting pressure on agriculture. The forest coverage of the study area has also declined drastically. In Whykong, 3702.6 ha of dense forest is lost between 2013-2023. In the Sabrang Union, a huge land was lost due to bank erosion, and 70.1 hectares of land was lost due to river bank erosion between 2013 and 2023. Permanent and seasonal migration is a common scenario in the study area. Seasonally, in search of livelihood opportunities, many people migrate to another place. On the other hand, land loss is responsible for permanent migration. The highest trend for migration is found in the Sabrang union. Due to the loss of homestead land as well as agricultural production, economic and livelihood crisis, and freshwater crisis, some people of the studied unions will mitigate shortly.

A multidimensional analytical approach has identified resilient crop farming, homestead farming, fodder farming, agroforestry, betel leaf farming, seagrass and seaweed farming, value-added products from seagrass and seaweed, value-added products from mangroves, biofertilizer production, and horticulture are the potential sustainable climate-resilient livelihoods options for the study area.

In Hnila, under the project, BDRCS can promote resilient crop farming, homestead farming, slatted houses for livestock rearing, semi-scavenger housing for poultry rearing, resilient fodder farming, agro-forestry, handicrafts, and biofertilizer production.

In Sabrang, homestead farming, slatted houses for livestock rearing, semi-scavenger housing for poultry rearing, resilient fodder farming, seagrass, and seaweed farming, value-added products from seaweed and seagrass, value-added products from mangroves, biofertilizer production, and handcrafts are suitable as climate-resilient livelihood interventions.

Likewise, in Whykong resilient crop farming, homestead farming, slatted houses for livestock rearing, semi-scavenger housing for poultry rearing, resilient fodder farming, agro-forestry, biofertilizer production, and handicrafts are climate-resilient potential livelihood interventions.

But within a short time (6 months returnable), actionable climate-resilient livelihood interventions in all three unions are found as slatted houses for livestock rearing, semi-scavenger houses for poultry rearing, fodder farming (Salinity-tolerant and drought-tolerant fodder variety promotion (local-Dhoincha and HYV) and handicrafts. Value-added products from seagrass and seaweed (Pickle and molasses value chain development from mangrove as NbS (Keora-Sonneratia apetala and Goalpata-Nypa fruticans) can be the options for the Sabrang union.

In terms of crop-field farming, Salt-tolerant T. Aman (BR-22 and BR-23, Bina shail), Salt-tolerant BRRI dhan (33, 56, 57, and 62 BRRI dhan 40, 41, 53, 54, 65), Salt-tolerant Bina dhan (7, 8, 10 and 16), Salt-tolerant potato, (BARI Alo-22, CIP Clone -88,163), Salt-tolerant sweet Potato, (BARI Mishti Alo-8,9), Salt-tolerant pulses, (BARI Mug- 2,3,4,5,6, BM-01, BM-08

BARI Falon-1, BARI Sola-9), Short-duration oilseeds, (BARI Sharisha-14,15 BARI Chinabadam 9, BINA China badam-1, BINA China badam-2, BARI Soyabean-6 BARI Til-2,3,4) are the potential varieties for the study area. Salt-tolerant potato (BARI Alo-22, CIP Clone -88,163), Salt-tolerant sweet Potato (BARI Mishti Alo-8,9), beets, pepper, cabbage will be the perfect match for homestead farming. Regarding fodder Nepier-1, Nepier-2, Nepier-3, Nepier-4, Pakchang, Markiron, and Rokona, Dhoincha are the potential varieties.

In terms of climate change adaptation and mitigation, as well as GHG-smart and women and disability-inclusive resilient livelihoods, there is also a need to build capacity through training related to community-based, local-led climate solutions. In the short term, the BDRCS can promote those livelihood interventions that will be beneficial in a short time as nutrition support and revenue generation. In the medium and long term, nature-based solutions can be promoted to contribute to carbon sequestration. Possible engagement with different government and non-government organizations including the Department of Agriculture Extension, Department of Livestock, Department of Forest, Department of Women and Children Affairs, Department of Social Service, Bangladesh Water Development Board, and non-government organizations who are working with climate-resilient livelihoods and nature-based solutions in nationally and locally will be more effective to ensure climate-resilient communities.

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CHAPTER ONE
INTRODUCTION

1.1. Introduction

Bangladesh is a nation that is highly vulnerable to the effects of climate change (Rahaman et al., 2020). The country has faced various hydro-meteorological threats, including cyclones, floods, salinity intrusion, storm surges, erosion, and drought (ADB, 2021). Growing threats to biodiversity and nature include the effects of climate change, such as cyclones, storm surges, sea waves, tidal surges, tidal floods, sea level rise, and increased storminess (Zappa et al., 2013). (Rahaman et al., 2020). In a low-lying delta region created at the confluence of the Ganges and Brahmaputra River systems, Bangladesh is situated in South Asia. It is also regarded as the largest delta in the world, with a riverine nation that is particularly vulnerable to geophysical hazards because of its topography and location. Long-standing climatological (such as drought), hydro-meteorological (such as cyclones, storm surges, and floods), and other geophysical (such as landslides and erosion) hazards affect the nation. Due to its funnel-shaped southern coast and being a riparian nation, it is vulnerable to cyclones and storm surges, medium-to-high soil salinity, sea-level rise, monsoon, and flash floods (Reliefweb, 2021).

1.2. Context of the study

According to the Sixth Assessment Report of the IPCC, South Asia's climate is changing, and the impacts are already being felt (Pörtner et al., 2022). According to the Global Climate Risk Index (GCRI), Bangladesh ranked 9th on the list of 10 most affected countries and placed 7th on the long-term (1998-2017) risk index because of extreme climatic events (Eckstein et al., 2020). A long-term trend of disasters in Bangladesh based on 120 years (1900-2020) data from EM-DAT data (https://www.emdat.be/) suggests that cyclones and floods are the two most recurrent disasters that cause enormous economic loss and are associated with some of the significant catastrophic events in the history of Bangladesh, such as 1970 Bhola Cyclone where roughly 500,000 lives were lost (NIRAPAD, 2021). From 7 years trend analysis starting from 2014 up to 2020, the 15 significant disasters (cyclone and storm surge, flood, salinity, and riverbank erosion) affected 42 million people, displaced 9.4 million people, damaged 4.6 million houses either fully or partially, caused 1,053 deaths, and resulted in an economic loss of $4.1 billion (NIRAPAD, 2021). Among the four major disasters, floods (including both Monsoon and Flash floods) affected 34.9 million people- it is the highest and 83% of the total affected 42 million; the next one to have a significant impact was cyclone and storm surge, which affected 7.05 million people and constitutes 16.78% of the affected population. These climate-induced extremes also restrict agricultural production in terms of land loss and production reduction.

The Southern region of Bangladesh, lying in the coastal zone, is exposed to salinity intrusion. In Bangladesh, the coastal region contains a deltaic plain that covers more than 30% of the arable land. 1.056 million hectares of coastal land, or about 1.689 million acres, are impacted to varying degrees by soil salinity (Miah et al., 2020). There has been a 26% increase in salinity-affected areas in Bangladesh over the past 35 years (Mahmuduzzaman et al., 2014).

People who live in coastal areas of Bangladesh cannot but have to change their agricultural practices, livelihoods, and groundwater contributions due to saltwater intrusion (Hasan et al., 2020). Bagerhat district is one of the vulnerable climate districts of the southwest coastal belt where salinity intrusion, tidal surges, storm surges, and cyclones are common phenomena. This district has a shortage of clean drinking water due to salinity intrusion and sea level rise (Nahin et al., 2020). Saline water intrusion into the agricultural land restricted agricultural production, reducing livelihood options. People's dependence on the extraction of mangrove resources is increasing daily. Coastal floods, tidal surges, riverbank erosion, saline intrusion in water and soil, tropical cyclones, etc., have significantly risen in Bangladesh's coastal region due to climate-induced sea level rise (Rahaman et al., 2020). Climate change is gradually increasing disasters like floods, riverbank erosion, cyclones, tornadoes, hailstorms, water logging, saline intrusion, etc., growing threats for the coastal residents (Rahman et al., 2017). In Patuakhali, extreme poverty in 2010 was 14.7% and increased to 27.4% in 2016 (HIES, 2010; 2016). In this district, the reported number of violence against women was 59 in 2013 and increased to 132 in 2015. Salinity is responsible for reproductive health disturbance, which causes disabled childbirth (Rahaman, et al.; 2022). HIES 2016 also mentioned the chronically disabled in Patuakhali 32% (HIES, 2016). Climate-induced migration is increasing in this district, and internal migration increased to 11.30% during 2000-2010, which was 4.80% during 1991-2000 (Brennan, 2020). Rahaman finds 33.90% seasonal migration in the Patuakhali district. Rahaman also mentioned that during the winter and summer, seasonal migration increases (Rahaman, et al. 2022).

The geographical location, climate, and topography of Cox's Bazar create a unique environment where local communities are exposed to multiple natural hazards and experience recurring extreme weather events. Vulnerable Bangladeshi communities in the district have long borne the brunt of cyclones, landslides, and flash floods. The Rohingya crisis has increased the size of the population at risk and is driving the creation of new risks due to deforestation, hill cutting, and infrastructure pressure. Since August 2017, more than 700,000 Rohingya refugees have temporarily settled in the Ukhiya (Sub-district) Upazila, a region of critical environmental importance (Quader, 2019). This significant addition to the area's population resulted in more pressure on the resources, especially the forest resources. Population growth affects the local ecosystem and forest resources (Hassan et al., 2023). Most of Ukhiya's vegetation area has been converted to agricultural land and settlements to meet demand (Babu, 2020). Local forests are affected visibly by the influx of refugees into these areas, which has exacerbated conflicts between humans and wildlife. Extensive levels of deforestation, land leveling, and hill-cutting activities took place in Cox's Bazar District in Bangladesh to accommodate them (Ahmed et al., 2020; Kamal et al., 2022). This results in a dispute between the host community and the refugee. As Cox's Bazar is a huge tourist attraction and tourism offers business opportunities, more and more hotels, and resorts have been constructed by cutting down lots of trees and cutting hills. This unplanned urbanization has become a core triggering point for landslides (Rasel et al., 2021). Besides, the Hill cutting and the extensive loss of ground cover vegetation loosen the soil, bringing new risks, leading to soil erosion, sedimentation, siltation, and landslides. These effects are particularly noticeable during the rainy season. Most of the vegetation area has been converted to agricultural land and settlements to meet the rising demand (Babu, 2020). As a result, the livelihood opportunities of the local people are under threat.

1.3. Objectives of the study

The overall objective of the study is to develop climate-smart and disaster-resilient economically viable livelihood options for the climate-vulnerable area. Specifically, the objectives of this assignment are to:

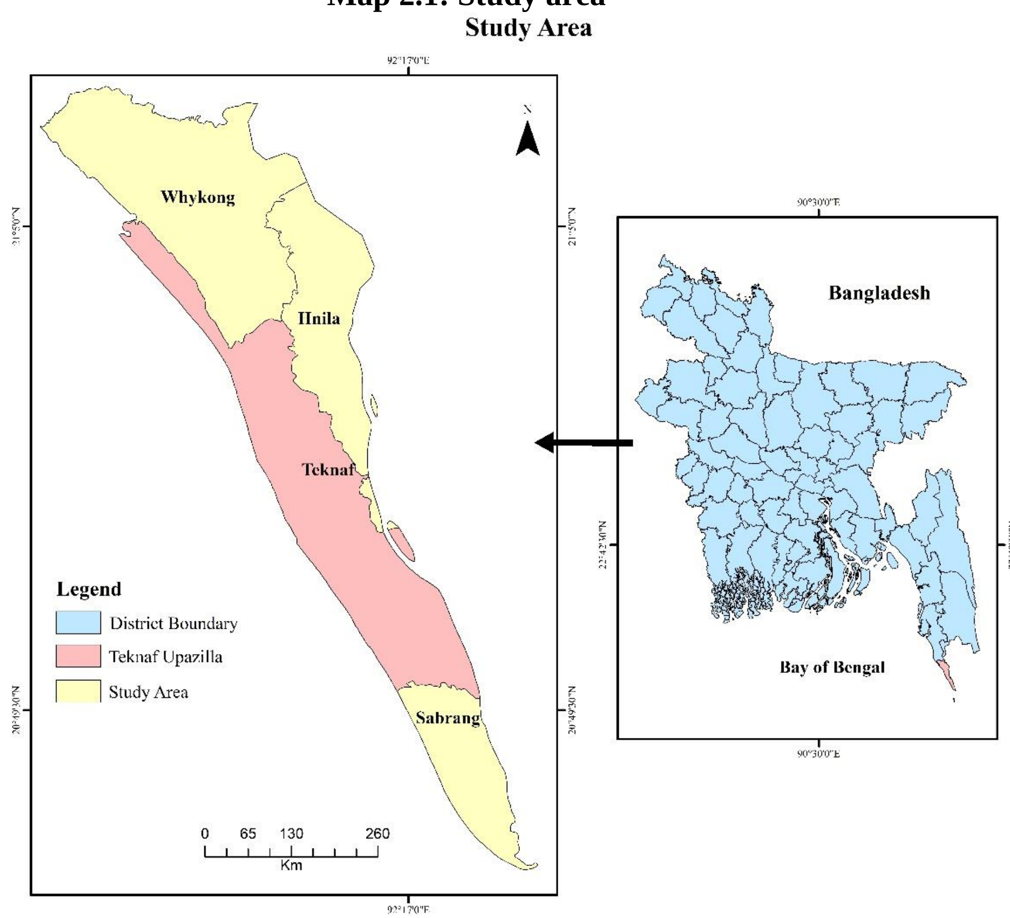
- To conduct a risk assessment to identify the current and future impacts of climate change on target communities living in Teknaf, focusing on their livelihood and their environment.
- To assess the potential environmental and social impacts of proposed climate-smart livelihood options, considering changes in land and water use, greenhouse gas emissions, biodiversity, and social dynamics to ensure a positive impact on the environment and social well-being.
- To propose locally appropriate livelihood options that are economically and sustainably viable for improving communities' coping capacity against existing and future climate risks.

CHAPTER TWO
RESEARCH METHODOLOGY

2.1. Study area

The study was conducted in three unions (Hnila, Whykong, and Sabrang) of Teknaf Upazila (Sub-district) of Cox's Bazar district (Map 2.1). The Teknaf Upazila, which is located on Bangladesh's southern border with Myanmar, occupies an area of around 388.68 square kilometers (km) between latitudes 21°10 and 20°40 north and 92°05 and 92°25 east. It is part of an exposed coast that is limited on the north by a hilly region and the Ukhia Upazila, on the south and west by the Bay of Bengal, and the east by the Naaf River and the coast of Myanmar. The Naaf River is roughly 55 km long, flows south, and empties into the Bay of Bengal at the end (Chowdhury et al., 2011). The Teknaf peninsula, which lies in Bangladesh's most southeasterly region, features a varied topography including hills, piedmont plains, tidal floodplains, and beaches (Moslehuddin et al., 2018).

Map 2.1: Study area



2.2. Data collection

For the study secondary information, relevant policies, and articles were collected from different pertinent institutions and sources. Long-term observational data on climate, agriculture, and hazards were collected from the Bangladesh Meteorological Department (BMD), the Department of Agricultural Extension (DAE), and the Department of Disaster Management (DDM).

IPCC Sixth Assessment Report (AR6), Bangladesh Climate Change Strategy and Action Plan (BCCSAP), National Adaptation Plan (NAP), Mujib Climate Prosperity Plan, Nationally Determined Contribution (NDC), National Plan for Disaster Management (NPDM, 2021 to 2025), Standing Order on Disaster -2019, 8th Five-Year Plan of Bangladesh, Delta Plan, Integrated Coastal Zone Management Plan, Southern Agricultural Master Plan, Agriculture Policy, Water Policy, Forest Policy, OECD Building Resilience Systems were reviewed and analyzed.

Primary information (qualitative and quantitative) was collected through **Participatory research using** Household Survey (HHS), Focus Group Discussion (FGD), and Key Informant Interview (KII).

The household survey sample was determined using Slovin's Sample Determination Formula with a 95% confidence level within the 5% margin error:

$$\mathbf{n = N/ (1+Ne^2)}$$

Where n is the sample size, N is the target population size, 183189 (BBS, 2011), and e =5% is the margin of error.

According to the formula mentioned above, the sample size of the household survey was 399. To maintain the proportionality with the individual union’s population size, the adjusted sample size was set at 402. According to the BBS, 2021, the percentage of persons with disabilities (2.8%), youth (33%), and minorities in Teknaf (6.03%), for the homogeneous distribution. However due to the absence of minorities, the study did not cover the minority respondents homogeneously in all three unions The study covered the Sex, Age, and Disability, and Minorities (Hindus, Buddhists, Christians) segregated 402 households from three unions that were selected randomly **(Table 2.1)**.

Table 2.1: The household survey sample

Respondent type	Hnila	Sabrang	Whykong
Adult (36-65)	54.0%	54.0%	61.1%
PWD	4.8%	4.0%	5.6%
Youth (18-35)	41.3%	42.1%	33.3%
Male	42.9%	27.0%	53.2%
Female	57.1%	73.0%	46.8%
Minorities	0.0%	0.8%	9.5%
Bangalees	100.0%	99.2%	90.5%

A total of 12 FGDs (4 in each union) were conducted with men, women, persons with disabilities, and market actors (input sellers and buyers) to understand the existing climate vulnerability, capacity, and resources to deal with shocks, capacity, and resource needs, access to services, access to market and finance, etc. A total of 16 KIIs were conducted from the local level to the national level (Table 2.2).

Table 2.2: List of KII

Stakeholders	KIIs at Local to National Levels
National: BRC Delegate, V2R Project Manager, Dept. of Disaster Management, Bangladesh Meteorological Department (BMD), BDRCS Disaster and Climate Change Department	5
Cox's Bazar: Dept. of Agriculture, Department of Livestock, Department of Forest, Department of Fisheries, Dept. of Women and Children Affairs, DRRO, Water Development Board, BDRCS (Cox's Bazar unit), SRDI, Local Government, BSCSIC	11

The study has attempted to understand the existing salinity level in water and soil in the coastal districts (Patuakhali, Barguna, and Cox's Bazar) to understand crop suitability and water availability. All available drinking water sources (pond, canal, river, PSF, RO) and soil from the homestead and agricultural land were covered for salinity measurement with georeference. Along with the soil and water sample collection, the study also collected social organizations' georeference using a GPS Logger from the study area.

2.3. Data Analysis

2.3.1. Multi-hazard risk assessment

This study developed a multi-hazard risk map for each union for the study area through (1) the collection of extreme event data through household surveys and the DDM reports over 30 years (1993-2023); (2) the identification of the most important effective factors (land use, land elevation, slope, water network, etc. through Remote Sensing and GIS; (3) Hazard modelling using a generalized linear model (GLM), a support vector machine (SVM) model, and a functional discriminant analysis (FDA) model and construction of multi-hazard risk maps (MHRM).

2.3.2. Local scenario generation through micro-climate downscaling and climate projection

The statistical downscaling methods are used to develop local climatic scenarios (temperature and precipitation) and the CMIP6 Max Planck Institute (MPI-M) Earth System Model MPI-M Earth System Model (ESM) version 1.2 (MPI-ESM1.2) high resolution (MPI-ESM1-2-HR ssp370) applied to predict daily average temperature, and rainfall for the period of 2020 to 2100.

2.3.3. Soil and surface and underground water quality measurement

Surface and groundwater and soil salinity of different sources from each union (pond, canal, river, homestead, agricultural land) were measured in **CPE Soil, Water and Environment Lab** as Electro Conductivity (EC) of water and soil solution (ECw) to understand the salinity level of surface and groundwater sources and homestead and agricultural land. A georeferenced source map was also produced for the sample location of the study area.

2.3.4. Cost-benefit analysis of Climate-smart Agriculture (CSA)

The cost-benefit analysis (CBA) for climate-smart agriculture (CSA) is measured using the following formula (Devinia et al., 2022):

$$NPV\ (B, C) = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

Where T represents the lifecycle of the adaptation practice, B represents the benefits, C represents the costs, and r is the applicable discount rate. In this study, we compared the changes in cost and benefits of the prioritized CSA practice.

2.3.5. GHG-smart CSA identification

The EX-Ante Carbon-balance Tool (EX-ACT), developed by the Intergovernmental Panel on Climate Change (IPCC) methodology for greenhouse gas (GHG) emissions inventories, would be used to measure the carbon-smart and nitrogen-smart CSA for the study area. It will provide a consistent way of estimating and tracking the outcomes of agricultural interventions on GHG emissions considering Agriculture, Forestry, and Other Land Use (AFOLU) inland and coastal wetlands, fisheries and aquaculture, farming inputs, and infrastructure.

2.3.6. Sustainable Livelihoods Assessment

The livelihoods assessment will consider enablers (social capital, physical capital, human capital, financial capital, natural capital, technological capital, etc.) Using a sustainable livelihood framework developed by DFID.

GIS and RS Mapping will help to organize the location-specific livelihood options, and the market actors, their functions, and backward & forward linkages.

2.3.7. Resilient Livelihoods final option identification

The resilience system for the study area (union-based) will be analyzed, followed by the OECD Resilience System Analysis. In HHS and FGD, land use, agriculture, livelihoods and food security, water allocation system, infrastructural development, economy, etc., were analyzed to develop climate-resilient livelihoods in each union.

The climate-resilient livelihood value chain analysis process will consider the following climate-resilient matrix for each intervention.

Table 2.3: Resilient Livelihood Matrix

Name of intervention	Climate change adaptation potentiality	Climate change mitigation potentiality	Less affected by climate extremes	Productivity	Cost-benefit ratio	Accessible for Women	Accessible for the person with a disability

CHAPTER THREE
POLICY LANDSCAPE IN BANGLADESH

3.1. Climate change and disaster policy landscape in Bangladesh

Bangladesh has made commendable efforts to streamline regulatory and institutional settings in realizing the aspiration of climate-resilient sustainable development by creating required policies and regulatory frameworks. Over the years, the Government has formulated the following policies, plans, and programs to address climate change and disaster management in the country:

- Bangladesh Climate Change Strategy and Action Plan (BCCSAP), 2009
- Nationally Determined Contributions (NDC), 2015, Enhanced & Updated in 2021
- NDC Implementation Road Map, 2018
- Bangladesh Delta Plan, 2100
- National Adaption Plan (NAP), 2022
- Mujib Climate Prosperity Plan 2030

There has been progress in formulating policies and strategies to address Bangladesh's climate change, disaster risks, and vulnerabilities. The Government has prepared the National Adaptation Programme of Action (NAPA) (2005), the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) (2009), the Disaster Management Act (2012), the National Disaster Management Policy (2015), the National Plan for Disaster Management (2021–2025), and the 8th Five-Year Plan (2021–2025), Delta Plan, among other policies and plans. The procedures and programs have recognized climate-induced problems like droughts, declining groundwater levels, land degradation, flooding, and riverbank erosion. BCCSAP 2009 is the fundamental strategy of Bangladesh to ensure the basic needs of the poorest and most climate-vulnerable population, including women and children, are protected from climate change impacts, taking into consideration their specific needs: food security, safe housing, employment, and access to essential services (BCCSAP, 2009). In BCCSAP, 2009 and National Plan for Disaster Management (NPDM) 2021-2025 the government identified investment priorities to reduce the climate and disaster impacts, including integrated early warning systems, the establishment of cyclone shelters and Killas, flood proofing, improved crops, and cropping systems, improved irrigation and water management (BCCSAP, 2009; NPDM, 2019). The Standing Order on Disaster Management (SOD-2019) also prioritizes proper control of cyclone shelters for the coastal belt to reduce loss and damage induced by cyclones through the active participation of Disaster Management Committees at different levels.

Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009 is a 10-year program (2009-2018) designed to build the capacity and resilience of the country to meet the challenge of climate change. The BCCSAP is designed as a 'living document' to continue implementing the nation's climate change adaptation and mitigation programs and deepen understanding of the phenomenon. The BCCSAP references adaptation, mitigation, research and development, capacity building, institutional development, mainstreaming, disaster management, and knowledge management (BCCSAP, 2009). BCCSAP is the only document that mainly addresses the issue of climate change and the Government's future potential strategy and actions. Still, it does not address the disability issue. However, persons with disabilities are the most vulnerable to the impact of climate change. Not only so, but also BCCSAP does not prioritize climate-induced displacement though this is one of the primary concerns for climate change all over the country.

The Bangladesh Delta Plan (BDP-2100), alongside the **8FYP** and **MUJIB CLIMATE PROSPERITY PLAN DECADE 2030,** also mentioned the importance of forests in the environmental balance and stated conserving forests but did not provide a detailed forest adaptation strategy for climate resilience and disasters (BDP, 2018; GoB, 2020; GoB, 2021). The **Bangladesh Climate Fiscal Framework 2020** has been developed as an updated version of the **Climate Fiscal Framework 2014** by the Finance Division with support from its **Inclusive Budgeting and Financing for Climate Resilience (IBFCR) Project,** which has prepared a **CIP-EFCC** which has a significant focus on forest conservation with reforestation program (BCFF, 2020).

Agriculture is the main livelihood option all over Bangladesh, but being nature-based, agriculture is the most vulnerable sector due to climate-induced disasters. The Agriculture Policy 2018 prioritized necessary support for the capacity building of women in promoting household food and nutrition security (National Agriculture Policy, 2018). Still, no specific measures for flood and salinity-tolerant crops and cropping patterns were identified to promote salinity and flood-affected areas. But in the 8th Five-Year Plan, GoB raised attention to shift to better management of the environmental and climate change risks by taking long-term investments in water management, farmers' protection against flooding in wet seasons, irrigation in dry seasons, supplementary irrigation even in wet seasons, protection against saline water intrusion in coastal areas, proper drainage both in wet and dry seasons, protection against river erosion, and safeguard measures against the water-related hazards (storm surge/cyclone) in the coastal belt. In the 8th Five-year Plan, GoB also embedded attention on introducing nanotechnology in agriculture to promote science-led agriculture technology systems for the development of drought, submergence, and saline-prone agriculture, considering adaptation to climate change, proper use of genetically modified technology in agriculture and promoting the adoption of modern agricultural practices in the dry land, wetland, hills and coastal areas including use of environmentally friendly green technologies (e.g., IPM, INM, AWD, etc.) and climate-smart/resilient technologies; introduce salinity, submergence, and other stress-tolerant varieties, especially in the Southern regions (Meisner & Ali, 2017). Though the Government is keen to promote climate-smart agricultural technologies, there is no attention to fostering nature-based solutions and indigenous varieties in climate-smart agriculture.

Forest Policy 2016 incorporated a country-wide tree-planting movement by encouraging women, youth, ethnic groups, and natural resource management NGOs to promote climate-resilient private tree growing. It also focused on strengthening the resilience of forest ecosystems and dependent communities to climate change. The Forest Policy, though, also focused on creating a 'coastal green belt' of thick mangroves and other suitable climate resilience species to reduce the vulnerability of coastal communities to the impact of climate change-induced disasters and newly accreted land (char) are handed over to the Forest Department for extensive coastal plantation with resilient climate species (National Forest Policy, 2016). However, none of the interventions was proposed for flood-vulnerable and riverbank erosion-prone communities. BDP 2018 also considered Nature-based land and water management practices focusing on creating a green belt, green coastal protection, and flood-resilient housing on the coast. It has proposed initiatives on climate-smart aquaculture technology, establishment and maintenance of wetland fish sanctuaries, development of adaptive livestock measures, and strengthening veterinary services systems for the livelihoods of climate-vulnerable people (BDP-2100, 2018). **Forest Investment Plan (FIP)** (2017-2022) has been developed to identify investment opportunities to increase forest cover, reduce deforestation and forest degradation, and improve the livelihoods of forest-dependent people by implementing participatory/social forestry. An updated **Forestry Master Plan (FMP)** has been developed from **2017** to **2036** after the completion of the previous FMP in 2015 to address the upcoming and ongoing challenges related to anthropogenic issues and climate change (MoEF, 2017). The Master Plan was updated to deal with the emerging environmental and socioeconomic challenges and capitalize on the opportunities thrown up by the emerging global consensus in dealing with environmental issues. The new FMP has been prepared as a part of the **Climate Resilient Participatory Afforestation and Reforestation Project (CRPARP)**, funded by the **Bangladesh Climate Change Resilience Fund (BCCRF)** (MoEF, 2017). However, the Green Belt for coastal resilience from challenging climatic conditions is mentioned along with community resilience through Institutional reforms and capacity building. Strengthening community participation and promotion of Public Private Partnerships for reforestation. Supporting monitoring, evaluation, and database facilities, but another solution, such as a nature-based solution, is not addressed in the latest Forest Master Plan (MoEF, 2017). **Reducing Emissions from Deforestation and Forest Degradation Plus** enhancing forest carbon stocks tackling rural poverty, and conserving biodiversity in developing countries—termed as **REDD+** since the Conference of Parties (COP) 15 are emerging as a central policy instrument to halt land-use related emissions from developing countries like Bangladesh (REDD+, 2015).

The Ministry of Water Resources of the Government of Bangladesh has made the **Coastal Zone Policy (CZPo) 2005** concerning development objectives of reduction of vulnerabilities, sustainable management of natural resources, empowerment of communities, women's development and gender equity, and conservation and enhancement of critical ecosystems (MoWR, 2005). This Policy provides general guidance so that coastal people can pursue their livelihoods under secured conditions in a sustainable manner without impairing the integrity of the natural environment (MoWR, 2005). This Policy directly includes all people in the reduction of vulnerabilities sections mentioning that 'it should include special measures for children, women, the disabled and the old' despite the scope in the other areas. However, it is unclear what special measures will be taken for all segments of society, including persons with disabilities, women, and children, to reduce their vulnerabilities and ensure their participation in the coastal development process. CZPo also prioritizes vulnerability reduction induced by disaster and climate change, but no direction was made regarding climate change adaptation and disaster risk reduction. The CZPo has mentioned promoting coastal forestry and maintenance of sea-dykes regarding disaster risk reduction and climate adaptation, but none of the activities were proposed to adapt to sea-level rise (MoWR, 2005). Though the Policy has ensured equitable distribution and access to resources for neglected and disadvantaged groups, there is no provision for fisher folk though 12% of the total population is involved with fishing (MoWR, 2005; p. 6; Ministry of Fisheries and Livestock, 2019. Volume 36: 135p). Likewise, the **Bangladesh Water Act 2013,** which was enacted by the Water Resources Planning Organization (WARPO) under the Ministry of Water Resources, mentioned salinity intrusion in the coastal area along with flood and adaptive measures of streets and roads as flood control embankments could be utilized (WARPO, 2013). However, the GoB does not mention any adaptation measures for climate-vulnerable areas. In coastal regions, tube wells with arsenic, iron, or salt removal units, desalination facilities for treating saline surface water, rainwater collection, and PSFs with raised and lined ponds are recommended in the **National Strategy for Water & Sanitation in Hard-to-Reach Areas of Bangladesh 2011** along with raising tube wells for saving water (GoB, 2011). Though **Bangladesh Climate Change Strategy and Action Plan 2009** mentioned climate change impacts through floods, cyclones, erratic rainfall, riverbank erosion, and sea level rise only said allocating drinking water with no other climate change adaptations (BCCSAP, 2009). The National Plan for Disaster Management (NPDM 2021-2025) places importance on disaster risk management linked with rapid urbanization and climate change, and the necessity of DRR for sustainable development, and is flexible and adaptive in cognizance of the changing nature of risks (NPDM, 2020). **The Mujib Climate Prosperity Plan Decade 2030** includes national disaster risk financing and management to safeguard food and water security by adapting food supply chains to climate change (GoB, 2021). Water resilience in Bangladesh needs to be integrated and resilient water resources management to ensure continuity of water supply and to provide safe and secure water mentioned in both The Mujib Climate Prosperity Plan and **Eight Five-year plan** (GoB, 2020; GoB, 2021). **The National Adaptation Plan of Bangladesh (2023-2050)** addressed climate change adaptation, ensuring the quality of polder construction, green belt development, creating co-management committees and making existing water management groups functional, coordination with disaster management committees, community-based rainwater harvesting or freshwater pond management, tidal river management to manage tidal floods and sediment, elevated houses for flood resilience, development of retaining walls around villages (NAP, 2022). Bangladesh formulated the **National Adaptation Plan, 2022,** in its adaptation endeavors. Bangladesh has prepared NAP to reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience and to facilitate the integration of climate change adaptation into relevant new and existing policies, programs, and activities in a coherent manner, in particular, development planning processes and strategies, within all relevant sectors and at different levels, as appropriate. Bangladesh is also in the process of updating the BCCSAP.

Fisheries stand as one of Bangladesh's most prolific and dynamic sectors. In rural areas, it ranks as the second largest source of employment. In the fiscal year 2018–2019, Bangladesh achieved a total production of 4.27 million MT, with aquaculture alone contributing more than half of this output (56.24%). Currently, the fisheries sector accounts for 3.57% of Bangladesh's GDP, constituting approximately one-fourth (25.30%) of the agricultural GDP and 1.39% of the overall export earnings. Notably, in the realm of inland open-water production, Bangladesh secured the 3rd position during 2017–2018. Additionally, the nation secured the 5th spot globally for aquaculture production **(Shamsuzzaman et al., 2022). The National Fisheries Strategy 2006** highlights sustainable growth and income diversification to prevent the negative impacts of seasonal fishing restrictions. The **National Shrimp Policy 2014** focuses on environmental balance, nutrition, and export market expansion. Shrimp is one of the most important exportable merchandise in Bangladesh. Shrimp production increased to 2.54 Lack MT in 2017-18 from less than one lac MT in 2001-02. Challenges include the depletion of natural resources due to urbanization, infrastructure, and pollution. Marine fisheries have experienced a decline in share, while inland capture fisheries face threats from over-fishing, destructive practices, and pollution. The inland capture fisheries are continuously shrinking mainly because of over-fishing, use of destructive gears, silting up of water bodies, closure of natural fish passes, non-fishers' control of the ‘Jolmohal’ by malpractices in lease and by encroachment; and pollution of water bodies by agro-chemicals, industrial wastes, and urban sewers, etc. Marine fisheries are experiencing a decline in their share in total fish production – shrinking from almost 18% in 2009-10 **(8thFYP, 2020).** Livelihoods are severely affected by climatic and non-climatic changes in Teknaf. Increased salinity of both soil and water has seriously affected all livelihood resources, in particular agriculture, fishery, livestock, and forestry. Natural and several anthropogenic factors remain the major form of vulnerability for the farmers and fishers of the society **(Khanam, 2017).**

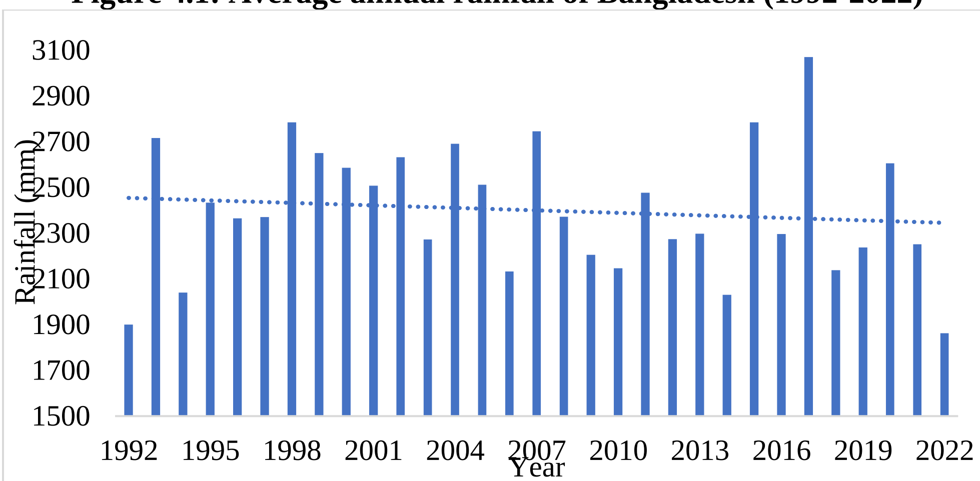
Livestock stands as one of the rapidly growing sectors in Bangladesh, making a noteworthy contribution of approximately 2% (1.90%) to the nation's GDP and over 16% (16.52%) to the agricultural sector during FY 2021-22. The livestock count exceeded 43 crores in the same fiscal year. Notably, the livestock sector's GDP contribution has exhibited a consistent annual growth of 5.39% over the past five years, as reported by the **Department of Livestock Services (DLS).** This sector bears significance as it directly supports around 20% of the population and indirectly impacts the livelihoods of 50% of the people. Noteworthy production figures for FY 2021-22 include approximately 131 (130.74) lakh metric tons of milk, around 93 (92.65) lakh metric tons of meat, and an impressive 2335 million eggs **(Hossan, 2023).** Livestock plays a multifaceted role in Bangladesh's economy, directly contributing about 3% to the agricultural GDP and offering employment opportunities to 15% of the workforce. The country possesses a high cattle density of 145 large ruminants per square kilometer, although many stem from a genetically disadvantaged base **(MoFL, 2007).** The **Livestock Policy and Action Plan of 2005** and the **National Livestock Development Policy (2007)** focus on enhancing productivity in milk, meat, and egg production while prioritizing small and marginalized farmers, encouraging private sector involvement, and bolstering market development. These policies underscore the importance of livestock as a traditional source of rural employment, particularly beneficial in areas with limited income options. The role of dairy animals in enhancing household food security for low-income groups is also recognized within the National Livestock Development Policy. Notably, 10 key areas have been identified to shape the National Livestock Development Policy **(MoFL, 2007; DLS, 2005).** The **National Livestock Extension Policy (NLEP)** of 2013 aligns with broader goals of eliminating hunger, addressing food security, and combating malnutrition. This policy encompasses various facets such as livestock services, breed conservation, artificial insemination, feed development, extension services, vaccine production, training, and disease diagnosis **(Mia, 2013).** The National **Integrated Livestock Manure Management (ILMM)** Policy of 2015 reflects Bangladesh's commitment to addressing Short-Lived Climate Pollutants (SLCPs), particularly those emanating from livestock manure. Recognizing barriers such as knowledge gaps and policy absence, this policy aligns with international efforts to achieve Sustainable Development Goals by promoting integrated approaches and sustainable practices **(MoFL, 2015).** However, challenges persist, as indicated by the experiences of Cox’s Bazar livestock farmers in 2021, where 44% reported significant losses and 21% partial losses **(FAO, 2021).** Animal diseases remain a prominent constraint to livestock development, with their prevalence accounting for half of all livestock deaths. Furthermore, issues like lack of organized markets, accessibility to high-quality animal breeds, and limited technological know-how pose challenges for smallholders in Bangladesh **(Ali & Hossain, 2022).**

CHAPTER FOUR
STUDY FINDINGS

4.1. Climatic Scenario in Bangladesh

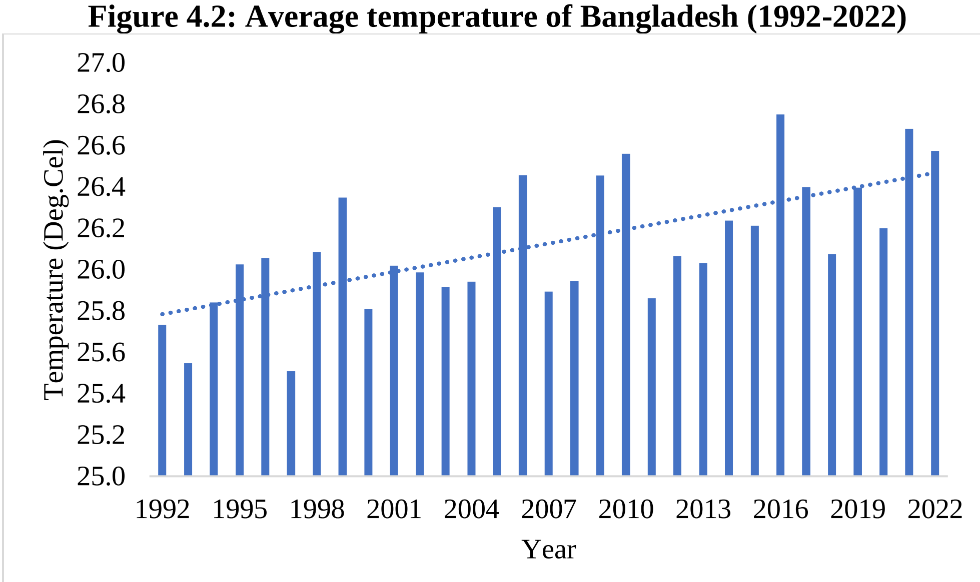
Several studies have noted that average temperatures have been increasing and annual total rainfall has been decreasing in Bangladesh. According to thirty years of climatic parameter data from the Bangladesh Meteorological Department, the annual rainfall is following a decreasing trend of 3.64 mm/year **(Figure 4.1),** and the average temperature is increasing by 0.0228 °C/year **(Figure 4.2).** According to Figure 4.3, annual wind speed is also increasing all over Bangladesh. The increasing rate is 0.0279 m/s per year.

Figure 4.1: Average annual rainfall of Bangladesh (1992-2022)



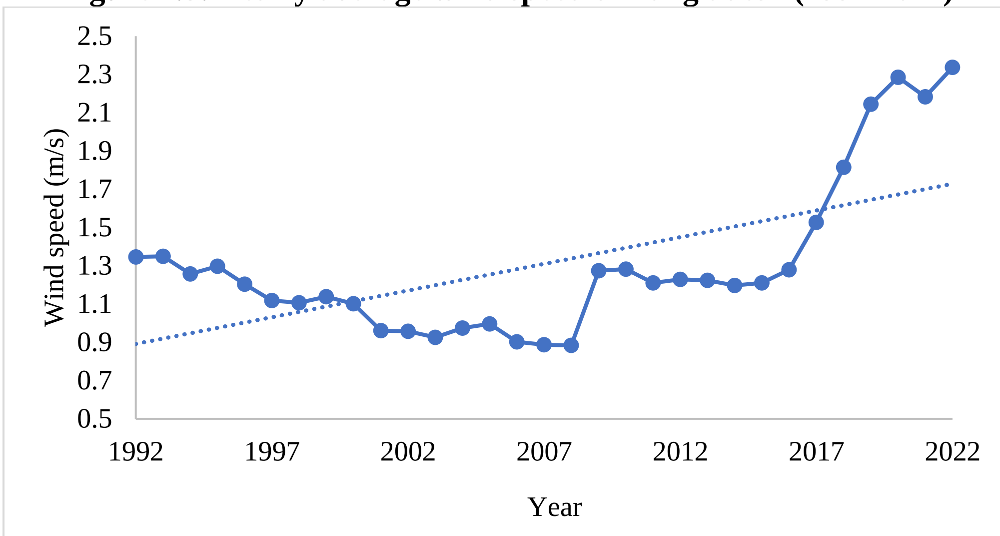
Source: BMD, 2023

Figure 4.2: Average temperature of Bangladesh (1992-2022)



Source: BMD, 2023

Figure 4.3: Yearly average wind speed of Bangladesh (1992-2022)



Source: BMD, 2023

4.2. Climatic scenario in the study area

Based on an analysis of yearly average temperature patterns in Teknaf **(Figures 4.4, 4.5, and 4.6)**, the trend of rainfall showed a decreasing trend. On the other hand, the temperature shows an increasing trend, and the wind speed scenario shows a decreasing trend. The dashed blue line is the linear climate change trend. The trend line is going up from left to right, the temperature trend is positive, and it is getting warmer in Teknāf due to climate change. In the lower part, the graph shows the so-called warming stripes. Each colored stripe represents the average temperature for a year - blue for colder and red for warmer years. Starting from the year 2000, these warming stripes begin with a warm month and gradually transition to consistently warmer temperatures over time.

Figure 4.4.: Yearly Temperature Change in Teknaf

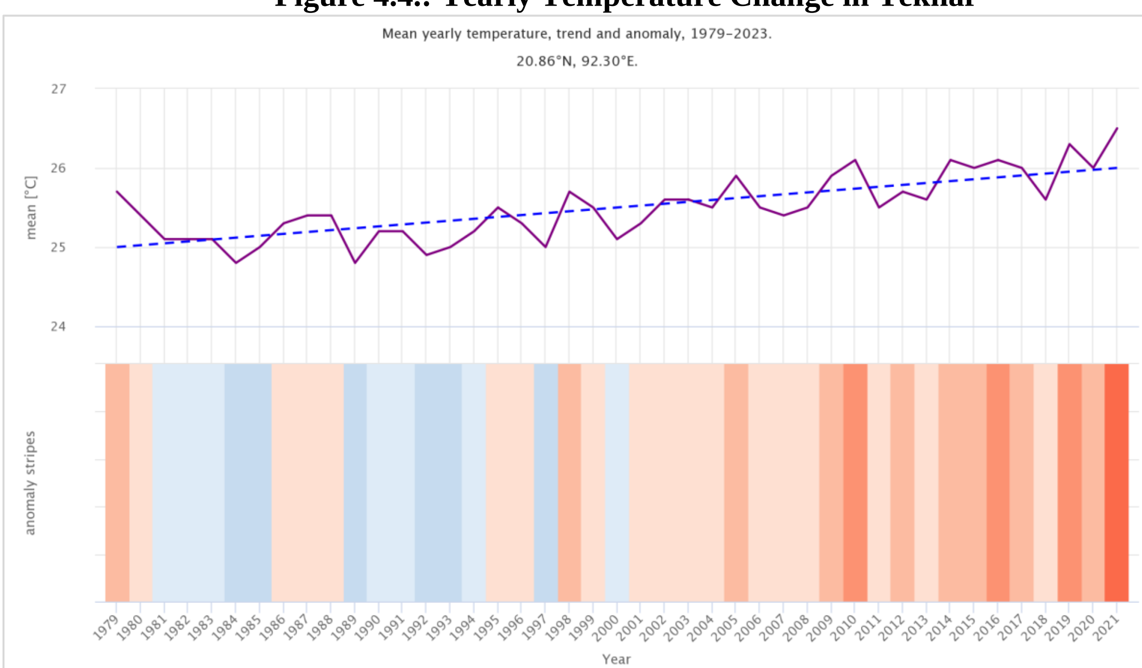
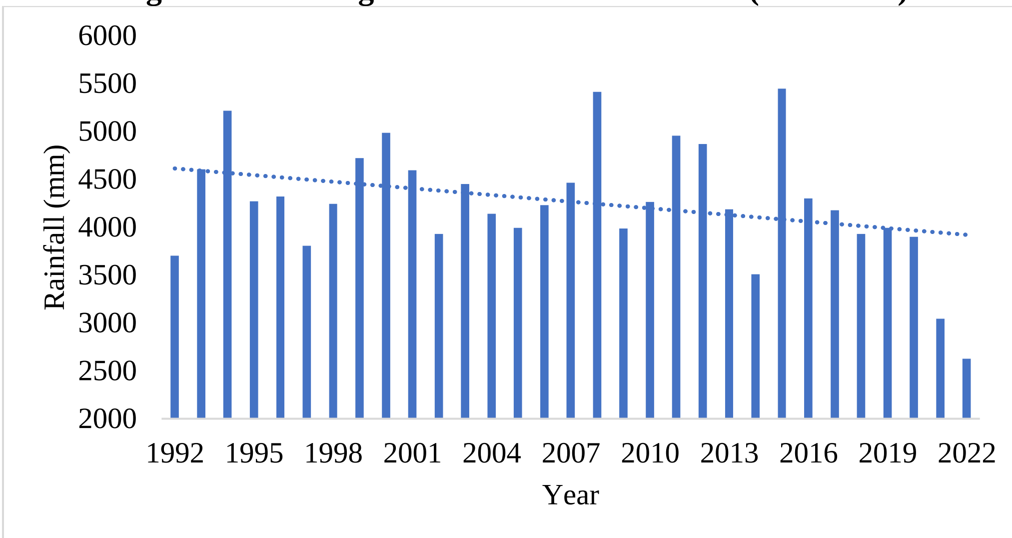


Figure 4.5: Average annual rainfall of Teknaf (1992-2022)

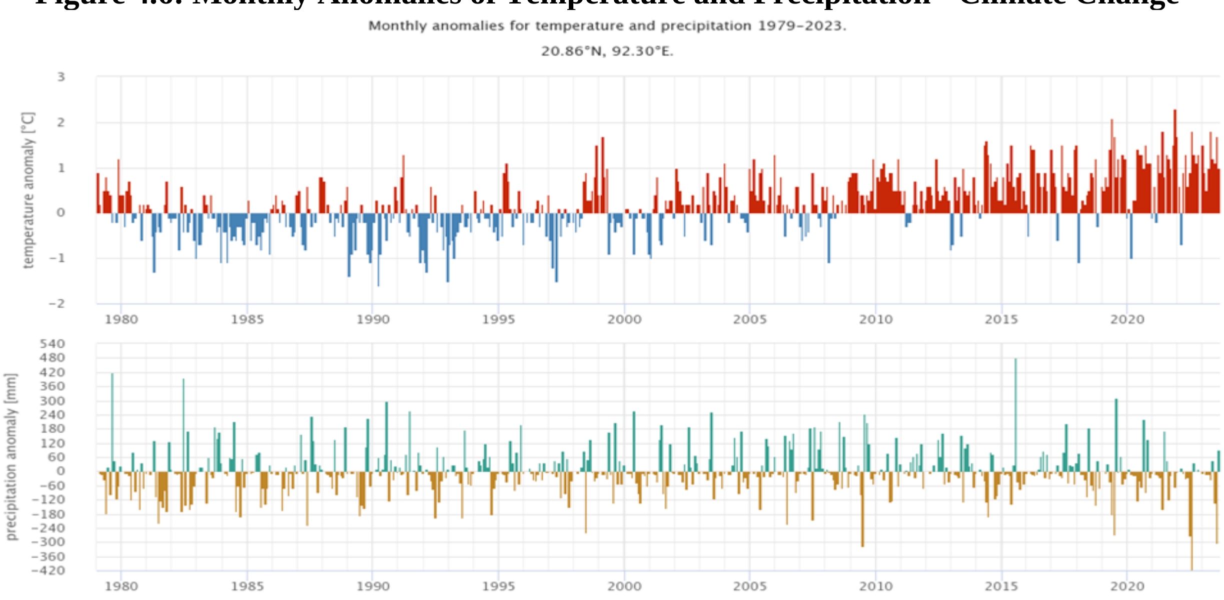


Source: BMD, 2023

The monthly anomaly graph illustrates temperature anomalies for each month from 1979 until the present day. These anomalies indicate deviations from the 30-year climate mean, with red months signifying warmer periods and blue months indicating colder ones compared to the norm. The graph reveals a noticeable increase in the frequency of warmer months over the years, indicative of the global warming associated with climate change.

Similarly, the lower graph displays precipitation anomalies for each month from 1979 to the present. These anomalies indicate whether a given month had more or less precipitation than the 30-year climate mean. It is evident from the data that recent years have seen a predominance of drier months, signifying a shift towards reduced precipitation.

Figure 4.6: Monthly Anomalies of Temperature and Precipitation - Climate Change



4.3. Climate and disaster vulnerability in the study area

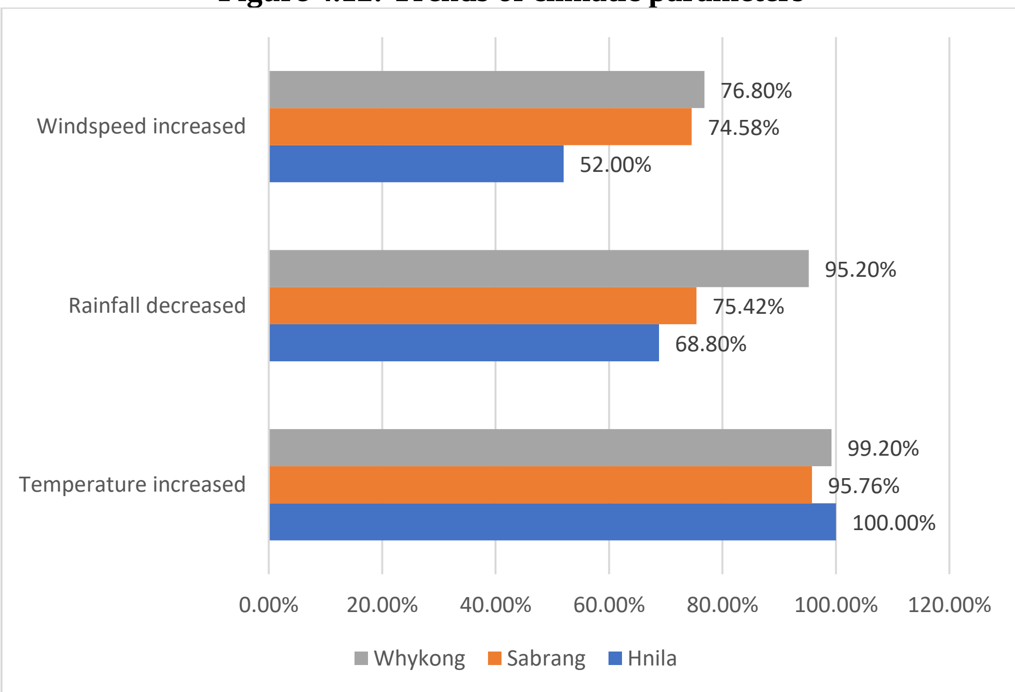
4.3.1. Climate vulnerability

Based on the respondent's perception, the study reveals that trends of temperature are increasing in all three unions, but the rainfall is decreasing **(Table 4.1)**. On the other hand, the respondents of Hnila mentioned the wind speed is usual whereas the respondents of Sabrang and Whykong mentioned the trend of wind speed is increasing. The Director of BMD reported that though the rainfall is decreasing, heavy rainy days are increasing. This scenario was also found by the citation of FGD participants in all three unions. The FGD participants of Sabrang and Hnila also reported that in the monsoon rain is absent but in pre-monsoon and post-monsoon rain is increasing in their locality.

Table 4.1: Trends of climatic parameters

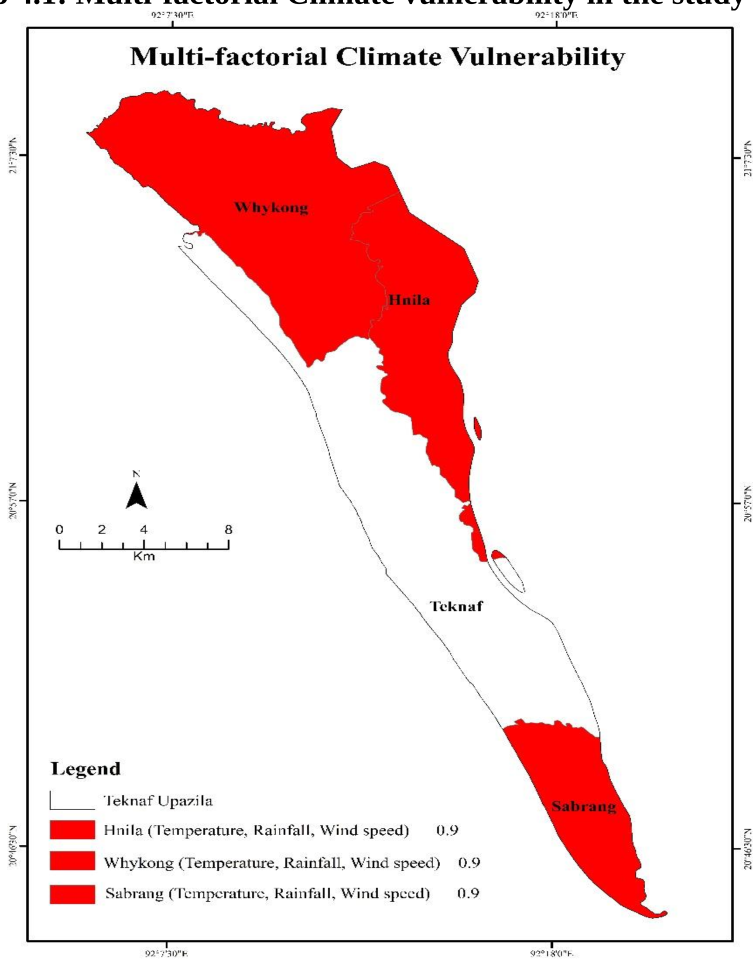
Name of the Union	Temperature	Rainfall	Wind Speed
Hnila	+	-	~
Sabrang	+	-	+
Whykong	+	-	+

Figure 4.12: Trends of climatic parameters



Using Artificial Intelligence (AI), considering local climate scenarios and future trends of climatic parameters, the visualization of the geospatial multi-factorial (Temperature, rainfall, wind speed) climate vulnerability of the study area shows that all three unions are highly vulnerable to rising temperature, decreasing rainfall, and increasing wind speed (Map 4.1).

Map 4.1: Multi-factorial Climate vulnerability in the study area



4.3.2. Disaster vulnerability

The Cox's Bazar district including the study area is exposed to climate-induced disasters including cyclones, storm surges, agricultural drought, and salinity intrusion. A range of disaster effects on households is revealed by the data presented (Table 4.2). Although just 115 homes have been impacted, the drought is noteworthy due to its protracted and wide-ranging effects on agricultural and water supplies. Floods, which have displaced 49,103 households and caused property damage, demonstrate its destructive power. 73,976 households were affected, demonstrating the significant impact of storms, and highlighting the importance of being prepared. Hailstorms caused damage to 11,141 households in Cox's Bazar. Hydrometeorological vulnerabilities are highlighted by waterlogging, storm surges, and erosion (which respectively affect 6,957, 449, and 944 households). Meanwhile, the effect of salinity is seen on 1503 households.

Table 4.2: Disaster-affected households in Cox's Bazar (2015-2020)

Name of disaster	Number of the affected household
Agricultural drought	115
Flood	49103
Water Logging	6957
Cyclone	73976

Storm and tidal Surge	449
Thunderstorm and Lightning	295
River and coastal Erosion	944
Salinity	1503
Hailstorm	11141

Source: Bangladesh Disaster Related Statistics (BDRS), 2021.

The DRRO of Cox's Bazar reported that landslide is one of the major disasters in Cox's Bazar. In the last decade, a huge death toll occurred due to the landslides in Cox's Bazar as well as in the Chottogram division. It has been observed that in the year 2021, death casualties (72), number of injuries (10), and number of shelters damaged (5000) due to landslides in Cox's Bazar was the highest than any other year from 2010-2022 **(Table 4.3).**

Table 4.3: Death casualties and injury due to landslide in Cox's Bazar

Type of Casualty	Death	Injured	Shelter damage
2010[1]	54	0	0
2011[2]	0	0	0
2012[3]	0	0	0
2013[4]	0	0	0
2014[5]	0	0	0
2015[6]	13	7	4
2016[7]	0	0	0
2017[8]	6	4	0
2018[9]	11	4	0
2019[10]	12	0	0
2020[11]	2	0	0
2021[12]	72	10	5000
2022[13]	5	0	4
Total	**175**	**25**	**5008**

[1] UNB, 2018
[2] NIRAPAD, 2015
[3] NIRAPAD, 2017
[4] The Daily Star, 2018b
[5] NIRAPAD, 2015
[6] NIRAPAD, 2015
[7] NIRAPAD, 2017
[8] NIRAPAD, 2017
[9]; The Daily Star, 2018a;
[10] reliefweb, 2019
[11] dailysun, 2020
[12] NIRAPAD, 2021; NEWAGE BANGLADESH, 2021
[13] ProthomaloEnglish, 2022; Kamal et al., 2022, ISCG, 2022; Prothomalo, 2022; reliefweb, 2022

T**able 4.4** shows the various disaster and their occurrences in Hnila, Sabrang, and Whykong unions. According to the perception of respondents, flood, thunderstorm, and tornado occurrences have not changed in the three unions. But cyclones, heatwaves, seashore breaks, and agricultural drought occurrences have increased. Cold waves have significantly decreased.

Table 4.4: Trends of disaster

Name of Disaster	Hnila	Sabrang	Whykong
Flood	~	~	~
Flash Flood	+	~	+
Riverbank Erosion	~	+	~
Cyclone	+	+	+
Tidal inundation	-	+	+
Heatwave	+	+	+
Cold wave	-	-	-
Thunderstorm	~	~	~
Seashore break		+	
Tornado	~	~	~
Agricultural Drought	+	+	+
Salinity	+	~	+
Landslide	+	~	~
Waterlogging	+	+	~

From **Table 4.5** it is observed that in the Hnila, the flood occurrence frequency of 0.3 for each respondent in the last five years which is low, flash flood occurrence frequency of 0.8 which is moderate, water logging frequency is 0.9 which is relatively high, and agricultural drought is 0.8 which is a relatively frequent occurrence. In the Sabrang union, flood and erosion occur with a frequency of 0.4 which is low, water logging frequency is 1.4 which is very high and agricultural drought occurs with a frequency of 1.7 which is relatively frequent. In Whykong union, flood and flash floods occur with frequencies 1.2 and 1.6 which means they frequently occur, erosion 0.6 is moderate.

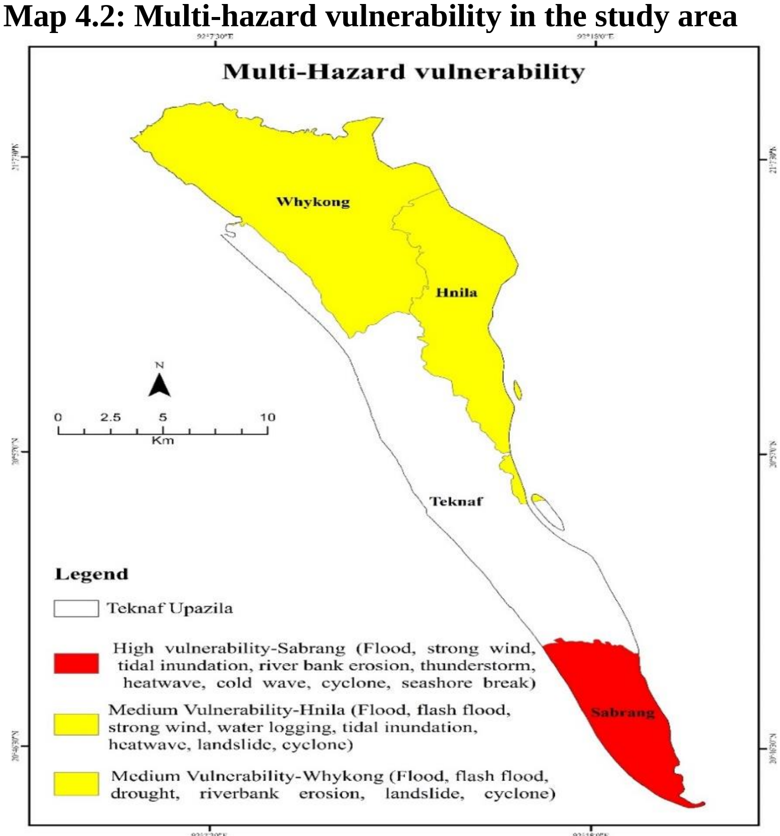
Table 4.5: Frequency of disaster occurrences in the last five year

Disaster name	Hnila	Sabrang	Whykong
Flood	0.3	0.4	1.2
Flash Flood	0.8	0.3	1.6
Erosion	N/A	0.4	0.6
Water logging	0.9	1.4	0.1
Agricultural drought	0.8	1.7	0.2
Heavy rain	N/A	N/A	N/A
Hailstorm	N/A	N/A	N/A
Tornado	N/A	N/A	N/A

Thunderstorm	N/A	0.5	N/A
Heatwave	1.5	2.2	0.2
Cold wave	N/A	0.3	N/A
Cyclone	2.6	4.5	1.8
Tidal inundation	N/A	0.5	N/A
Salinity Intrusion	0.2	0.2	N/A
Landslide	1.3	N/A	N/A
Seashore break	N/A	0.8	N/A

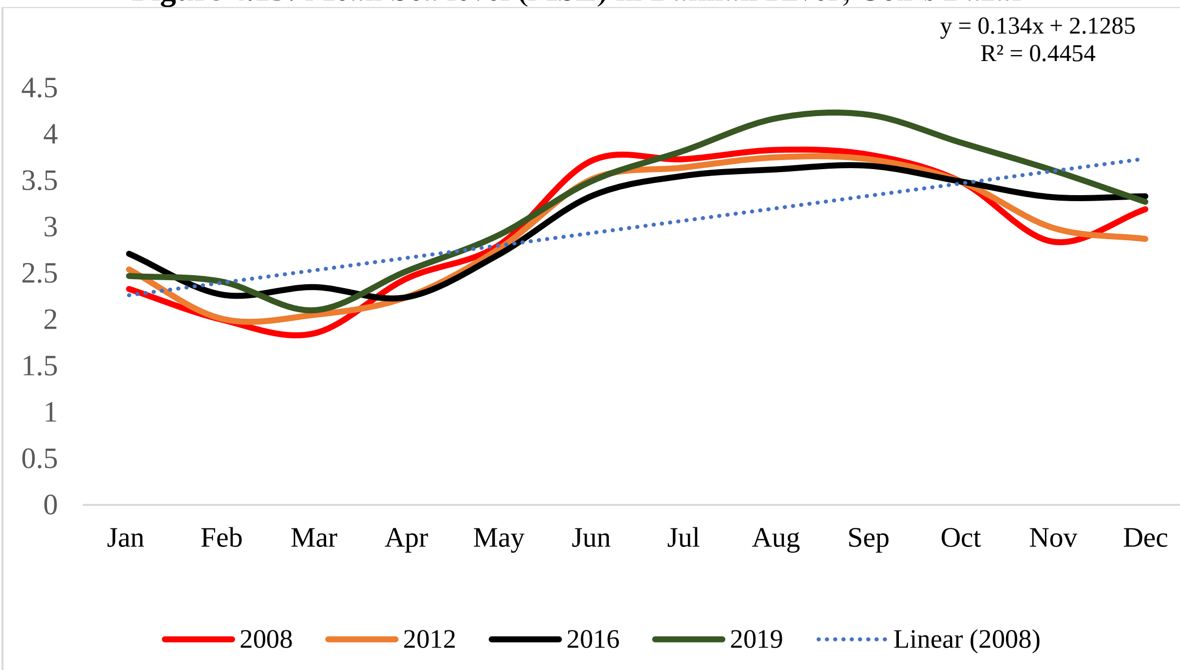
Based on the Multi-hazard vulnerability considering floods, strong wind, tidal inundation, riverbank erosion, thunderstorm, heat wave, cold wave, cyclones, and seashores in the study area **(Map 4.2)**; the Sabrang union is highly disaster vulnerable due to floods, strong wind, tidal inundation, riverbank erosion, thunderstorm, heat wave, cold wave, cyclones, and seashores. On the contrary Hnila, and Whykong are medium vulnerable due to floods, flash floods, landslides, cyclones, tidal inundation, etc. In Hnila Union water logging is a common scenario due to heavy rainfall and inundation from the Naf River. In this union canal mouths are closed by Naf River accretion resulting in water logging. In the Whykong Union in the summer season streams are dried out and this creates seasonal drought. The FGD participants of Sabrang reported that waterlogging is increasing in this union due to maladaptation practices. They have reported unplanned road construction from Teknaf to Sabrang without a proper outlet, unplanned marine drive without a proper outlet and Sabrang Eco Park is responsible for waterlogging.

Map 4.2: Multi-hazard vulnerability in the study area



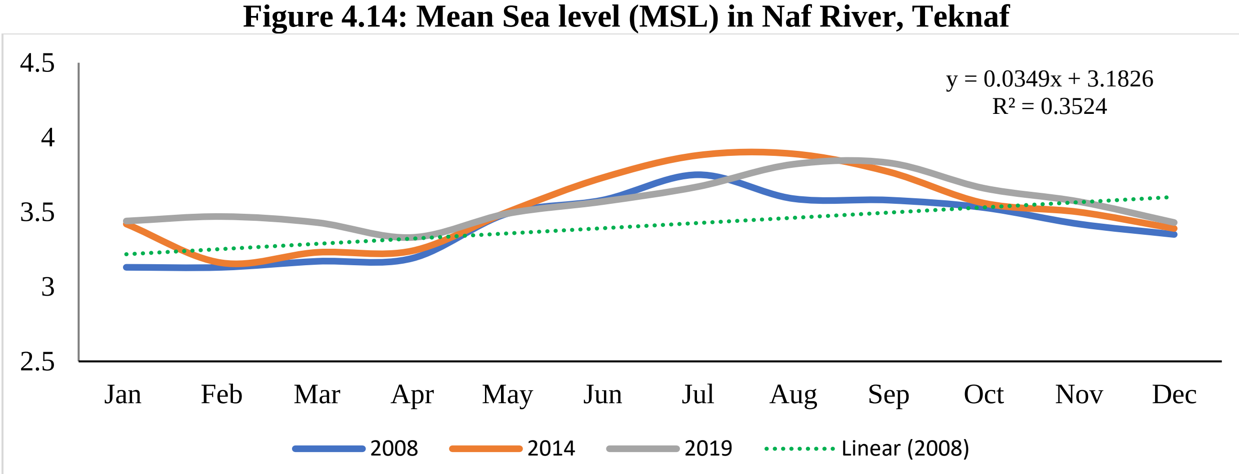
The Mean Sea Level (MSL) increasing trend was found along Cox's Bazar coast by analyzing MSL data from 2008 to 2019 from the Naf River and Bakkhali Point. The Mean Sea Level (MSL) of the Bakkhali point was found as an increasing trend with a rate of 0.134 mm per year ***(*Figure 4.13)** and at the Naf River point, the increasing trend was found to of 0.1771 mm per year for Teknaf *(***Figure 4.14).**

Figure 4.13: Mean Sea level (MSL) in Bakhali River, Cox's Bazar



Source: BIWTA, 2023

Figure 4.14: Mean Sea level (MSL) in Naf River, Teknaf



Source: BIWTA, 2023

With an average storm surge of 5.5 meters, Cyclone Mahasen in 2013 had the greatest average storm surge ever seen. Both Cyclones Bulbul (2019) and Amphan (2020) had substantial storm surges, with average storm surges of 4 meters for each. On the low end, Cyclone Jawad in 2021 had an average storm surge of 0.75 meters, which was closely followed by Cyclone Komen in

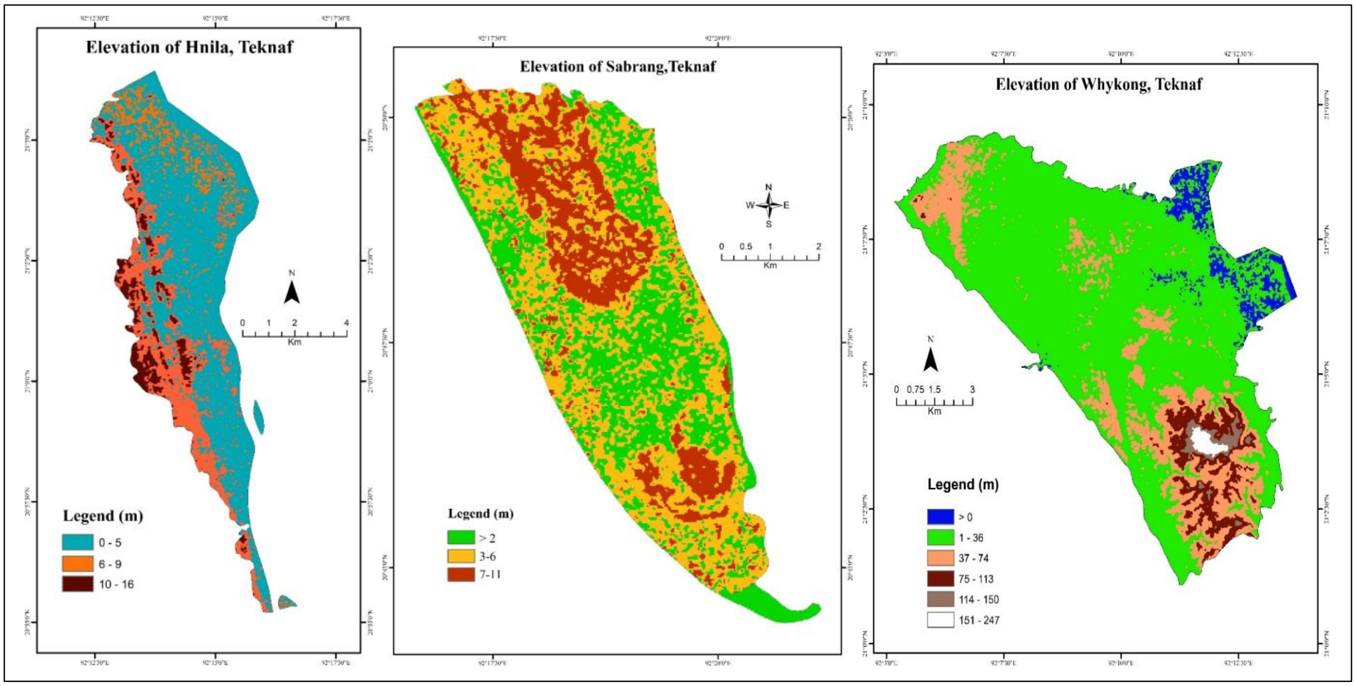
2015, which had the lowest average storm surge of 0.9 meters. Compared to tropical cyclones, these had considerably less severe storm surges. Average storm surges from Cyclones Roanu, Mora, Fani, and Yaas ranged from 1.35 to 3.25 meters, showing a moderate impact on coastal locations.

Table 4.6: Impacted storm surge in the study area (2013-2022)

Cyclone	Storm surge (meter)	Average storm surge (meter)
2013- Cyclone Mahasen	5 – 6	5.5
2015- Cyclone Komen	0.3 – 1.5	0.9
2016- Cyclone Roanu	1.7 – 2.7	2.2
2017- Cyclone Mora	3 – 3.5	3.25
2019- Cyclone Fani	1.2 – 1.5	1.35
2019- Cyclone Bulbul	3.5 – 4.5	4
2020- Cyclone Amphan	3 – 5	4
2021- Cyclone Jawad	0.5 – 1	0.75
2021- Cyclone Yaas	1.8 - 2.2	2
2022- Cyclone Sitrang	2 - 3	2.5

In the Teknaf districts, using the Digital Elevation Model (DEM), the highest elevation is found in the Whykong union. The highest elevation is 247 meters from the mean sea level in Whykong Union as it is a hilly area. Most of this union has an elevation of 1-36 meters. The southeastern part of this union is found to be a highly elevated area. The north-central part of the Sabrang union also lies within the 7-11-meter elevation. Considering the elevation of this union which is below 2 meters on the coastal side and the height of storm surges; it is more exposed to storm surges and land erosion. The maximum elevation of the Hnila union is 10-16 meters, which is only seen in some small areas, most of this union has an elevation of 0-5 meters. The eastern side of Dakhin Hnila, Noapara is less than 6 meters. The elevation of the eastern part of Teknaf Highway Road is less than 6 meters which indicates these areas are comparatively highly vulnerable to inundation **(Map 4.3).**

Map 4.3.: Elevation of Hnila, Sabrang, and Whykong union



Source: DEM, 2023

4.4. Impact of climate change and disaster in the study area

Climate change and disasters also have an impact on socio-economic and livelihood activities in the study area. Based on respondents' perceptions, a Composite Vulnerability Matrix was developed by normalizing the participants' responses; the study identified different vulnerable occupational groups and found that fishermen of unions are highly vulnerable **(Table 4.7)**. The disaster caused by climate change mostly affects the farmers of Whykong and Sabrang. In Sabrang, the people who depend on boat hawking for their livelihoods are also highly vulnerable. In all three unions, day laborers are highly vulnerable which was noted by the matrix. The FGD participants of all three unions reported that fishermen and day laborers are the most susceptible groups. The fishermen of Sabrang mentioned that their fishing days have reduced, and the death toll increased due to climatic extremes. Islam et al. (2021) also reported a similar argument and said that extreme weather and climatic events reduced fishing days every year. The day laborers reported that most of them were engaged in fish processing, carrying, and agricultural labor. But both livelihood activities are shrinking day by day. The day laborers who are involved with the construction are facing trouble working the whole day during the summer. The farmers from all three unions reported that because of the lack of irrigation and salinity, winter and summer crops are more vulnerable than monsoon (Kharif II). In terms of livestock and poultry, they also reported that ducks and hens are more vulnerable than cattle, ship, and goats. But in the livestock sector, sheep is comparatively low vulnerable than cattle and goat because sheep can tolerate heat, and cold. The occupational **Vulnerability Index** was developed by normalizing respondents' perception values with high, medium, and low vulnerability. A Composite Vulnerability Index Matrix was developed based on respondents' perceptions by normalizing the participants' responses. Farmers of the Hnila are less vulnerable than the other two unions because salinity intrusion and tidal inundation are lower than the other two unions which was mentioned by the farmers in the FGD.

Table 4.7: Occupational Vulnerability Index

Occupation	**Hnila**	**Sabrang**	**Whykong**
Fishermen			
Farmer			
Small trader			
Boatman			
Day labor			

Index	
Low	0-33%
Medium	34-65%
High	66-100%

Figure 4.15 represents the comparison of the impact of the disasters' increasing trend in previous and present times on Hnila, Sabrang, and Whykong Union's people. In the Hnila union, most of the people respond that the impact of climate change is increasing (98.41%), in Sabrang the response is close to Hnila (94.44%) and in Whykong there is a relatively lower (53.17%) response containing that they face climate change impact more than previous. In Whykong a significant number of people (46.83%) responded that they do not face climate change impact more than previously. FGD participant Roikhong reported that because of that existing high elevation, usually they do not face inundation, cyclones, and waterlogging. But water crises during dry periods made them vulnerable to livelihoods and sometimes flash floods washed away livelihoods' assets. The participants also mentioned that they are highly vulnerable to earthquakes. For example, the earthquake of February 2023 caused havoc in that community. **Figure 4.16** also represents how much additional stress on daily life is exerted by the increased impact of the disaster on the people of Hnila, Sabrang, and Whykong. Of the 77.8% of respondents of Sabrang reported that the increased impact of the disaster has increased food costs while Whykong (51.59%) and Hnila (51%) are comparatively lower than Sabrang. Reduced intake of food also significantly affects Sabrang's people (72.22%), Hnila (58.73%), and Whykong (45.24%). Increasing health costs also create effective stress on people which is in Hnila the highest percentage of respondents (61.11%), in Sabrang (57.94%), and in Whykong (40.48%) face the higher impact. Increasing drinking water costs and housing costs have more impact on creating stress. The FGD participants from all three unions mentioned that they live in their own houses but due to cyclones and increased wind, they need to repair almost each year. They also reported that raw materials (bamboo, timber, straws, etc.) are not sufficient in their locality. They need to collect these materials from outside at a high cost.

Figure 4.15: Increasing disaster impact in the present time in comparison to the previous time

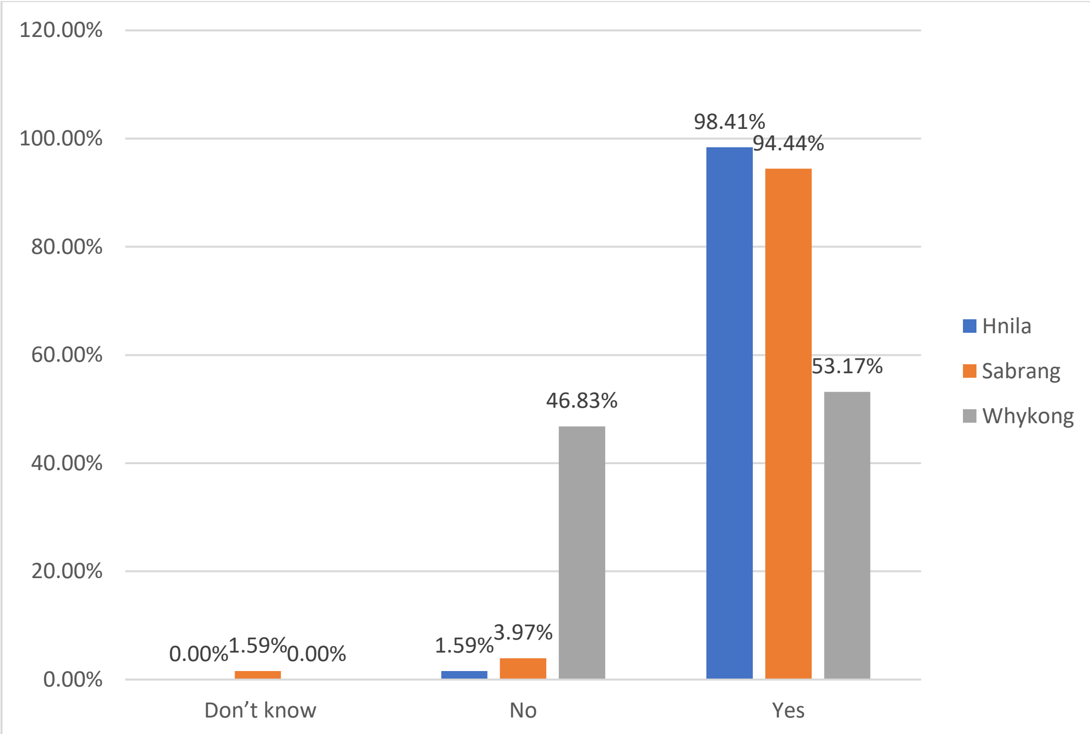
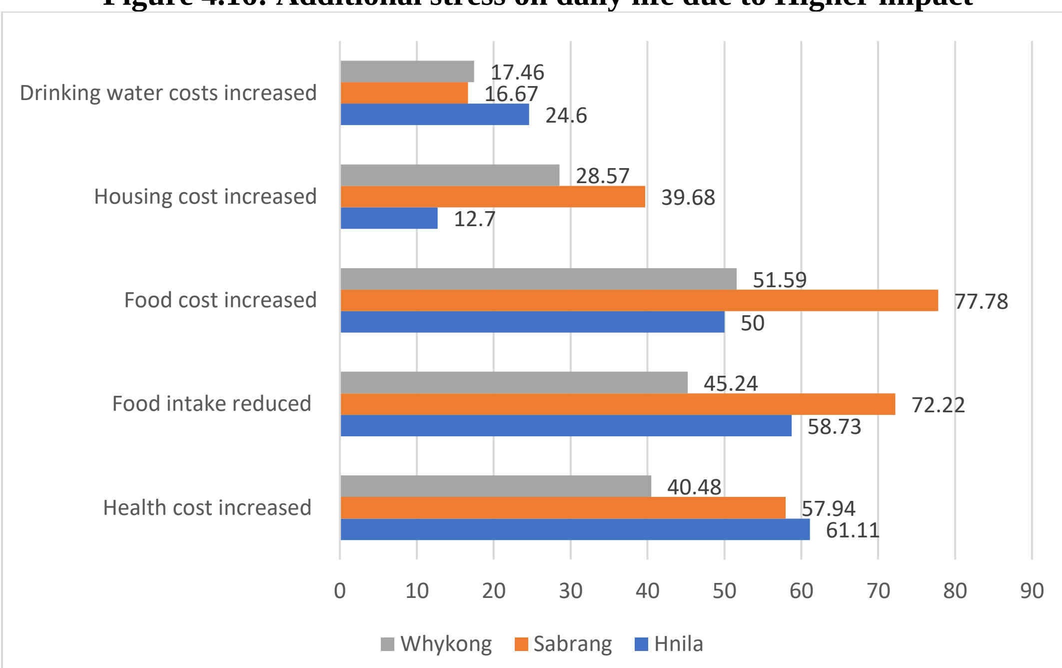


Figure 4.16: Additional stress on daily life due to Higher impact



4.5. Impact of climate change on agriculture, food security, and livelihoods

The study also demonstrates climate-induced calamities, including heatwaves, groundwater depletion, salinity, waterlogging, and heavy rainfall severely damaged agriculture, homestead farming, livestock, poultry, etc. **Table 4.8** shows that climate-induced hazards such as salinity, heavy rains, water logging, and land erosion are the root causes of the destruction of agriculture and livelihood opportunities. Most of the FGD participants pointed to this issue, highlighting the damaging effects of salinity during summer and winter on cropland and homestead farming. On the contrary, informants also explained that crop production during summer is challenged due to a lack of irrigation caused by groundwater depletion and surface and groundwater salinity in the study area. Some of the participants also explained agricultural drought and increasing trends of dry days are responsible for the water crisis and reduced agricultural production. They also reported that dry days have increased gradually in the last couple of years. A yearly number of dry days information from the Bangladesh Meteorological Department supports this statement and shows that there were 134 days dry days in 2013 which increased to 242 days in 2022 (BMD, 2023). Rohingya influx is highly responsible for groundwater depletion which was cited by the FGD participants of Hnila and Whykong. They also added that the surface water problem was crucial during the dry period before the Rohingya influx but now the groundwater crisis has threatened water supply for domestic use, livestock, and agriculture. The Department of Public Health Engineering reported their Emergency Multi-sector Rohingya Crisis Response Project (GoB-WB) that 5700 tubewells in the Rohingya response area are under operation as excessive withdrawals of water from 600-880 ft which is causing environmental degradation in Cox's Bazar district (DPHE, 2023). Salinity also damaged the availability of fodder which restricts livestock rearing. Also, heat waves increased the death toll of livestock and poultry. The FGD participants of farmers, day laborers, and elderly people cited that during hot days they cannot work in the field for a long time. The salt farmers also mentioned that untimely rainfall, cold waves, heavy fog, and untimely tidal inundation are threats to salt production. Usually, October-April is the salt production period. In 2021-22 during this period heat waves swept throughout the country and there was no cold wave, rainfall, or cyclone. As a result, in 2021-22 Bangladesh's salt production hit 62 years high which was 18.39 lac tons but in 2016-17 it was only 9.71 lac tons (BCSIC, 2023). Abdul Goni, a salt farmer from Sabrang reported that generally, they can produce 400 kg salt from one acre of salt field within 5-7 days. If within this period, there is climatic extremes like cold wave, cyclone, or untimely rainfall occur, they lose this amount of salt. If this type of extreme happens in each month of the salt production period (October-April, 7 months) they face huge losses from salt production. Mr. Goni also added that many of the salt farmers have lost their assets and become poor because of the climatic extremes in their locality. Agriculture and Livelihood **Vulnerability Index** was developed normalizing respondents' perception values with high, medium, and low vulnerability. A Composite Vulnerability Index Matrix was developed based on respondents' perceptions by normalizing the participants' responses.

Table 4.8: Impact of climate-induced disasters on agriculture and livelihoods

Vulnerable sectors	Cold waves & fog	Groundwater depletion	Flood	Heavy rainfall	Salinity	Heatwave	Tidal inundation	Wind speed
Homestead vegetable								
Crops								
Poultry								

Livestock								
Salt farming								
Index	High		71%-100% response					
	Medium		36%-70% response					
	Low		0%-35% response					

Deputy Director of Agriculture Extension, Teknaf mentioned that wind speed is not considered for crop production, but it has a remarkable contribution to crop production failure. High or low wind speed influences the pollination of paddy and other seasonal crops. The increasing trend of temperature and decreasing total rainfall increase the soil's dryness. It decreases water availability for irrigation, and livestock during the dry season and restricts crop production during summer and winter. The information provided by the study participants in the household survey and focus group discussion shows that salinity also damages homestead gardens and crop fields and reduces crop production. In addition, late and early downpours also hamper crop and vegetable farming. Cold waves and heat waves also increase diseases in livestock and poultry and increase loss and damage (**Table 4.9).** The Livestock Officer of Teknaf reported that due to heatwaves and cold waves cardiovascular and respiratory diseases increase which increases the death toll during winter and summer. He also reported that in recent times, Lumpy Skin Diseases (LSD) is a crucial problem for livestock rearing. He also cited that during heavy rainfall this disease increases among livestock.

Table 4.9 demonstrates that disaster-induced loss and damage were numerous in Cox's Bazar from 2009 to 2014 and 2015 to 2020. Potato and wheat crops were negatively impacted compared to the previous study report of Bangladesh Disaster Related Statistics (BDRS) 2009 to 2014 and the update study report of BDRS 2015 to 2020, with losses of 27 to 720 acres and 0 to 19 acres, respectively. Paddy cultivation experienced significant losses compared to the two study periods, with 3410 to 26,436 acres damaged. The livestock, poultry, and fisheries also suffered significant losses, totaling 93.36 million BDT (0.85 million USD) to 673.35 million BDT (6.16 million USD) for livestock, 75.04 million BDT (0.68 million USD) to 134.13 million BDT (1.23 million USD) for poultry, and 48.49 million BDT (0.44 million USD) to 196.75 million BDT (1.80 million USD) for fisheries are respectively. Lastly, the fruits are also alarming to compare the two time periods.

Table 4.9: Climate-induced loss and damage from the crop, horticulture, livestock, fisheries, and poultry sector in the study area

Affected area (in acres) and loss of significant crops		
Crops	**Area in acres (2009-2014)**	**Area in acres (2015-2020)**
Paddy	3410	26436
Potato	27	720
Wheat	0	19
Jute	0	0
Affected loss of livestock, poultry, and Fisheries		

Component	2009-2014		2015-2020	
	BDT in a million	**USD in a million**	**BDT in a million**	**USD in a million**
Livestock	93.36	0.85	673.35	6.16
Poultry	75.04	0.68	134.13	1.23
Fisheries	48.49	0.44	196.75	1.80
Affected area and loss of significant Fruits (2015-2020) Area (acres)				
	Area (in acres) (2009-2014)		**Area (in acres) (2015-2020)**	
Fruits	7.92		86	

Source: BDRS, 2021; DAE, 2022; DLS, 2022.

Over the last 30 years, the heatwave years were 1998, 1991, and 2014. The heatwave information also shows that the trend of heatwave fluctuates and almost in each decade heatwave comes into the study area. The production of crops, vegetables, fruits, livestock, and other domestic and wild animals are all negatively impacted by both heat waves and cold waves. From **Table 4.10**, the total heat wave is shown as the highest annual frequency of days with Tmax ≥35 during 1992–2020 at Cox's Bazar and Teknaf stations. It is seen that the highest annual frequencies of days with Tmax ≥35 are in 2019 at two stations during the mid-March to Mid-June (summer season) during which heat waves are expected to spread in most places in 2019.

Table 4.10: Annual frequency of heatwave days over 2015-2022

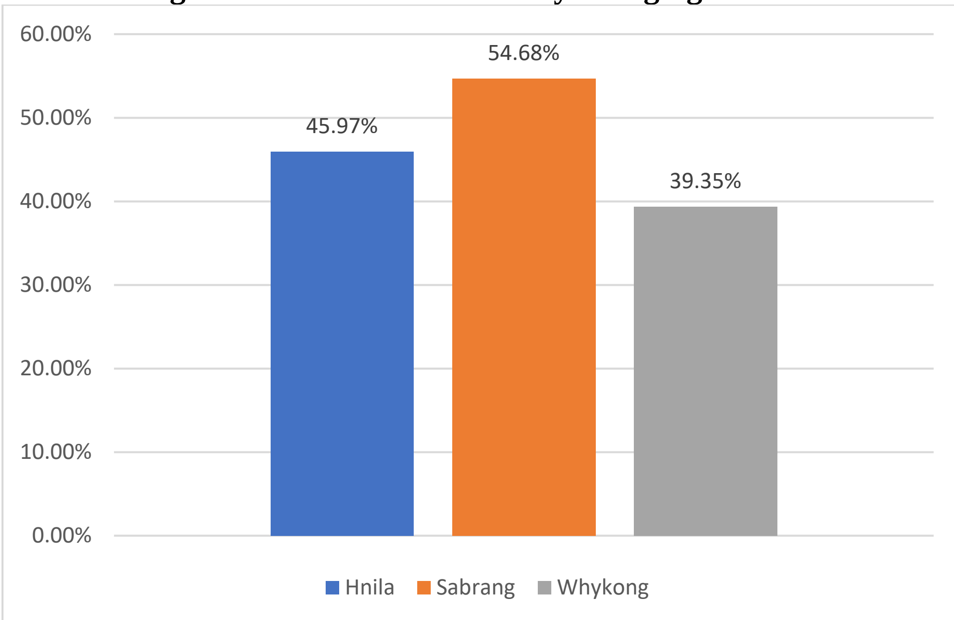
Year	Teknaf	Cox's Bazar
1992	0	4
1993	2	5
1994	2	4
1995	6	11
1996	0	1
1997	1	9
1998	9	28
1999	5	31
2000	4	9
2001	3	26
2002	5	7
2003	1	15
2004	2	18
2005	2	12
2006	1	9
2007	0	3
2008	4	15

2009	1	14
2010	4	32
2011	0	1
2012	0	4
2013	0	3
2014	8	30
2015	1	15
2016	5	5
2017	2	8
2018	3	7
2019	6	24
2020	8	15
2021	13	20
2022	4	5

Source: BMD, 2023

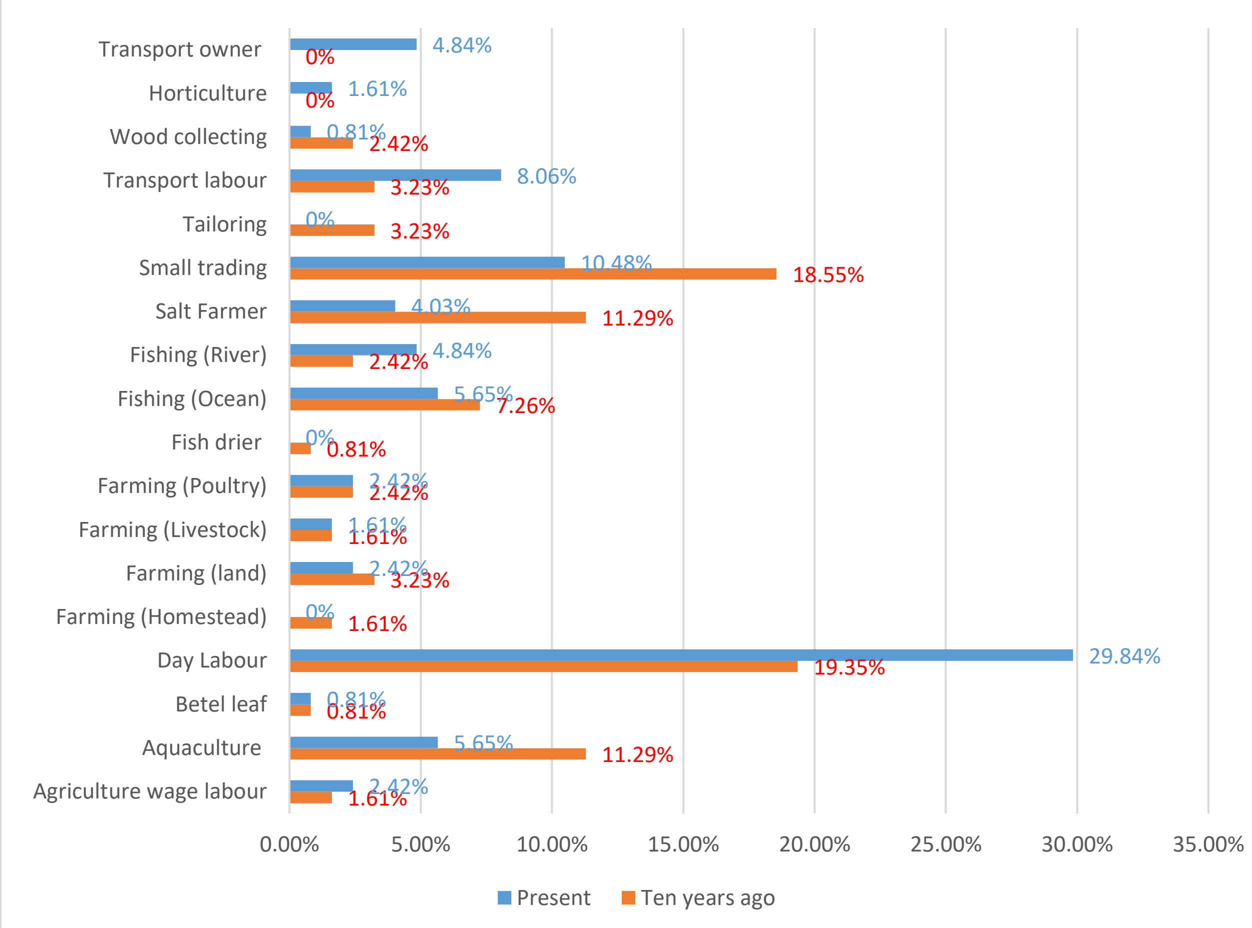
The higher increasing trend in the seasonal frequency of heatwave days is because maximum temperatures are reached during the summer season from mid-March to mid-June. However, these extreme temperatures are not only observed during summer, but also during the monsoon season (mid-June to mid-October) and, in some cases, during winter (mid-October to mid-March). During summer and winter, the DLS Officer cited that many livestock (cattle, goat) and poultry (hen, duck) die from diseases because of consecutive heat and cold waves**.** The FGD participants reported that during winter and summer, livestock and poultry death tolls increase. A woman from Sabrang reported that in the last year, during winter, 36 ducks died. The FGD participants also mentioned that there is no specialized veterinary support from the government or non-government sector. As a result, most livestock rearers depend on local unskilled veterinary medicine sellers, which causes more livestock death toll. The FGD participants also reported that consecutive crop and livestock production failure had decreased the employment rate amongst smallholders and agricultural laborers who experience limited access to food and suffer from seasonal hunger. Reduction of livelihood options and food insecurity causes poor nutrient intake for climate-vulnerable people, which leads to poor health and lessened immunity. As a result, within the last ten years (2012-2022), many people are changing their livelihood activities. F**igure 4.17** represents the livelihood activity-changing scenario of three unions named Hnila, Sabrang, and Whykong unions. In the Sabrang union, there was a maximum (54.68 %) change in livelihood activity. In the Hnila union, the graph showed a significant number of people's (45.97 %) livelihoods changed due to climate change. In the Whykong union, there is comparatively low change (39.35 %) in livelihood activity.

Figure 4.17: Livelihood activity changing scenario



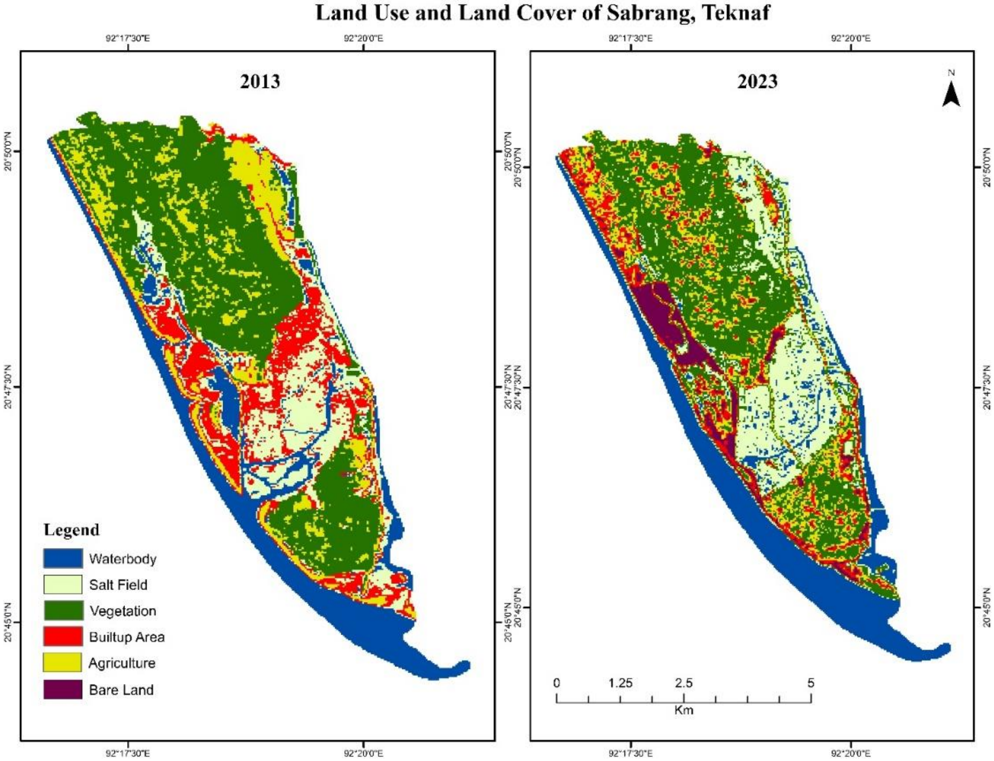
F**igure 4.18** represents the livelihood activities present and ten years ago. From the graph, people were mostly involved in day labor which increased from 19.35% to 29.84%, transport labor from 3.23% to 8.06%, and agriculture wage labor from 1.61% to 2.42%. Many respondents are feeling discouraging in small trading, salt farming, aquaculture, fishing, farming (land), and farming (homestead) which are decreasing day by day. The FGD participants from three unions reported that due to increasing input costs, production loss due to salinity and water logging, consecutive losses because of cyclones, and lack of irrigation during summer and winter, they are not interested in farming. In 2013, the price of urea fertilizer was 16 taka/kg, but by 2023, it stood at 25 taka/kg (The Daily Star, 2013; The Daily Star, 2023). Male FGD participants from Sabrang cited that they are not able to rear cattle, buffalo, and goats because of a lack of fodder. A study was conducted by WFP and finds that unlike most other parts of Bangladesh, livestock ownership is scarce with limitations in land holding sizes restricting the availability of grazing land and fodder production is minimal (WFP, 2017). In this regard, the Livestock officer mentioned that in the salinity-affected and water-logged areas, local varieties of fodder are not produced. He also added that salinity-tolerant and flood-tolerant fodder can be introduced in those areas. Nepier-1, Nepier-2, Nepier-3, Nepier-4, Pakchang, Markiron, and Rokona can be suitable varieties to introduce in the study area. The Department of Livestock (DLS) innovated some salinity and waterlogging tolerant varieties for the salinity and waterlogging-affected areas of Bangladesh. It has conducted experiments and found better outcomes from Nepier-1, Nepier-2, Nepier-3, Nepier-4, Pakchang, Markiron, and Rokona (DLS, 2022).

Figure 4.18: Scenario of livelihood activities at present and ten years ago

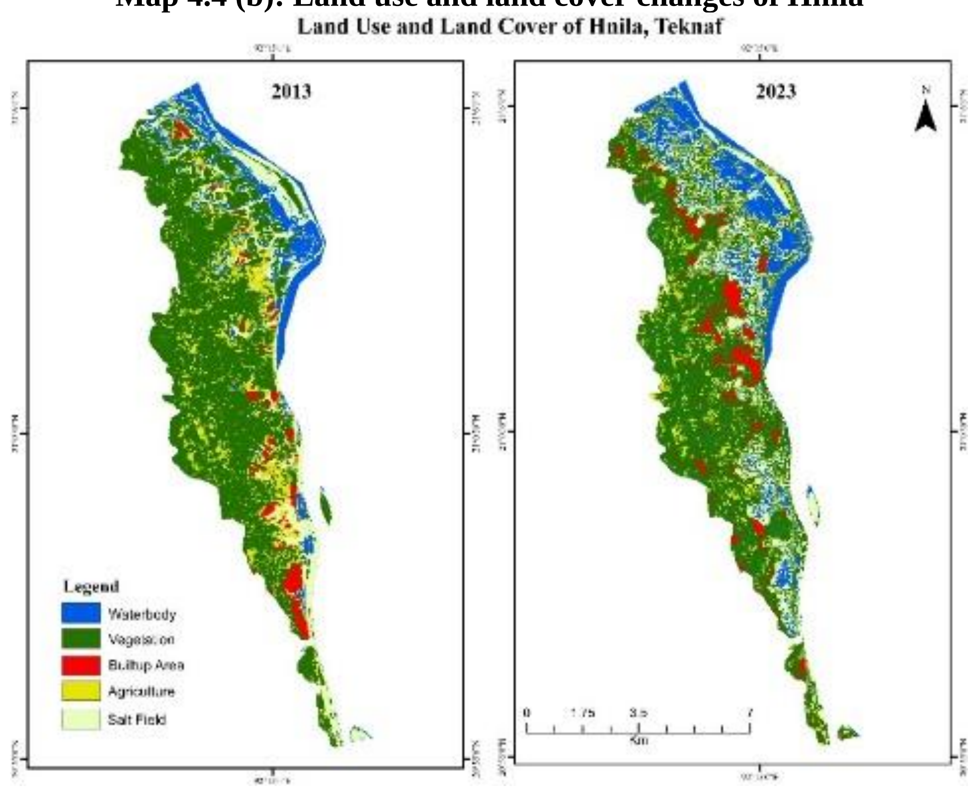


Agricultural land loss is a common scenario in all unions because of salinity intrusion, water logging, riverbank erosion, agricultural drought, and conversion of agricultural land into residences and other development purposes. The FGD participants of the study area reported that the major causes of decreasing agricultural land are new settlements, tourism development, salinity intrusion, bank erosion, agricultural drought caused by the delay of the rainy season, and sometimes insufficient rainfall. The Scientific Office of SRDI reported that rainfall is comparatively lower in this region so agricultural drought is a common phenomenon that restricts crop farming.

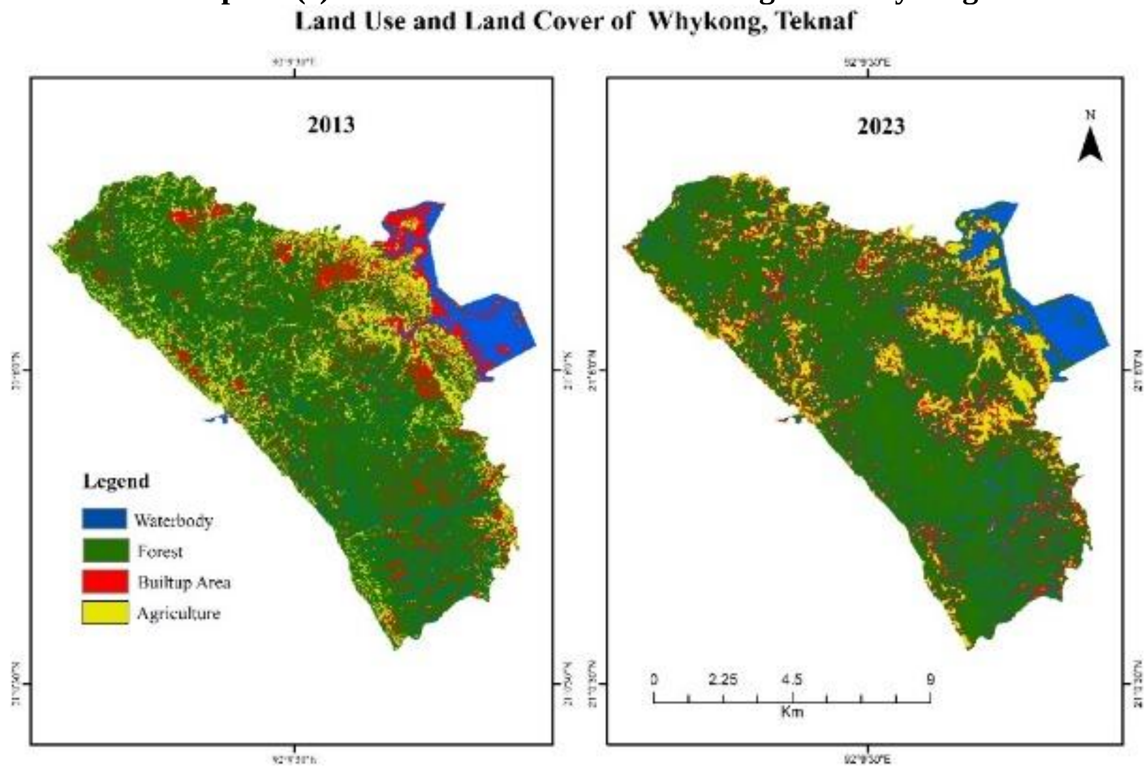
Map 4.4 (a): Land use and land cover changes of Sabrang



Map 4.4 (b): Land use and land cover changes of Hnila



Map 4.4 (c): Land use and land cover changes in Whykong



The agricultural land of Whykong is decreasing rapidly which is exerting pressure on agriculture. In Whykong Union waterbody is increasing. Earlier, farmers were only dependable on agricultural crop production in the area. But now, due to salinity intrusion and rising soil salinity, they get involved with shrimp farming and paddy farming in the same field for six months of intervention. In this union, within 2013-2023, 199.26 hectares of agricultural land decreased but 198 hectares of water bodies and 92.16 hectares of built-up land increased. In the Hnila union, the agricultural land decline is also a common scenario within this period, agricultural land decreased by 134.19 hectares, and salt field, built-up area increased by 44.1 and 116.82 hectares respectively. In Sabrang and Hnila salt farming area is increasing because of salinity intrusion and lack of irrigation. Together cold waves, unexpected rainfall in winter, and untimely cyclones are responsible for reducing salt production. People are utilizing their land as salt farms which was reported by BCSIC and FGD participants from these unions. The BCSIC also mentioned that they are providing loan and capacity-building support to the salinity-affected smallholders in these unions to recover the crop-induced loss and damage.

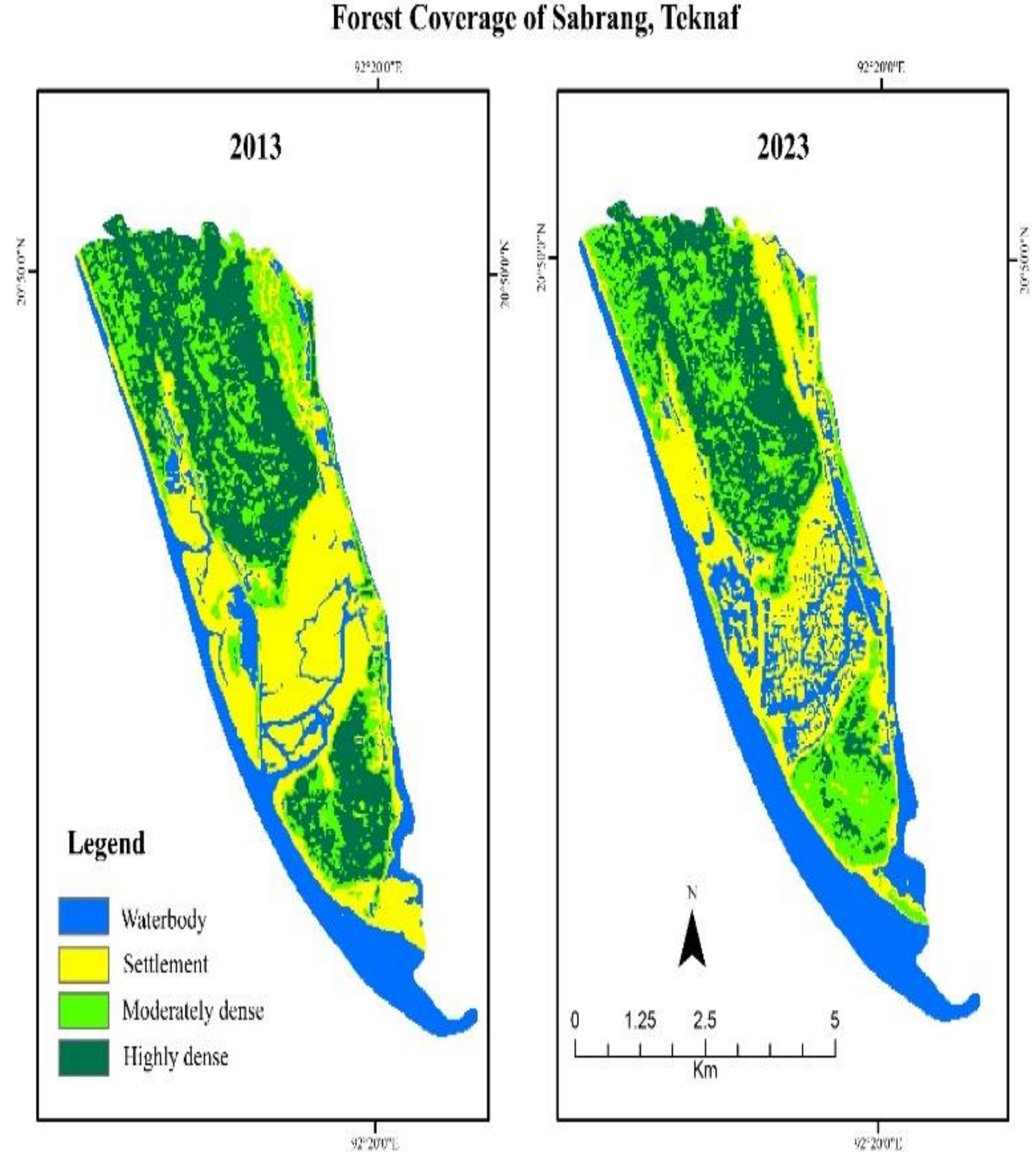
In the Sabrang, agricultural land has decreased by 19.62 hectares. **(Map: 4.4, Table: 4.11)**. On the contrary bare land increased 201.24 hectares and salt fields increased 62.01 hectares. It is mentioned that in 2013 there was no bare land in this union. But in 2023, almost 201.24 hectares increased because the existing canals were dried up by human intervention like marine drives, bridges, and tourism, which resulted in some agricultural land turning into bare land.

Table 4.11: Land cover and land use change in the study area

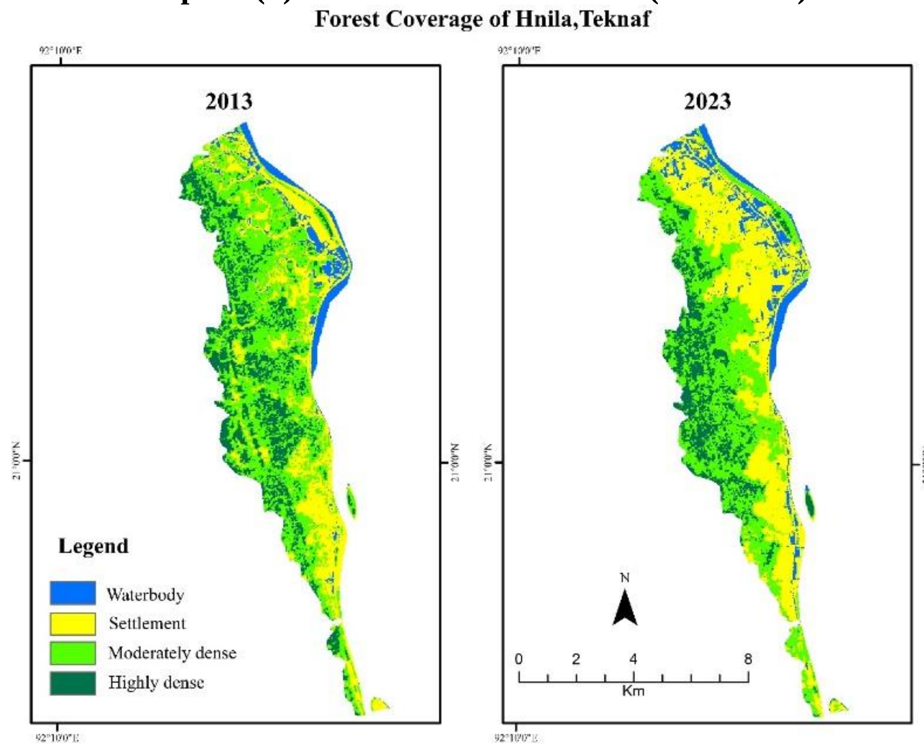
Union	Classification	Area (Hectares)		Changes (Hectares)
		2013	2023	
Whykong	Waterbody	559.8	757.8	‘+’198
	Built up	1166.13	1258.29	‘+’92.16
	Agriculture	1394.91	1195.65	‘-’ 199.26
	Forest	7765.2	7674.3	‘-’ 90.9
Sabrang	Waterbody	636.39	710.55	‘+’74.16
	Salt field	575.55	637.56	‘+’62.01
	Built up	494.82	299.34	‘-’ 195.48
	Agriculture	498.6	478.98	‘-’ 19.62
	Vegetation	1272.69	778.32	‘-’ 494.37
	Bare land	0	201.24	‘+’201.24
Hnila	Waterbody	596.25	844.56	‘+’248.31
	Salt field	828.9	873	‘+’44.1
	Built up	187.02	303.84	‘+’116.82
	Agriculture	663.12	528.93	‘-’ 134.19
	Vegetation	3281.4	3006.36	‘-’ 275.04

The forest coverage of the study area was measured using the Normalized Difference Vegetation Index (NDVI). Band 5 (NIR) and band 4 (RED) of Landsat-8 data were used to create an NDVI map. In Whykong highly dense vegetation decreased by 8263.35 to 4560.75 hectares and moderately dense increased by 495.09 hectares. The NDVI map also shows that the forest coverage also decreased in Hnila and Sabrang union. In 2013, the highly dense forest in Hnila and Sabrang was 1183.05 Ha and 1092.33 Ha but in 2023 it stands at 868.14 Ha and 764.55 Ha **(Map 4.5).** FGD participants from Roikhong of Whykong and Rongikhali and Jummapara of Hnila, who live in nearby hills said that landslides, flash floods, mudflow, and hill erosion have increased. They also mentioned from 2018 almost every year they are affected by landslides after a long intervention of 2007. They also mentioned that the snake bites-related death toll has increased in recent times after the degradation of forest coverage areas. The Forest Officer cited that they are observing increasing trends of temperature and decreasing trends of rainfall in Teknaf. The average increasing trend of temperature in Teknaf is much higher than the average increasing trend in Cox’s Bazar district **(Figures 4.5 & 4.8)**.

Map 4.5 (a): Forest land use in Sabrang (2013-2023)



Map 4.5 (b): Forest land use in Hnila (2013-2023)



Map 4.5 (c): Forest land use in Whykong (2013-2023)

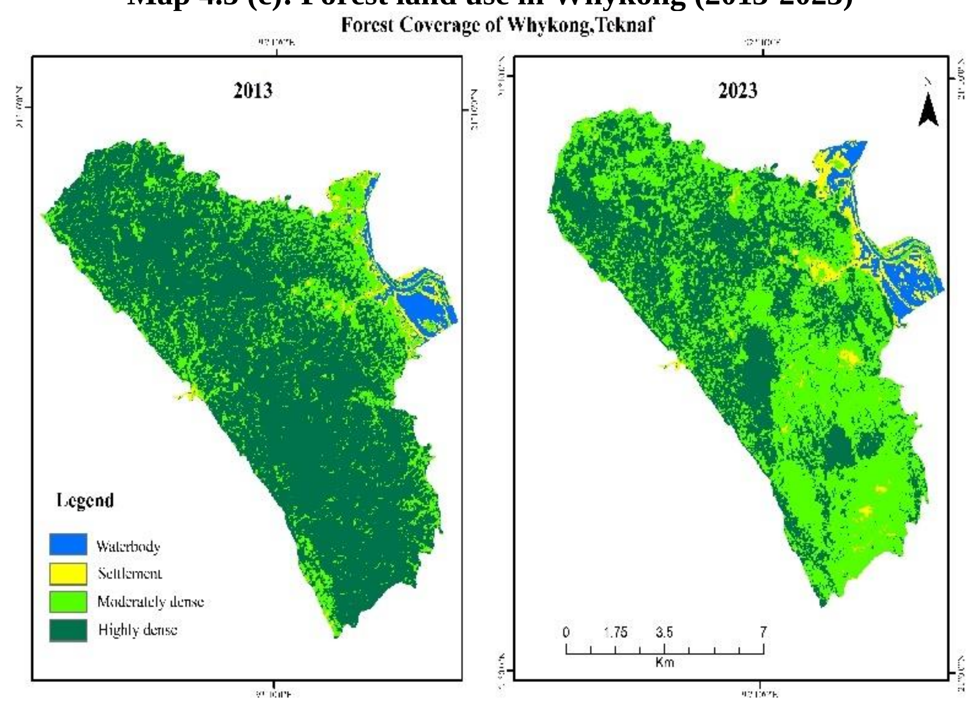


Table 4.12: Forest coverage change

Union	Classification	Area (Ha)		Changes
		2013	2023	
Whykong	Moderately dense	277.65	495.09	'+'217.44
	Highly dense	8263.35	4560.75	'-' 3702.6
Hnila	Moderately dense	2493.63	2001.96	'-' 491.67
	Highly dense	1183.05	868.14	'-' 314.91
Sabrang	Moderately dense	1072.71	909.81	'-' 162.9
	Highly dense	1092.33	764.55	'-' 327.78

Riverbank erosion is prevalent in the Sabrang union though two other unions are also vulnerable to land erosion **(Map 4.6). Table 4.13** represents the Bay of Bengal shoreline changes between 2013 to 2023 years in the Sabrang Union and Naf Riverbank erosion and accretion in Whykong and Hnila Union. In Shah Porirdwip (Dhakin para) of Sabrang union around 70.1 hectares of coastline changed between 2013 to 2023 years. Some parts of Whykong like the Noapara eastern side 18.0 hectares and the Hnila union of Mina Bazar 20.0 hectares areas are deposited. The FGD participants from Sabrang reported that in the last thirty years, almost 10 km of the southeastern corner of the union has been lost due to erosion. A study analyzed over 30 years (1989-2019) of coastal erosion and accretions of Teknaf, the maximum erosion rate has been estimated at 565.4 hectares/ year (Mou et al., 2021). They also reported that not only riverbank erosion but also seashore break is responsible for land erosion in this union.

Map 4.6: Land Erosion

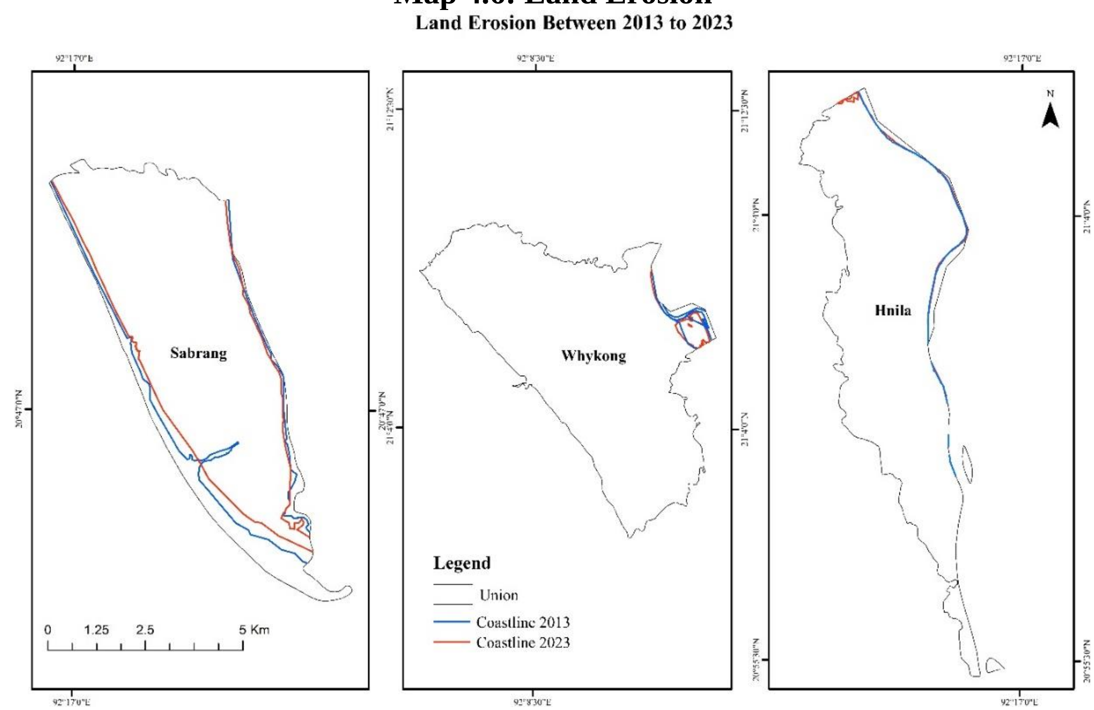


Table 4.13: Erosion and shoreline shifting measurement.

Union	Erosion (Ha)	Accretion
Sabrang-Shah Porirdwip (Dhakin para)	70.1	
Sabrang-Shah Porirdwip eastern side (Naf River)		32.0
Whykong (Noapara) eastern side		18.0
Whykong (Noapara) south-eastern side	63.0	
Hnila (Mina Bazar)		20.0

Land ownership is very poor among the studied population. Most of the respondents do not have agricultural land ownership. **Table 4.14** depicts that with an average land size of 11.73 decimals and high involvement in agriculture at 39.36%, 18.75% of the population in the union of Hnila owns agricultural land. In a similar vein, Sabrang has a population of 21.43% who own agricultural land, with an average land size of 18.51 decimal, but only 22.22% of whom are actively engaged in farming. With an average land area of 17.33 decimal and lower ownership of agricultural land (11.90%), cultivation accounts for 11.90% of all land use in Whykong. The differences in land ownership, land area, and level of cultivation among the three unions are revealed by these statistics.

Table 4.14: Agricultural land and cultivation scenario

Union	Agricultural land ownership	Average land size	Involvement in cultivation
Hnila	18.75%	11.73 decimal	39.36%
Sabrang	21.43%	18.51 decimal	22.22%
Whykong	11.90%	17.33 decimal	11.90%

The information given in **Table 4.16** describes the causes and contributing elements to agricultural difficulties in the two unions of Hnila and Sabrang. The rating was measured on a 1 scale. In Hnila, increased soil salinity, which received ratings of 0.7 out of 1 during Rabi and Khariff I and 1 during Khariff II, is a key factor affecting soil quality. With ratings of 0.7 and 1 during Rabi, and Khariff I respectively, loss of soil fertility is also a significant issue. During Khariff II, the region experienced hydrological disasters, notably waterlogging, which were rated as a 1. A difficulty with a rating of 1 is the inadequate irrigation facilities, especially the lack of irrigation in Khariff I. During Rabi and Khariff I in Sabrang, the growing soil salinity factor is given a rating of 1. Loss of soil fertility is noted with a consistent rating of 0.7 across all three seasons. Waterlogging as a hydrological disaster received a rating of 0.3 during Khariff II. Similarly, insufficient irrigation facilities, particularly the absence of irrigation, are a concern, receiving ratings of 0.7 during the Rabi season **(Table: 4.15)**.

Table 4.15: Causes of refraining from farming

Union	Factor	Causes	Rabi	Khariff I	Khariff II
Hnila	Soil	Increasing soil salinity	0.7	1	1
		Losing soil fertility	0.7	1	0.00
	Hydrological disaster	Waterlogging	0.00	0.00	1

	Insufficient irrigation facility	No irrigation facility	1	0.00	0.00
Sabrang	Soil	Increasing soil salinity	1	1	0.00
		Losing soil fertility	0.7	1	1
	Hydrological disaster	Waterlogging	0.00	0.00	0.3
	Insufficient Irrigation facility	No irrigation facility	0.7	0.00	0.00

The FGD participants of the study area also reported that salinity, soil fertility loss, increased crop production cost due to rising input cost, loss of farmland due to erosion, lost crop production due to waterlogging, reduced crop production due to increasing pest and disease, lack of quality seeds; they refrain from farming.

The Department of Environment (DoE) formally recognized Teknaf as an Environmental Endangered Zone (EEZ) in 2005 and an ecologically essential area in 1999 **(BDP 2100; Rahman, 2022).** According to SRDI, the lowest soil salinity in Teknaf was 4.26 ppt (EC) and the highest soil salinity was 19.13 ppt (EC) **(SRDI, 2010)**. Research conducted in March 2023, Shahporir Dwip in the Sabrang union of the Teknaf Upazila had the greatest level of surface soil salinity in agricultural land (EC 45.4 ppt) **(CPE, 2023).** The increased salinity of the soil and water in the Teknaf Upazila has had a significant negative impact on all sources of livelihood, including agriculture, fishing, livestock, and forestry. According to a study, Sabrang has a medium salinity level while Hnila has a high salinity level. Agriculture, cattle (around 20% less production), fisheries (Loss of domestic fish species, approximately 70% yield losses), and forestry are vulnerable industries because of saline in Teknaf **(Khanam, 2017).** According to another study, the Teknaf shore had an average salinity of (23.605.08) mg/L **(Chowdhury, 2022).** Many rice fields are being used for shrimp farming because of the coastal area's salinity issue, and salt beds have grown in this area from 1999 to 2015 while agricultural land has been trending downward (Mia et al., 2020; Mahtab & Zahid, 2018). Salinity has an impact on the coastal regions in about 53% of cases. Due to soil degradation and salinity intrusion brought on by sea level rise, agricultural production will be reduced. The saline front begins to move inland throughout the winter, causing a rapid increase in the affected areas from 10% during the monsoon to over 40% during the dry season (Mahtab & Zahid, 2018). T**able 4.16** data presents information about salinity for the studied soil and water samples in ppt. 0.5 ppt in drinking water is allowable (WHO, 2008) but in the Sabrang union, the tubewell water contains 0.25 ppt to 0.84 ppt. The rainwater and agricultural fields EC is comparatively lower than other sources 0.07 ppt and 0.04 ppt. The salt field water EC is comparatively high from the tube well which is 4.35 ppt. The surface water sources namely the Naf River and Bay of Bengal contain comparatively high salinity. In the Hnila union, the agricultural field and jhiri, canal, waterfall, and pond water contain the comparatively lowest EC 0.03 ppt, 0.04 ppt, 0.09 ppt 0.16 ppt, and 0.30 ppt. The tubewell water of Hnila also contains salinity above the tolerance limit which is 0.69 ppt. In the Whykong union, the pond's water contains the lowest EC 0.10 ppt. The deep tubewell and well waters of this union contain 0.30 ppt, 0.32 ppt, and 0.53 ppt. The agricultural land salinity is significantly high from other sources which is 0.91 ppt (Map 4.7).

Map 4.7: Water sample location

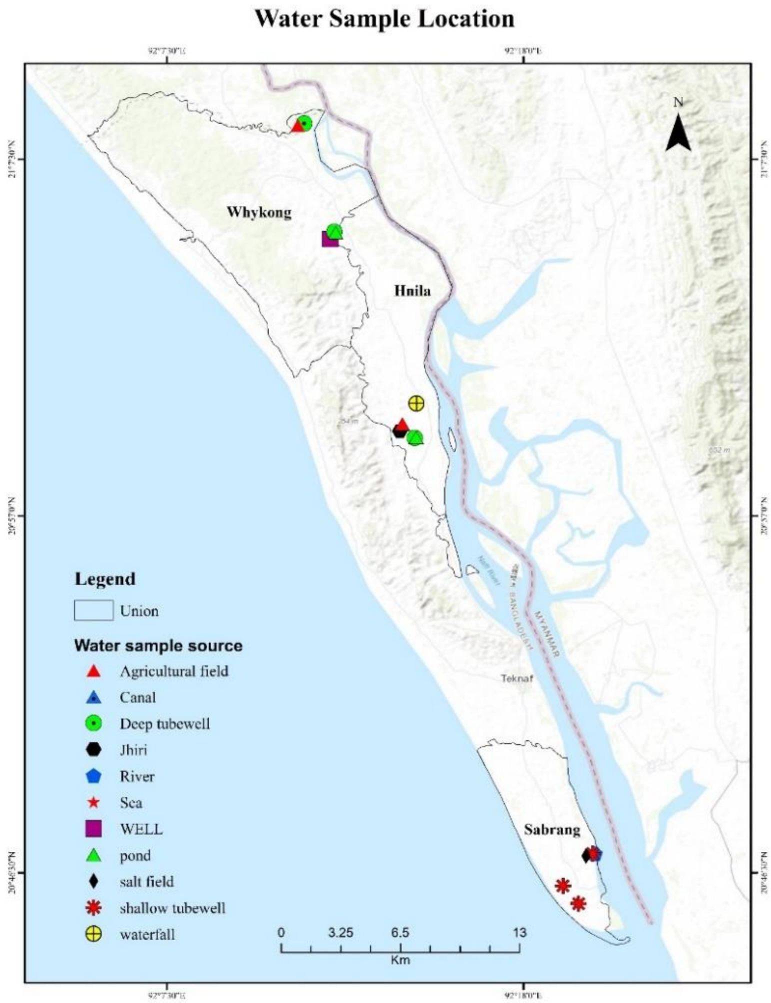


Table 4.16: Surface and groundwater salinity in the study area

Union	Location	Source	EC (ppt)
Sabrang	Dangapara	Tubewell (25ft)	0.25
	Dangapara	Rainwater	0.07
	Miabazar	Tubewell (26 ft)	0.84
	Miabazar	Agricultural field	0.04
	Miabazar	Bob	21.96
	Jaliapara	Naf River	0.03
	Jaliapara	Shallow tubewell 60 ft)	0.29
	Campopara	Salt field	4.35
Hnila	Purba Rangikhali	Deep tubewell (315ft)	0.69
	Rangikhali	Pond	0.30
	Jumma para, gazipara	Jhiri (Bosrar khal)	0.04
	Jumma para, rangikhali	Canal (Boro khal)	0.09
	Ulu samari	Agricultural field	0.03
	Rasulabadh	Salt field	1.30

	Rasulabadh	waterfall	0.16
Whykong	Raikhong, Barua para	Deep tubewell (800 ft)	0.30
	Raikhong, Barua para	Pond	0.10
	Raikhong, Dakkhinpara	Well	0.53
	Ulubunia, Delpara	Deep tubewell (650 ft)	0.32
	Ulubunia, Delpara	Agricultural field	0.91

Due to the rainy season, the soil salinity of the collected samples was found low. The saline area covers 6490 acres of total land in the Teknaf Upazila (SRDI, 2010). Research conducted in March 2023, the soil salinity in Teknaf indicates that a large number of agricultural lands are unsuitable for conventional farming methods. In terms of surface soil salinity, and agricultural land, Shahporir Dwip in the Sabrang union of the Teknaf Upazila had the highest level of EC 45.4 ppt (CPE, 2023). In many areas of the coastal zone, soil salinity and water salinity a typical risks. The main issues with growing vegetables in Cox's Bazar included pest and disease assault, soil salinity, saline water, and waterlogging (Barua & Rahman, 2020). The Agriculture Officer mentioned that Alternaria leaf spot, leaf spot, seed rot, white rust, and grey leaf spot of cabbage diseases attack in the salinity-affected area. **Table 4.1**7 data presented information about salinity in the soil of different sources from three unions. 4 ppt is suitable for crop farming (Clarke et al. 2014) but in the Sabrang, the highest salinity was found in the homestead soil at 0.19 ppt whereas in Hnila it is 0.08 ppt, and in Whykong, 0.07 ppt. In this point of view, homestead soil is suitable for vegetable cultivation. In agricultural land, soil salinity was found to be comparatively low because of mixing rainwater. Hossain et al (2012) find that soil salinity starts increasing post-monsoon and continues to increase pre-monsoon when it reaches the highest level the highest (5.70 ppt) soil salinity was found in pre-monsoon at Shahporir Dwip (Hossain et al, 2012) and none of the lands was found suitable for crop farming. However, our study finds all of the agricultural land is suitable for during monsoon because in the rainy season, salinity is comparatively low.

Map 4.8: Soil sample location

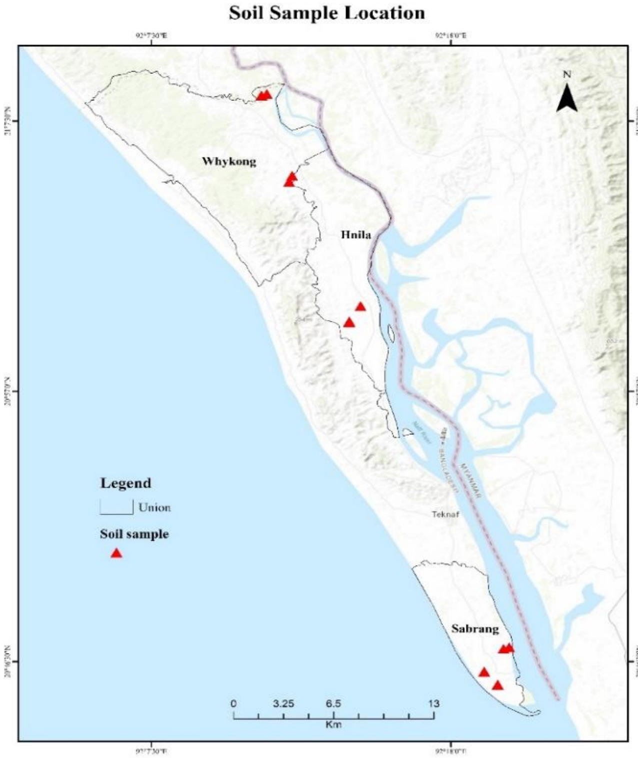
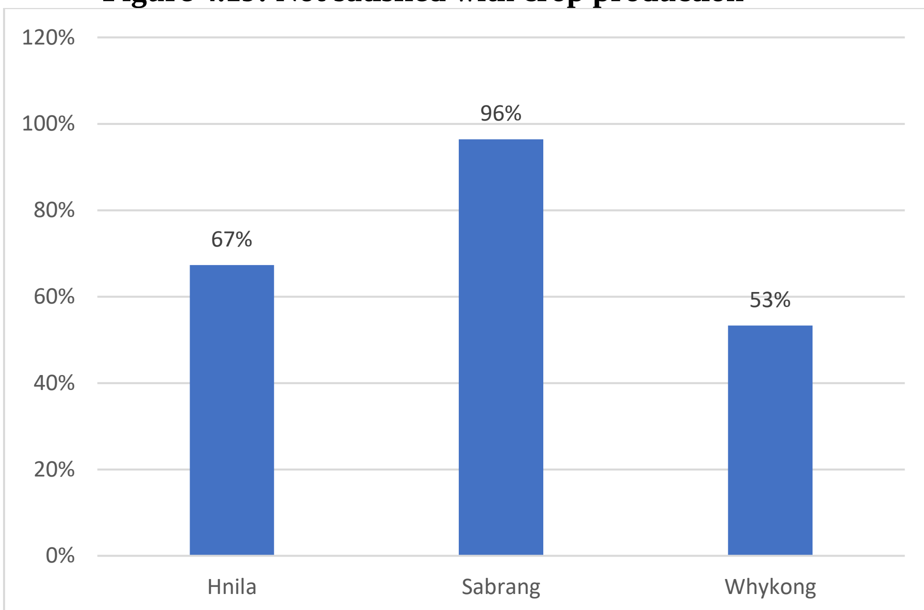


Table 4.17: Soil salinity

Union	Location	Land type	EC (ppt)
Sabrang	Dangarpara	Homestead	0.01
	Mia Mazar (Shaporir Dwip)	Homestead	0.03
	Mia Mazar (Shaporir Dwip)	Agriculture	0.03
	Jaliapara	Homestead	0.19
	Jaliapara	Salt field	0.69
Hnila	Purba Rangikhali	Homestead	0.05
	Jumma para, Rangikhali	Homestead	0.08
	Ulu Bunia	Agriculture	0.03
	Rasulabadh	Salt field	1.10
Whykong	Raikhong,	Homestead	0.07
	Raikhong, Dakkhinpara	Agriculture	0.06
	Ulubunia, Delpara	Homestead	0.06
	Ulubunia, Delpara	Agriculture	0.04

F**igure 4.19** shows that the respondents are not satisfied with the crop production of the Hnila, Sabrang, and Whykong unions. In the Sabrang union, significantly a higher percentage of respondents (96%) are not satisfied with crop production because of lower production, increased crop production costs, pests and diseases, and disaster-induced loss and damages. In the Hnila union, there is a significant percentage of respondents 67%) are not satisfied with crop production, which is comparatively lower than in the Sabrang. In Whykong (53%) respondents are not satisfied with the crop production. The FGD participants from all the unions remarked that because of decreasing crop production, increasing crop production costs, increasing production loss due to pests and diseases, and disaster-induced loss and damage; they are not satisfied with crop production. The farmers from Hnila reported that usually, rice production was 600-650 kg in each Bigha (33 decimal) land but in the last couple of years, the production is decreasing. They also added that in the last year, they have found an average of 300-400 kg of rice in each bigha.

Figure 4.19: Not satisfied with crop production



In all three unions, disaster-induced crop loss and damage have increased in all three crop seasons (Rabi, Kharif I, and Kharif II). In the Rabi season, the respondents of Hnila experienced a production loss of 0.53 kg per decimal, while Sabrang and Whykong faced losses of 0.67 kg and 0.57 kg per decimal, respectively in the last year. Kharif I appears to have had the most production loss for the union Sabrang at 0.42 kg per decimal, and Kharif II appears to have had the highest production loss for the union Whykong at 1.04 kg per decimal which is depicted in **Table 4.18**.

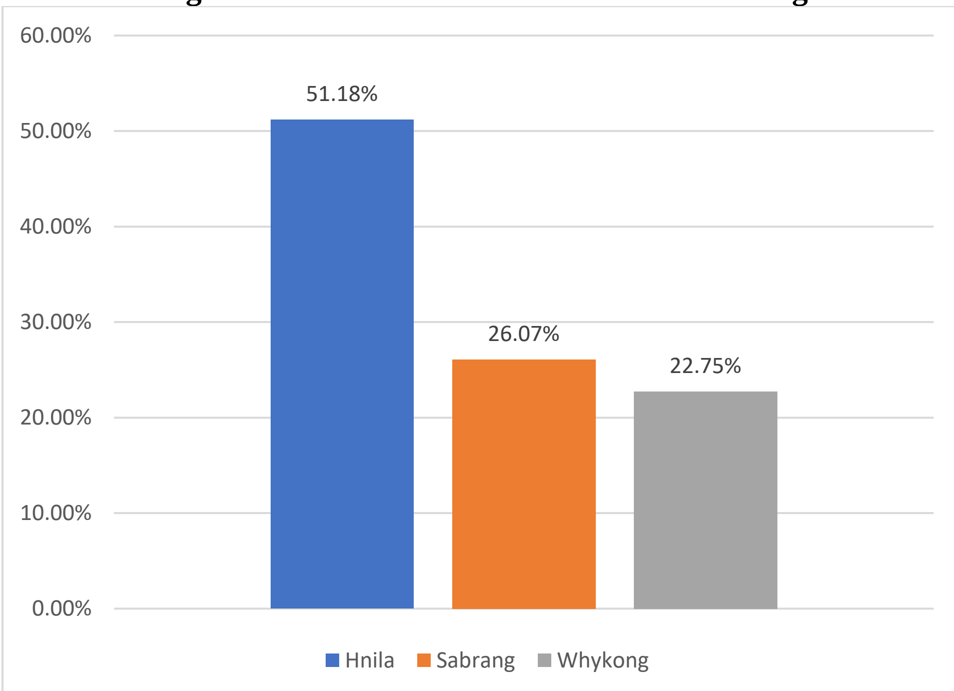
Table 4.18: Union-wise seasonal production loss

Union	Production loss (KG/decimal)		
	Rabi	**Kharif I**	**Kharif II**
Hnila	0.53	0.34	0.96
Sabrang	0.67	0.42	0.82
Whykong	0.57	0.38	1.04

Figure 4.20 shows that the respondents are involved with the homestead farming of the Hnila, Sabrang, and Whykong unions. In the Hnila union, a higher percentage of respondents (51.18%) are involved with homestead. In Sabrang, there is only 26.07% of respondents are involved with homestead farming, which is comparatively lower than in Hnila. In Whykong the lowest (22.75%) of the respondents do practice homestead farming. The FGD participants of the Sabrang and Whykong reported that because of agricultural land quality degradation, lack of homestead land

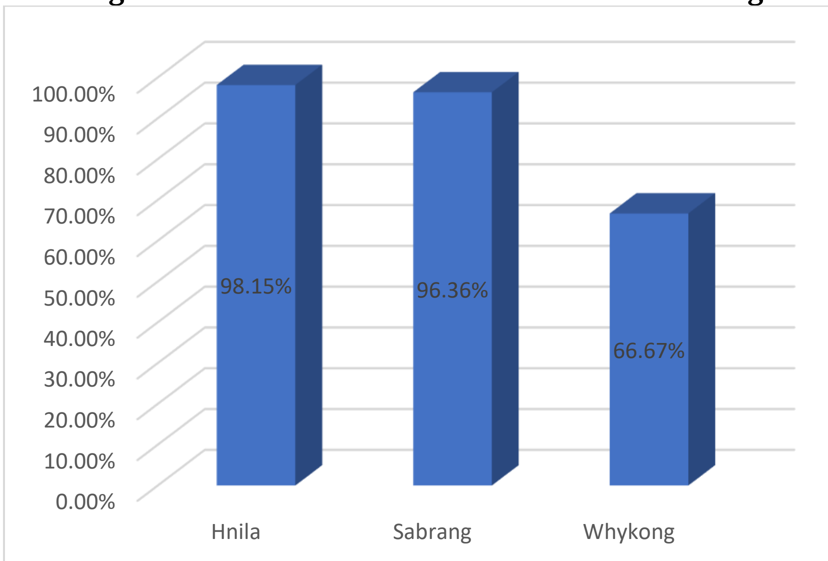
ownership increased soil and water salinity, loss of soil fertility, soil drying up, pest and diseases, and insufficient seasonal rainfall hinders the homestead production.

Figure 4.20: Involvement in homestead farming



In all three unions, most of the respondents are not satisfied with the production from homestead farming. F**igure 4.21** shows that 98.15% of respondents in Hnila are not satisfied which is 96.36% of Sabrang and in Whykong 66.67% of the respondents are not satisfied with the homestead production. The women FGD participants in all the unions explained that during winter and summer, they face loss and damage due to salinity. Not only that but also, but they also faced an irrigation crisis during this period. During monsoons, sometimes heavy rainfall destroys the homestead crop production, so they are not interested in practicing homestead farming.

Figure 4.21: Not satisfied with homestead farming



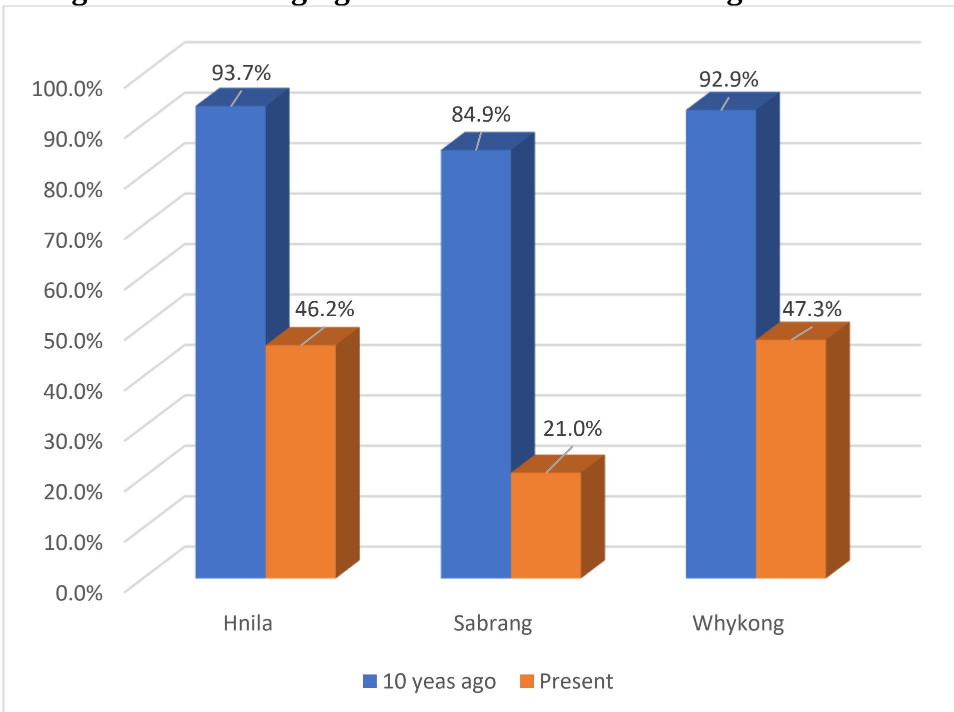
A production loss of 10.47 kg per household was recorded during the Rabi season in Hnila. Likewise, during the Kharif I and Kharif II seasons, Hnila experienced a loss of approximately 5.07 kg per and 17.70 kg per household respectively. **Table 4.19** illustrates that notably, Whykong experienced the highest production losses, with each household losing roughly 20.42 kg, 9.23 kg, and 36.60 kg during the Rabi, Kharif I, and Kharif II seasons, respectively.

Table 4.19: Union-wise seasonal total production loss

Union	Union-wise homestead production loss (Kg/household)		
	Rabi	**Kharif I**	**Kharif II**
Hnila	10.5	5.1	17.7
Sabrang	19.2	8.3	30.7
Whykong	20.4	9.2	36.6

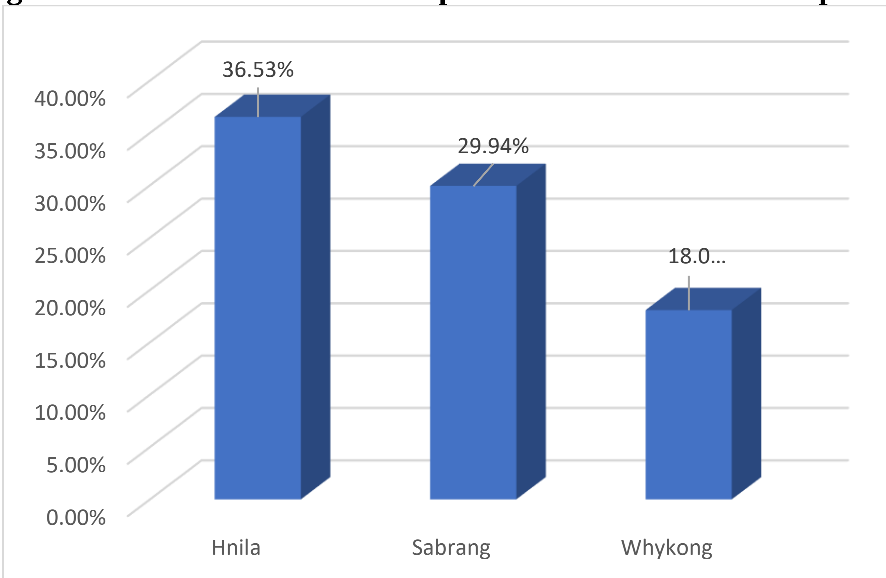
F**igure 4.22** shows the changing scenario of livestock rearing from 2013 to 2023 in the Hnila, Sabrang, and Whykong unions. In the Hnila union, 93% of respondents were involved with livestock rearing which dropped to 45% in 2023. In Sabrang, the changing scenario of livestock rearing from 2013 to 2023 is 84.9 % to 21%, which shows a significant reduction. In Whykong, in 2013, 92.9% of the respondents were engaged in livestock rearing but in 2023 it fell to 47.3 % which indicates a significant transformation in livestock farming. Due to a lack of fodder, people are not interested in livestock rearing. A farmer from Sabrang reported that each month each cattle requires fodder which costs at least BDT 5000.00. They need to buy fodder from far away which is not suitable for livestock rearing. He also added the need for salinity and flood-tolerant fodder cultivation in the nearby lands.

Figure 4.22: Changing scenario of livestock rearing in 2013-2023



A limited number of respondents from all three unions are satisfied with the production of livestock which is depicted in F**igure 4.23**. In the Hnila union, 36.53% are satisfied with the production of livestock which is 29.94% in Sabrang and 18.08% in Whykong. The livestock-rearing farmers cited that public grazing lands are reduced and somewhere there is no grazing land so they cannot feed the livestock properly. They also reported that livestock production decreased because of increasing diseases in summer and winter. Recently during monsoon, many of the livestock also died. In the Chattogram division, losses from livestock in the rainy season were counted and found that it is increasing. From 2009 to 2014, the losses from livestock in the rainy season were 539.92 BDT BDT (4.94 million USD) which was increased to 4,013.52 million BDT (36.74 million USD), from 2015 to 2020 (BDRS, 2015; BDRS, 2021).

Figure 4.23: Satisfaction with the production of livestock and poultry



Aquaculture practice is minor in the study area. In Sabrang only 5% of respondents are involved with shrimp farming in Gher. There is no pond for aquaculture. On the other hand, in Hnila and Whykong, only 2% and 4% are involved with aquaculture in ponds (Table 4.20)

Table 4.20: Aquaculture scenario

Union	Ownership of pond/Gher	Average size (Decimal)	
		Pond	**Gher**
Hnila	2%	2.2	0
Sabrang	5%		8.3
Whykong	4%	3.0	0

In Sabrang the respondents who are involved with aquaculture as shrimp farming in Gher, none of them are satisfied with production (F**igure 4.24).** Similarly, in the Whykong union, there is also a significant number of respondents (75.00%) who are not satisfied with aquaculture production, which is 66.00% in Hnila. The shrimp farmers reported that due to inundation and flood, most of the shrimp firms submerge during monsoon. Not only so but also shrimp farming cost has increased, and production has decreased because of diseases. The farmers of Hnila and Whykong who are involved with pond aquaculture reported that feed cost has increased and during winter and summer, most of the pond dry up which is responsible for decreasing fish production.

Figure 4.24: Satisfaction with fish production

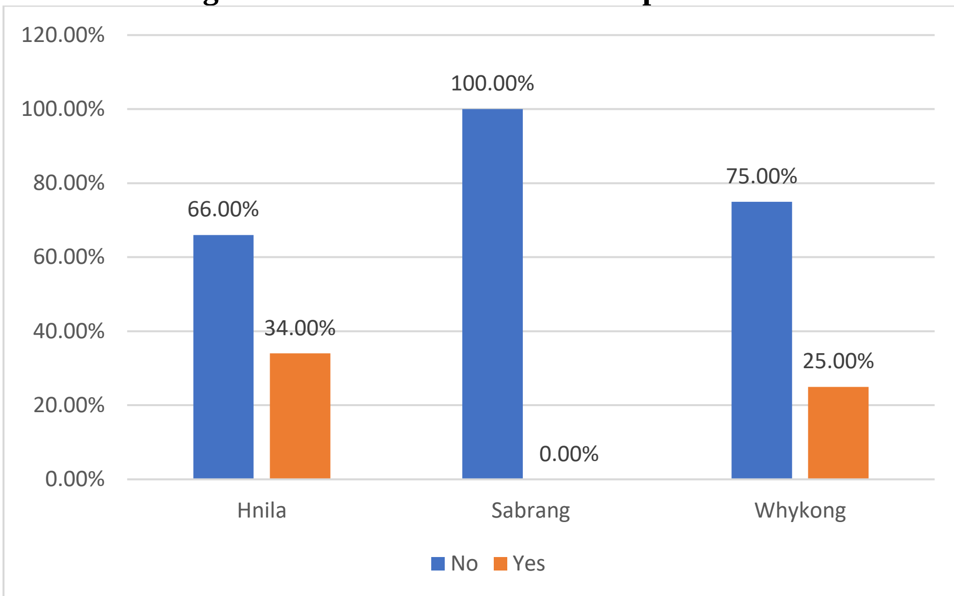
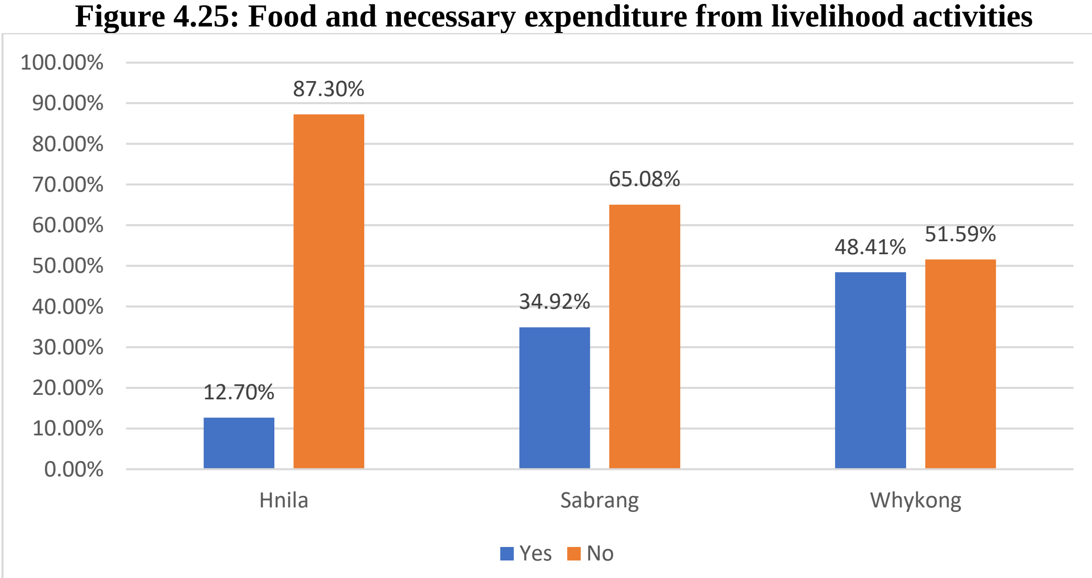


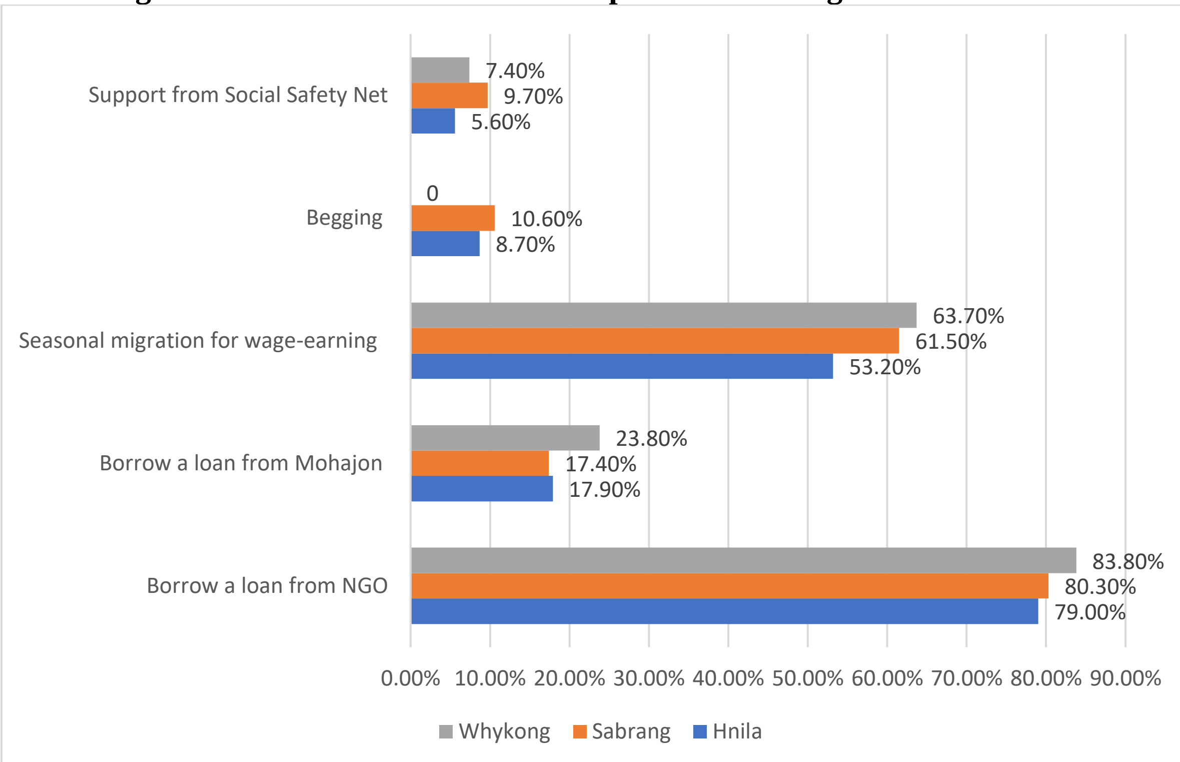
Figure 4.25 represents the scenario of food and necessary expenditure from existing livelihood activities in the study area. In the Hnila, relatively a small percentage (12.70%) can cover the expenses of food and necessary expenditures from their existing livelihood activities. In Sabrang, 34.92% of the respondents can cover their expenses which is 48.41% in Whykong. The respondents said they have insufficient food all year round and most of them are living hand to mouth. They cannot afford medicine costs for their household members. They also don't have solvency for child education.

Figure 4.25: Food and necessary expenditure from livelihood activities



As a result, they manage their household expenses with different mechanisms which is depicted in **Figure 4.26.** There is a miserable scenario found in Sabrang and Hnila that some of the respondents are involved with begging to cover their household expenses.

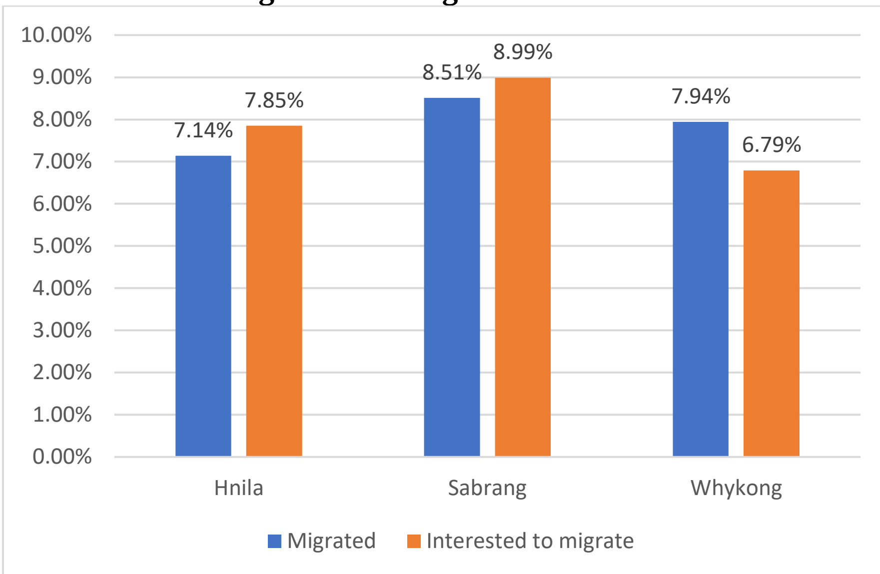
Figure 4.26: Year-round food and expenditure management mechanism



4.6. Climate change and displacement

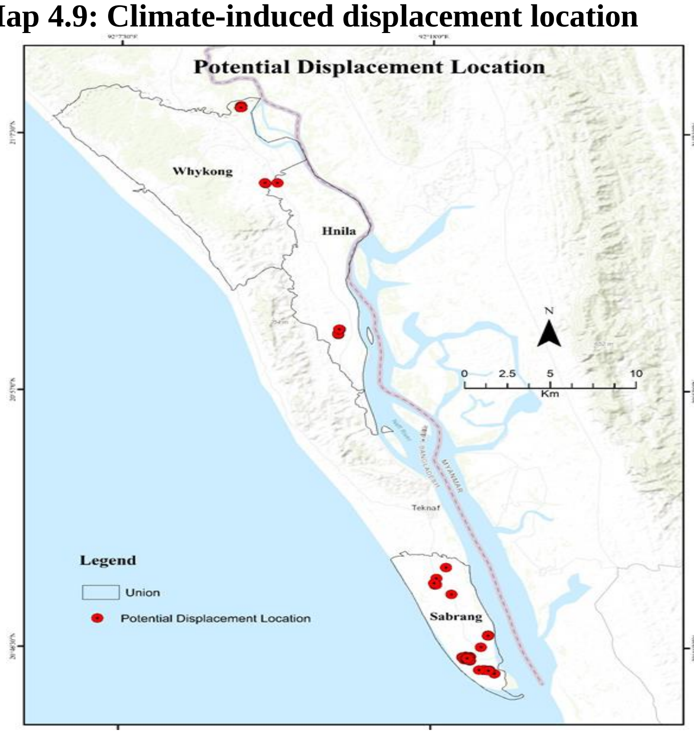
Displacement and migration are common scenarios found in the study area. The study reveals that the highest number of respondents (8.99%) from Sabrang are interested in migrating from their current location. Similarly, from Hnila, 7.85%, and Whykong, 6.79% of respondents plan to relocate to another place. Besides intended migration, in Sabrang, 8.51% of respondents migrated to other places. Following Sabrang, and other unions Hnila and Whykong respectively, 7.14% and 7.94% of respondents migrated to other locations **(Figure 4.27).**

Figure 4.27: Migration scenario



Due to losing homestead land, agricultural production, economic and livelihood crisis, and freshwater crisis, most of the people of some locations will mitigate massively, which is detected using ABM (Agent-based Model) **(Map 4.9).** Displacement and migration are common scenarios found in the study area. Internal migration and external migration are both active in all three unions resulting in demographic changes. The potential displacement percentage is higher in the Sabrang Union than Whykong and Hnila Union. The FGD participants from the studied unions reported that most of the people are migrating to Chottogram metropolitan and some are migrating to Cox's Bazar.

Map 4.9: Climate-induced displacement location



4.7. Access to early warning and advisories

According to respondents, access to early warning systems is available in all three of the studied area's unions, while only 1.80% (Hnila), 0.80% (Sabrang), and 0.80% (Whykong) of people have access to climate advisory systems **(Figure 4.28)**. Respondents also stated that television, mobile, and social media are the sources of climate advisories in the study location.

Figure 4.28: Status of climate advisory and early warning

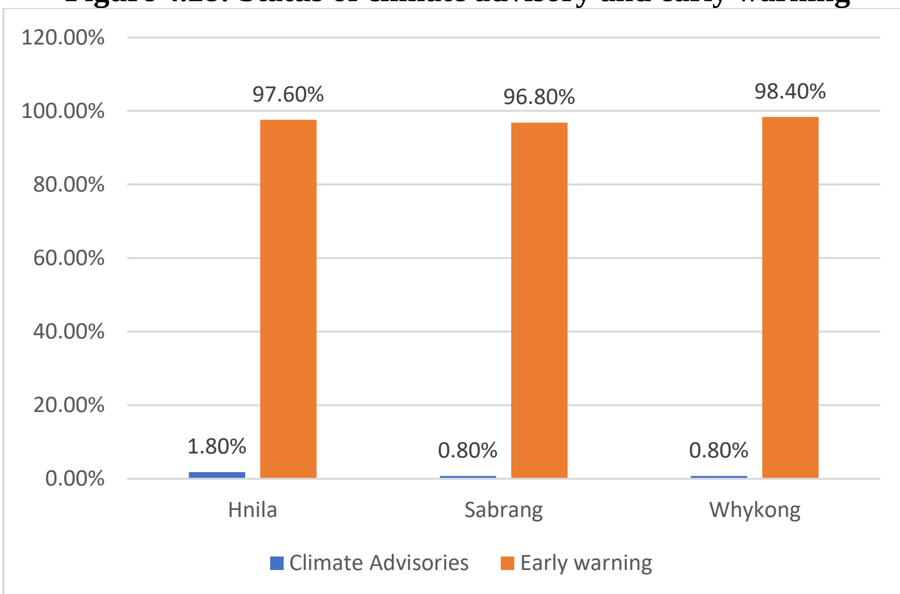


Figure 4.29 represents the existing traditional early warning signs in Hnila, Sabrang, and Whykong. As early warning signs; traditional flags, sirens, and canvassing with mega-phone (Miking-local announcing instrument) are being used in the study area. The miking is mostly used for warning in three unions which are Hnila (96%), Whykong (93.70%), and Sabrang (89.70%). After miking they get an early warning from flags which are accordingly in Sabrang (85%), in Whykong (79.40%) and in Hnila is comparatively low (50%) than Sabrang and Whykong. Siren is comparatively lowest used than miking and flag.

Figure 4.29: Traditional warning signs

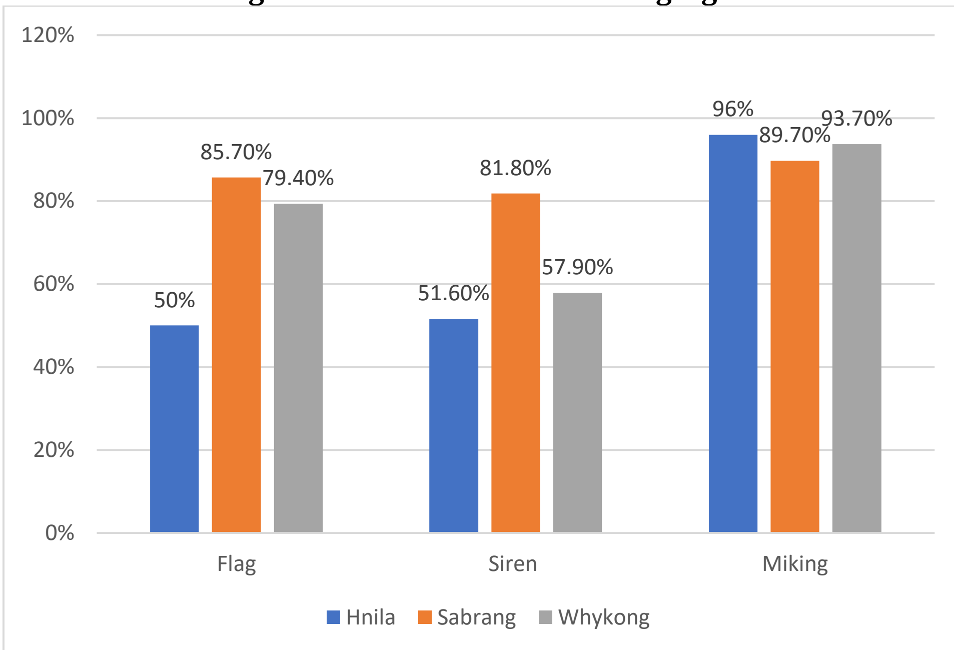
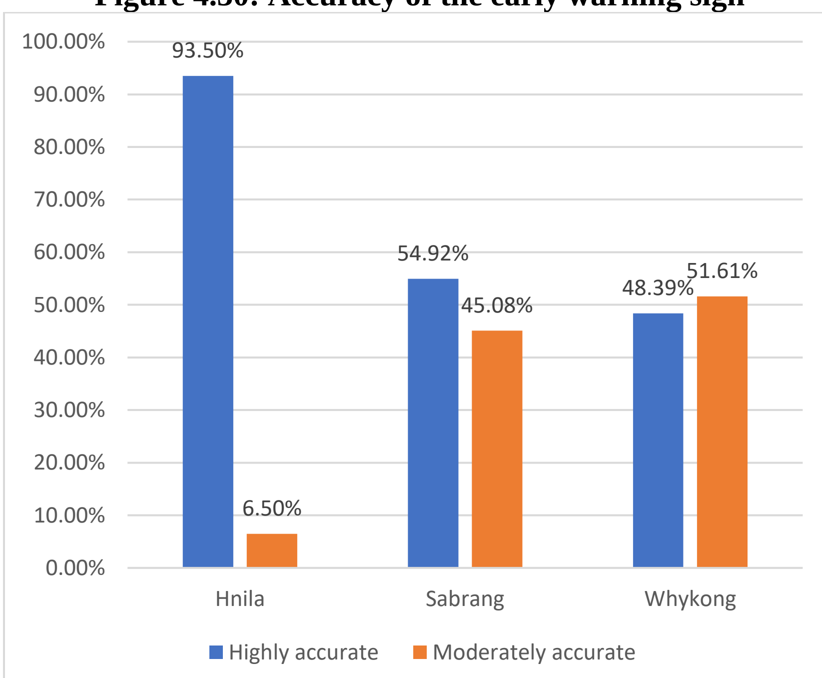


Figure 4.30: Accuracy of the early warning sign



In Hnila there is the highest (93.50%) accuracy of the early warning sign. In Sabrang F**igure 4.30** shows a significant percentage of accuracy (54.92%) but has a significant percentage of moderate accuracy (45.08%). In Whykong, there is almost the same accuracy and moderate accuracy.

4.8. Access to Social institution

Some social institutions are working to promote climate and disaster-resilient communities in the study areas in government and non-government sectors. **Map: 4.10** has captured the existing institutions from the study area using a GPS logger nearby communities that are responsible for community support. The availability of Services such as cyclone preparedness, resilient farming, forest-dependent livelihoods, integrated water management, social safety net, livestock vaccination services, etc. available from these institutions.

Map 4.10: Existence of institutions

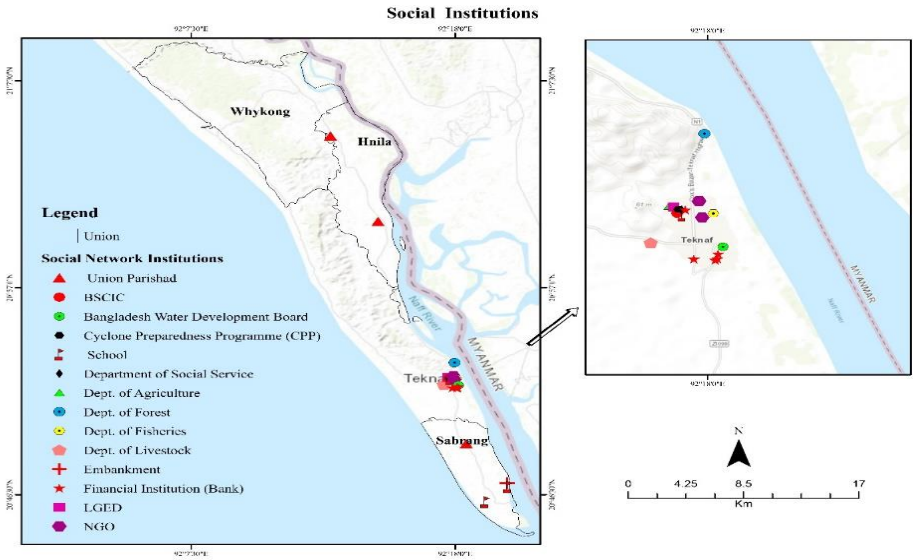


Table 4.21: Institutional support for climate-resilient livelihoods

Name of Institution	Climate resilient intervention
Department of Agriculture Extension	This Department introduced Salt tolerant crop varieties from different institutions. Farmers can get climate-resilient varieties from this institution which are Salt-tolerant T. Aman (BR-22 and BR-23, Bina shail), Salt-tolerant BRRI dhan (33, 56, 57, and 62 BRRI dhan 40, 41, 53, 54, 65), Salt-tolerant Bina dhan (7 and 16 Bina dhan-8 and 10), Salt-tolerant potato, (BARI Alo-22, CIP Clone -88,163), Salt-tolerant sweet Potato, (BARI Mishti Alo-8,9), Salt-tolerant pulses, (BARI Mug-2,3,4,5,6, BM-01, BM-08 BARI Falon- 1, BARI Sola-9), Short-duration oilseeds, (BARI Sharisha-14,15 BARI Chinabadam 9, BINA China badam-1, BINA China badam-2, BARI Soyabean-6 BARI Til-2,3,4)
Department of Livestock	There are no direct interventions of DLS relevant to climate resilience, but farmers can get support on vaccination, flood, and salinity-tolerant fodder varieties through DLS.
Department of Fisheries	Department of Fisheries doesn't have direct support for climate-resilient aquaculture, but farmers can get advisory support on Net fishing, cage fishing, shrimp diseases control, healthy pond, and gher management, water quality management, etc.

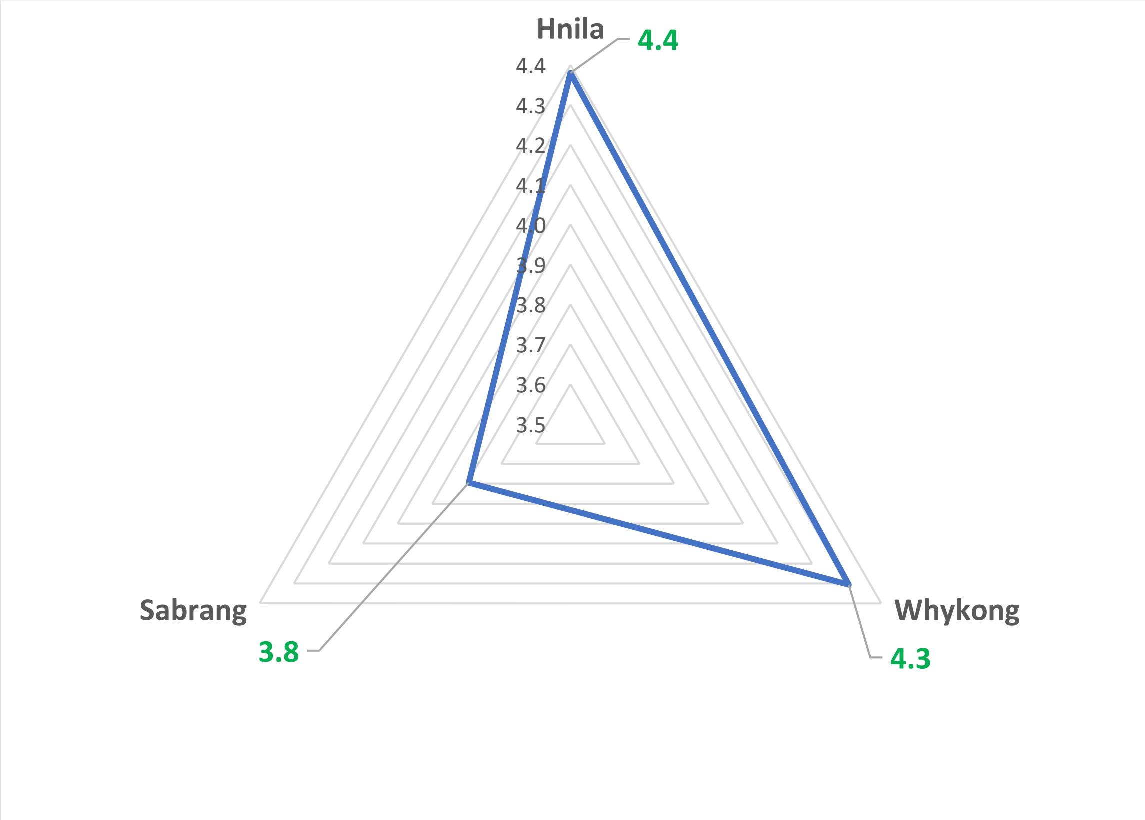
Department of Social Service	Department of Social Service is responsible for Social Safety Net issues.
Department of Women and Children Affairs	Capacity building on alternate livelihoods for women including handicrafts, sewing, homestead farming, and small cottages.
Bangladesh Water Development Board	Integrated Water Resource Management, watershed management.
Dept of Forest	Agroforestry, coastal forestry, NbS, participatory forestry.

CHAPTER FIVE
COMMUNITY RESILIENCE

5.1. Community resilient support

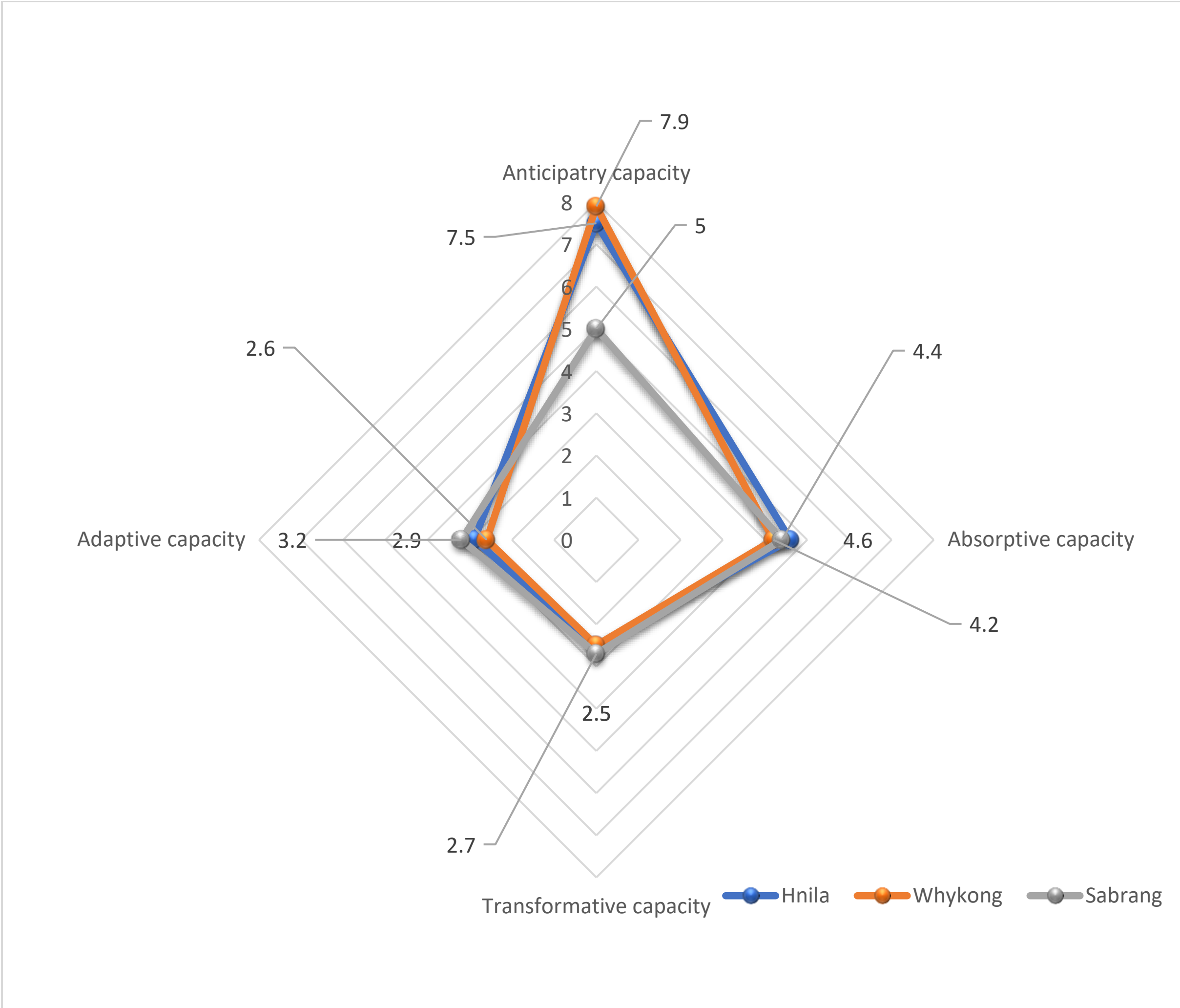
Union resilience capacity is measured based on four indicators (Adaptive capacity, Anticipatory capacity, Absorptive capacity, and Transformative capacity) adapted from OECD Resilience Building. The overall resilience score was measured on a scale of 10. None of the three unions were found to be resilient but, on a scale of 10, Hnila came out to be more resilient than the rest of the two unions with a score of 4.4. On the other hand, Sabrang was found to be the union with the least resilience (3.8).

Figure 5.1: Union Resilience Score



According to **Figure 5.2**, Whykong Union has the highest anticipatory capacity (7.9) and Sabrang has the lowest (5). The absorption rate is nearly identical in all three unions; however, the highest percentage is 4.6 in Hnila. The transformative potential in Whykong is the highest at 2.7, whereas it is the same in Hnila and Sabrang. The largest adaptive capacity is found in Sabrang, where it is 3.2.

Figure 5.2: Anticipatory, Absorptive, Transformation, and Adaptive Capacity in the study area



Anticipatory capacity

Anticipatory resilience capacity comprises preparedness, coordination capacity, and risk information access. In terms of union priority-based resilience, risk information is the lowest proctored for resilience in Hnila (7.9) and Whykong (7.9) unions, and in Sabrang, it is a medium proctored resilience parameter (5.0).

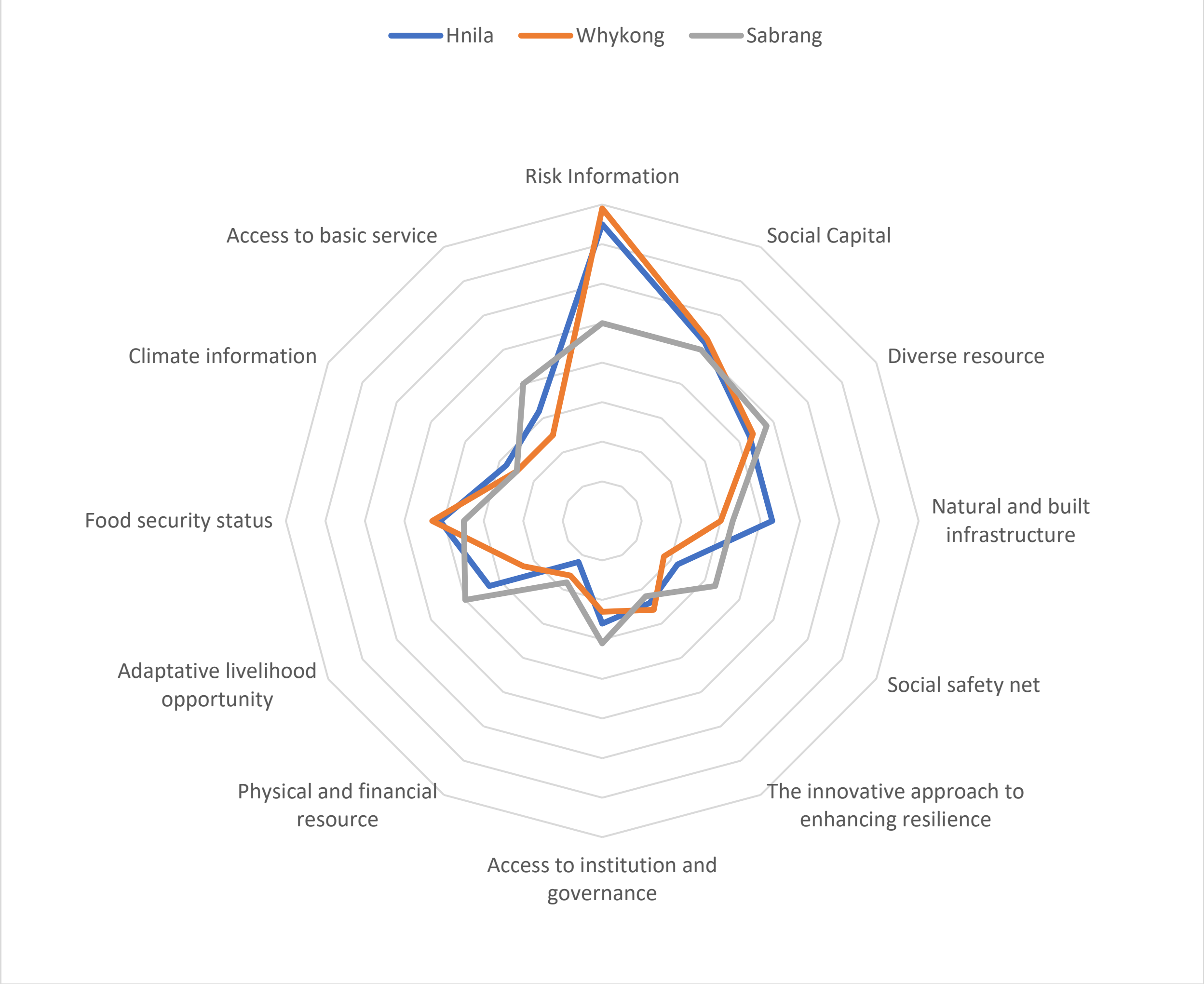
Absorptive capacity

Social capital (community support groups), diverse resources (access to common resources), natural and built infrastructure availability, and social safety net support are the components of absorptive capacity. In all three unions, social capital and diverse resources are categorized as moderate resilience parameters (scored 3.6-7) and natural and built infrastructure is moderate (4.3) in Hnila Union, but this parameter is also highly prioritized (scored below 3.5) in Whykong (3.0) and Sabrang (3.3). In all three unions of the study areas, the social safety net is the highest priority for resilience.

Transformation capacity
In Hnila, Whykong, and Sabrang the innovative approach to enhancing resilience and access to institutions and governance are the highest prioritized resilience parameters.

Adaptive capacity
Physical and financial resources, food security status, climate information, access to basic services, and adaptive livelihood opportunities comprise adaptive capacity. Physical and financial resources are the highest in all three unions. Adaptive livelihood opportunities are the highest in Hnila (3.3) and Whykong (2.3) and moderate in Sabrang (4.0). The food security status of Hnila and Whykong is moderate, with the highest in Sabrang (3.5). Both Hnila and Whykong unions have minimal access to climate information, so these unions are the most prioritized for resilience intervention. On the other hand, in terms of access to basic services, the status is highest in Hnila and Whykong and in Sabrang it is moderate.

Figure 5.3: Overall scenario of climate resilience in the study area



Community resilience includes adaptive, anticipatory, absorptive, and transformative capacities. **Adaptive capacity combines** physical and financial resources, adaptive livelihood opportunities, food security status, climate information, and access to essential services. **Anticipatory capacity**

combines community preparedness, coordination capacity with different stakeholders, and availability of climate risk information. The **absorptive capacity is also the combination of** social capital, diversified resources at the community level, natural & built infrastructural facilities to deal with climate and disaster shocks, and the availability of a social safety net. The **transformative capacity is** innovative approaches to enhance resilience, community skill in strategic resilience planning, and institutional governance.

T**able 5.1** shows the priority-based resilience indicators for the Hnila, Whykong, and Sabrang unions. The parameters are divided into several components of resilience, and their values show the importance of each factor in terms of resilience. A greater value indicates a higher significance. In Hnila and Sabrang union, Risk information parameters are the lowest priority parameters and have significant priority in other parameters. In the Whykong Union, almost all the parameters are high to medium priority.

Table 5.1: Union-wise priority-based resilience parameters

Parameters	Hnila	Whykong	Sabrang
Risk Information	7.5	7.9	5.0
Social Capital	5.2	5.3	5.0
Diverse resource	4.3	4.4	4.8
Natural and built infrastructure	4.3	3.0	3.3
Social safety net	2.2	1.8	3.3
Innovative approach to enhancing resilience	2.4	2.6	2.2
Access to institution and governance	2.6	2.3	3.1
Physical and financial resource	1.2	1.6	1.8
Adaptive livelihood opportunity	3.3	2.3	4.0
Food security status	4.1	4.3	3.5
Climate information	2.8	2.5	2.5
Access to basic service	3.2	2.5	4.0

Index: (0-3.5=High, 3.6-7=Medium, Above 7=Low

5.2. Livelihood-resilient planning

5.2.1. Cost-benefit analysis

Table 1 indicates that 77% of respondents are interested in adopting climate-smart farming whereas 75% are interested in adopting climate-smart livestock rearing. Among the respondents, the highest number (88%) of people are interested in adopting climate-smart poultry as resilient livelihoods. Along with these interventions, people are interested in adopting nature-based solutions like seagrass and seaweed farming and value-added products, homestead farming, aquaculture, horticulture, etc. (Annex I)

Prioritization of adaptation options is complex. Table 5.3 represents a multi-dimensional rank of priority adaptation options in all three unions as climate-resilient livelihoods which was identified through Spearman's rank-order correlation. The Spearman's rank-order correlation was computed to determine the relationship in the ranking of the climate-resilient livelihoods for each union for each value chain according to the following formula:

$$\rho = 1 - \frac{6\,\Sigma {d_i}^2}{n(n^2 - 1)}$$

According to the standard ranking of livelihood adaptation options, resilient crop farming, homestead farming and slatted houses for livestock rearing are the most prioritized livelihood options for Sabrang Union and Whykong Union. According to the ranking, Hnila Union homestead farming is the most prioritized livelihood practice.

A rank of 1 indicates that the option is deemed to be very important for the community people in terms of climate-resilient livelihoods. A Spearman's correlation was run to assess the relationship between the ranks of the options at each stage of the value chain (Table 5.2). All the ranks were independent of each other. The correlation coefficients indicate that there was a negative insignificant relationship between the ranks for the 402 respondents, rs=0.111, p=0.05. This implies that the ranking of the options in each stage does not influence each other. For instance, at the initial stage, the climate-vulnerable people considered the application of inputs as well as initial investment and climate-induced extremes to be very important for resilience.

Table 5.2: Standard Rank of the most prioritized options.

Practices	Rank		
	Hnila	**Sabrang**	**Whykong**
Resilient crop farming	7	9	8
Homestead farming	9	9	8
Slatted houses for Livestock rearing	8	9	8
Semi-scavenger houses for Poultry rearing	7	5	6
Aquaculture	7	7	7
Fodder farming	5	8	7
Agroforestry	6	8	7
Resilient boat for Sea Fishing	3	4	5
Resilient boats for river fishing	4	2	2
Betel leaf farming	2	3	3
Sea Grass and seaweed farming	3	2	2
Value-added products from seagrass and seaweed	4	4	4
Value-added product from mangroves	3	4	4
Ecological and conservation farming	1	1	1
Biofertilizer production	3	3	3
Biopesticide production	1	2	2
Small cottage	3	3	3
Handicrafts	2	2	2
Horticulture	1	1	1

Table 5.3. Spearman's rank correlation coefficients.

Variables	Promising Rank_1	Promising Rank_2	Promising Rank_3	Promising Rank_4
Promising Rank_1	1			
Promising Rank_2	-0.087	1		
Promising Rank_3	-0.414	-0.232	1	
Promising Rank_4	-0.282	-0.276	-0.111	1
Spearman rho = -0.111.				

The cost-benefit analysis (CBA) for climate-smart livelihoods (CSL) is measured using the following formula:

$$NPV(B,C) = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

Where T represents the lifecycle of the adaptation practice, B represents the benefits, C represents the costs, and r is the applicable discount rate (if required). In this study, we compared the changes in cost and benefits of the prioritized climate-resilient livelihood practices.

Table 5.4: Variables used in CBA

Item	Description
Investment cost	
Implementation costs	Costs incurred at the beginning of implementation (once-off costs and every year or every seasonal cost).
Maintenance costs	Costs are incurred every year or every season but exclude the one-off costs.
Operational costs	Costs that deal exclusively with labor, storage, and utility.
Inputs	Costs of raw materials.
Services	Transportation costs.
Benefits	
Increased yield	Output from the practices (Kgs/ltrs/number).
Discount rate	Loan interest (if required).
Lifecycle	The period in months/years from the implementation.
Price of outputs (Y)	Current market prices of each unit.
Price of Inputs	Current market prices of inputs used (BDT per unit)

For the study area, the Monthly CBA Net Present Value (NPV) is represented in **(Table 5.5)** which indicates the highest NPV values that denote the top prioritized intervention for three unions Hnila, Sabrang, and Whykong. The top five interventions are resilient crop farming, seagrass, seaweed farming, biofertilizer production, horticulture, and handicrafts respectively.

Table 5.5: Monthly CBA (NPV) of prioritized options in three unions in each unit

Practices	NPV (BDT)		
	Hnila	Sabrang	Whykong
Resilient crop farming	18738	18738	18738
Homestead farming	7432	7432	7432
Slatted houses for livestock rearing	3400	5335	4632
Semi-scavenger houses for Poultry rearing	2700	3220	2550
Aquaculture	6,301	0	5600
Fodder farming	3600	5800	3500
Agroforestry	NA	NA	NA
Resilient boat for Sea Fishing	NA	NA	NA
Resilient boats for river fishing	NA	NA	NA
Betel leaf farming	NA	NA	NA
Sea Grass and seaweed farming	15000	15000	15000
Value-added products from seagrass and seaweed	8000	12000	8000
Value-added product from mangroves	8000	12000	8000
Ecological and conservation farming	NA	NA	NA
Biofertilizer production	10000	8000	10000
Biopesticide production	NA	NA	NA
Small cottage	NA	NA	NA
Handicrafts	8000	8000	8000
Horticulture	9000	6000	8750

5.2.2. GHG-smart CSA identification

For the study area, GHG-smart potential livelihood interventions such as resilient crop farming, homestead farming, fodder farming, etc. are introduced by concentrating on both emissions reduction and carbon sequestration (Table 5.6). These potential livelihoods are deemed to be very important interventions for the community people in terms of GHG reduction. These GHG-smart livelihood interventions will improve soil health, water retention, sustainable agriculture, and climate resilience, all of which significantly align with the GHG reduction target.

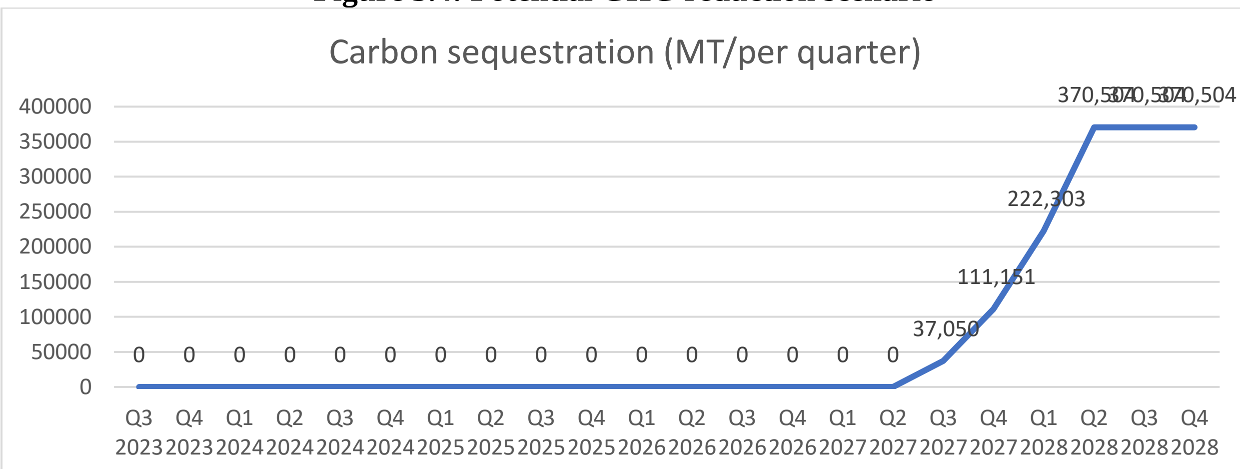
Table 5.6: GHG-smart potential livelihoods options

SL	Options
1	Resilient crop farming
2	Homestead farming
3	Fodder farming
4	Agroforestry
5	Betel leaf farming
6	Sea Grass and seaweed farming
7	Value-added products from seagrass and seaweed
8	Value-added product from mangroves
9	Ecological and conservation farming
10	Biofertilizer production

11	Horticulture

For the study area, the GHG-smart potential livelihood interventions in (Table 5.7) will result in a carbon sequestration process. The carbon sequestration process requires a transition period. In (Figure 5.4) A series instance of carbon sequestration is indicated as quarterly (year) vs. carbon sequestration volume. It is a forecast schedule over 6 year transition period in (Figure 5.4) which shows that CO_2 removals peak between years (2027-2028) quarter-2(Q2) CO_2 sequestration 37,050(MT/per quarter) and quarter-4 (Q4) CO_2 sequestration 370,504(MT/per quarter). Hereafter, they will approach equilibrium by gradually balancing the carbon cycle in offsetting potential green greenhouse gas (GHG) reduction.

Figure 5.4: Potential GHG reduction scenario



5.2.3. Sustainable Livelihoods Assessment

The sustainable livelihood options have been identified using the following livelihood assessment framework (social capital, physical capital, human capital, financial capital, personal capital, and natural capital, etc. **(Table 5.7).**

Table 5.7: Sustainable Livelihood Assessment Framework

Physical Assets: -Access to basic needs, services, and entitlements including food security -Stable, affordable housing -Personal security -Access to social services and information	-reduction in the proportion of income on rent; -moved into longer-term/more stable housing -Improved nutrition/eating habits (decline in the incidence of hunger) -gained access to telephone/computers -improved access to public transit -increased awareness of available social services -increased personal security

Social Assets: -Ability to engage in the community and broader society including social connections -Peer support -Participation in decision-making	-improved ability to work in a team with other people -improved relationships with people in government and non-government organizations -connection to community support
Human Assets: -Personal identity including self-esteem -Self-confidence -Motivation	-interest in and ability to plan, -Improved self-care -self-improvement -greater self-confidence -Reduction in high-risk behavior and 'coping' strategies -Involvement in leadership activities -Participation in decision-making
Human Assets: -Skills -Knowledge	-Developing on-the-job skills - Pursuing further education and training
Financial Assets: -Economic security -Access to finance -Savings	-development of savings -money for basic needs -access to bank or MFI -decreased debt
Natural assets: -Access to natural resource	-availability of raw materials -availability of land -availability of water

Based on the above framework (Table 5.8), in each union, the following livelihood options will be sustainable (Table 5.9). According to respondents, homestead farming, slatted houses for livestock rearing, semi-scavenger houses for poultry rearing, fodder farming, biofertilizer production, and handicrafts are the most suitable livelihoods in the study area. Also, resilient crop farming, agroforestry, betel leaf farming, ecological and conservation farming, and horticulture are suitable for Hnila and Whykong. According to the respondents of the Sabrang Union, seagrass and seaweed farming and the value-added products from those farming products and mangroves can provide a suitable livelihood.

Table 5.8: Union-wise sustainable livelihoods.

Sustainable livelihood options	Union		
	Hnila	**Sabrang**	**Whykong**
Resilient crop farming			
Homestead farming			
Slatted houses for livestock rearing			
Semi-scavenger houses for Poultry rearing			
Aquaculture			
Resilient Fodder farming			
Agroforestry			
Betel leaf farming			

Sea Grass and seaweed farming			
Value-added products from seagrass and seaweed			
Value-added product from mangroves			
Ecological and conservation farming			
Biofertilizer production			
Handicrafts			
Horticulture			

5.2.4. Resilient Livelihoods final option

The climate-resilient livelihood final options have been identified using the following MATRIX (Table 5.9).

Table 5.9: Resilient Livelihood Matrix

Name of intervention	Climate change adaptation potentiality	Climate change mitigation potentiality	Less affected by climate extremes	Productivity	Cost-benefit ratio	Accessible for Women	Accessible for the person with a disability
Resilient crop farming							
Homestead farming							
Slatted houses for livestock rearing							
Semi-scavenger houses for poultry rearing							
Aquaculture							
Fodder farming							
Agroforestry							
Betel leaf farming							
Sea Grass and seaweed farming							
Value-added products from seagrass and seaweed							
Value-added product from mangroves							
Ecological and conservation farming							
Biofertilizer production							
Handicrafts							

Horticulture							

Climate-smart livelihood options can be short-duration or long-duration. In terms of the local ecosystem, climate vulnerability, and immediate outcome-oriented activities, the following activities can be undertaken in different timeframes (Table 5.11). There are some proposed livelihood interventions with a timeframe. That may help to choose a proper intervention with an appropriate timeframe and supporting organizations, such as GoB or others. Handicraft is the most demanding livelihood intervention, especially for women. The Department of Women and Children Affairs and the Department of Social Services can support introducing resilient livelihoods in the study area. With the help of the Department of Agriculture Extension, some medium and long-term resilient livelihoods can be introduced in the study area as long-term interventions: resilient crop farming (introduction of salinity-tolerant and drought-tolerant HYV crop varieties), homestead farming (introduction of salinity-tolerant and drought-tolerant HYV crop varieties), and in terms of medium timeframe interventions, betel leaf farming, ecological and conservation farming and horticulture (Custard Apple, Sofeda) can be introduced in the study area. Slatted houses for livestock rearing, semi-scavenger houses for poultry rearing, fodder farming (salinity-tolerant and drought-tolerant fodder variety promotion (local-Dhoincha and HYV) are short-term livelihoods and biofertilizer production medium-term resilient livelihoods can be introduced with the support of the Department of Livestock.

Based on the capital investment, yield period, and revenue return period, the timeframe was developed as short-term (3-6 months), medium-term (6-12 months), and long-term (above 12 months). The timeframe-wise potential interventions are provided in Table 5.10.

Table 5.10: Timeframe-wise resilient livelihood options

Livelihood options	**Timeframe**			
	Short time	**Medium time**	**Long time**	**Support seeking organization**
Resilient crop farming (Introduction of salinity-tolerant and drought-tolerant HYV crop varieties)				Department of Agriculture Extension
Homestead farming (Introduction of salinity-tolerant and drought-tolerant HYV crop varieties.)				Department of Agriculture Extension
Slatted houses for livestock rearing				Department of Livestock
Semi-scavenger houses for Poultry rearing				Department of Livestock
Aquaculture				Department of Fisheries

Fodder farming (Salinity-tolerant and drought-tolerant fodder variety promotion (local-Dhoincha and HYV)				Department of Livestock
Agroforestry				Department of Forest
Betel leaf farming				Department of Agriculture Extension
Sea Grass and seaweed farming				World Food Programme (WFP)
Value-added products from seagrass and seaweed (Pickle and molasses value chain development from mangrove (Keora-Sonneratia apetala and Goalpata-Nypa fruticans)				Deshojo Bazar, Zahanara Green Agro
Value-added products from mangroves (Promotion of nature-based solutions such as Golpata (Nypa fruticans) and Keora (Mangrove apple).				Deshojo Bazar, BRAC
Ecological and conservation farming				Department of Agriculture Extension
Biofertilizer production				Department of Livestock
Handicrafts				Department of Women and Children Affairs, Department of Social Services
Horticulture (Custard Apple, Sofeda)				Department of Agriculture Extension

The existing barriers and enabled factors considering the willingness, capacity, input support, and existing market opportunities are provided in the following Table 5.11.

Table 5.11: Barriers and enabled environments for highly potential selected climate-smart livelihood options in three unions.

Livelihood options	Barriers	Enabling factors	Proposed interventions/varieties

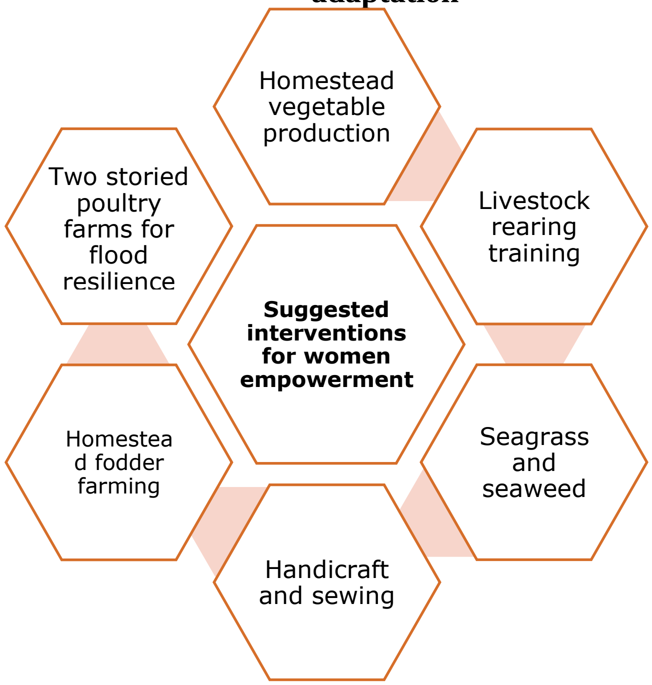
Resilient crop farming (Introduction of salinity-tolerant and drought-tolerant HYV crop varieties)	-Lack of access to resilient varieties -Lack of access to irrigation during dry periods	-Household and market demand -Interest in coping with the innovation -Supportive ecosystem	Salt-tolerant T. Aman (BR-22 and BR-23, Bina shail), Salt-tolerant BRRI dhan (33, 56, 57, and 62 BRRI dhan 40, 41, 53, 54, 65), Salt-tolerant Bina dhan (7 and 16 Bina dhan-8 and 10), Salt-tolerant potato, (BARI Alo-22, CIP Clone -88,163), Salt-tolerant sweet Potato, (BARI Mishti Alo-8,9), Salt-tolerant pulses, (BARI Mug-2,3,4,5,6, BM-01, BM-08 BARI Falon- 1, BARI Sola-9), Short-duration oilseeds, (BARI Sharisha-14,15 BARI Chinabadam 9, BINA China badam-1, BINA China badam-2, BARI Soyabean-6 BARI Til-2,3,4)
Homestead farming (Introduction of salinity-tolerant and drought-tolerant HYV crop varieties.)	-Lack of access to resilient varieties -Lack of access to irrigation during dry periods	-Household and market demand -Interest in coping with the innovation -Supportive ecosystem -Traditionally habituated with homestead farming	Salt-tolerant potato, (BARI Alo-22, CIP Clone -88,163), Salt-tolerant sweet potato, (BARI Mishti Alo-8,9), beets, pepper, cabbage
Fodder farming (Salinity-tolerant and drought-tolerant fodder variety promotion	-Lack of access to resilient varieties -Lack of access to irrigation during dry periods.	-Household and market demand. -Interest in coping with innovation -Supportive ecosystem -Potentiality to livestock, livestock-based product promotion.	Nepier-1, Nepier-2, Nepier-3, Nepier-4, Pakchang, Markiron, and Rokona, Dhoincha
Sea Grass and seaweed farming	-Lack of capacity	-Growing market -Supportive ecosystem	

Biofertilizer production	-Insufficient livestock	- Household and market demand -Interest in coping with innovation -Supportive ecosystem -Traditionally habituated with cattle and buffalo rearing	
Handicrafts	-Lack of capacity -Lack of access to finance	-Growing market -Interest in adopting intervention	
Horticulture	-Lack of access to seedling	-Historically salt-tolerant -Local and national market demand -Supportive ecosystem	Custard Apple, Sofeda

5.3. Gender-responsive adaptation plan

From the field observation, KIIs, and FGDs with community members, it was understood that some noteworthy interventions could be adopted for women empowerment and climate change adaptation among the women community in the study area. The participants stated that they lack knowledge of homestead vegetable production and gardening, so if they are provided with them, they could be more resilient. Along with homestead gardening, they could also be provided with training in livestock rearing and resilient fodder farming support. During the rainy season, women had to sit idle, so if they were provided with training on handicrafts and sewing along with a market linkage, then the women community could earn in this idle time along with handicrafts, and they could also rear poultry. If two storied poultry farms are made for poultry rearing during the flood, they can keep their poultries safe on the second floor, and during the dry season, both floors could be used for rearing.

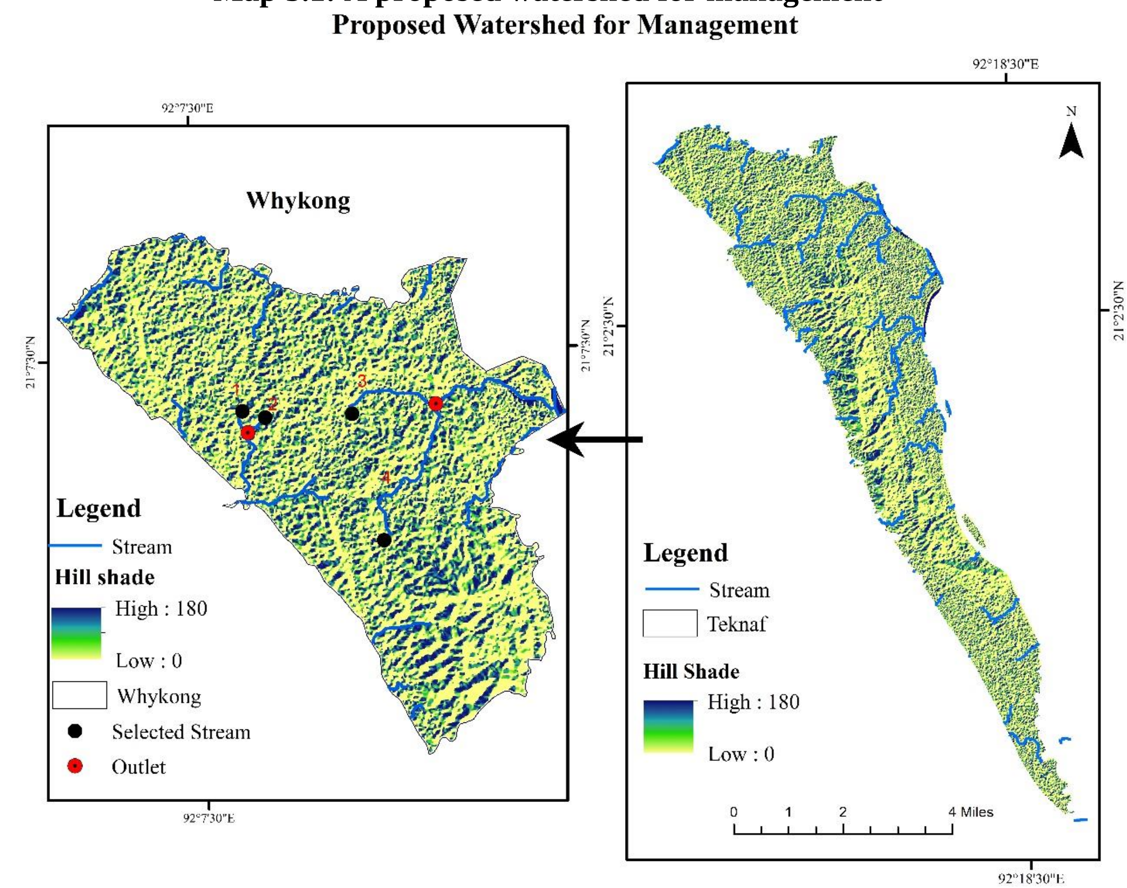
Figure 5.5: Suggested interventions for women's empowerment and climate change adaptation



5.4. Watershed management options

There is most important resilient intervention in the study area was found as watershed management to recover the drinking water and irrigation problem during winter and summer. In Hnila and Whykong, four watersheds were identified which can be potential sources of water for the community people. The volume of the watersheds was calculated with the help of the area and volume statistics module in ArcMap 10.3 3D Analyst Tool, in which the physical model of the water bodies was formed with the intersection of the underwater terrain obtained from TIN and water surface data. The physical model created was then divided into several triangular prisms by projecting each triangle vertex to the water surface **(Map 5.1).**

Map 5.1: A proposed watershed for management



The volume of water was then calculated by adding the volumes of each triangular prism based on the following equation.

$$V = \sum_{i=1}^{n} S_i \frac{(h_i + h_{i+1} + h_{i+2})}{3}$$

Where,

V=total volume of m^3,

Si is the projection area m^2 of the underwater terrain triangle surface on the water surface, h_i; h_{i+1} and h_{i+2} are the distance (m) of the underwater triangle vertexes to the water surface, and n is the number of triangular grids. The total volume of water (Liter) from each watershed is provided the following Table 5.12.

Table 5.12: Water supply potential from identified watersheds

Watershed No.	Length (M)	Width (M)	Height (M)			Water Volume (M2)	Water Volume (Liter)
			H1	H2	H3		
1	787.323	126	23	16	10	1620311	1620310734
2	760.618	100	28	14	10	1318405	1318404533
3	3212.445	112	24	11	7	5037114	5037113760
4	5466.171	85	47	25	7	12235113	12235112755

CHAPTER SIX
RECOMMENDATIONS AND CONCLUSION

6.1. Recommendations

It is an important part of the climate-resilient livelihood strategy for the Teknaf Upazila as well as an effective study; there is a need for an improved holistic approach. In terms of increased household income and its proper utilization, the Bangladesh Red Crescent Society and its allied partners should consider how it might be able to tackle multi-sectoral climate vulnerability. They should focus on areas where they can have the most impact by ensuring value for money, doing more with less, innovating, and partnering to impact against the climate change impacts. Livelihood interventions should also consider the impacts that a loss of livelihoods has on families and should seek interventions that effectively help curb negative coping mechanisms. This is particularly important for farmers in rural areas and other counterparts. Effective approaches include the integration of climate-resilient crop varieties, crop diversification, changing seasonal cropping patterns, and increasing irrigation.

Considering the scope of the project design and implementation in the study area, it is clear that BDRCS should explicitly address the climate-induced existing risks, as well as the potential risks that may be posed by the changing climatic scenario shortly. From this point of view, climate change adaptation and mitigation, as well as GHG-smart and women and disability-inclusive resilient livelihoods options should be introduced in the study area. Capacity building and training related to community-based local-led climate solutions and nutrition-sensitive should also be introduced to improve the health and well-being of the community people.

In the short term, the BDRCS can promote livelihood interventions that will yield benefits quickly, such as nutrition support and revenue generation. In the medium and long term, nature-based solutions can be promoted to contribute to carbon sequestration. At the community level, there is no climate information service, which is most important for climate-resilient livelihood promotion. In the long run, BDRCS can develop a climate information service along with early warning.

In terms of climate-resilient livelihood promotion in Teknaf, irrigation is crucial. Watershed management can be an efficient intervention that will contribute to autonomously resilient livelihoods in the community. The possible engagement of different government and non-government organizations including the Department of Agriculture Extension, Department of Livestock, Department of Forest, Department of Women and Children Affairs, Department of Social Service, Bangladesh Water Development Board, and those organizations working with climate-resilient livelihoods and nature-based solutions in nationally and locally will be more effective to ensure climate-resilient communities.

Along with some other climate-resilient crops and fodder varieties, Dhoincha, a local fodder variety with low cost, will be the more efficient agent of fodder. It has multi-co-benefits including carbon sequestration, protecting soil erosion, reducing soil salinity, and supporting the community as a source of food. Advocacy with the Water Development Board to ensure an outlet in the marine drive, and embankment is highly needed to recover agricultural land from the waterlogged area.

Market demand is growing for value-added products from seagrass and seaweed. Both species have soil salinity-reducing nature and carbon sequestration contribution. With a low-cost initiative, both interventions can be promoted to communities residing near the Bay of Bengal, especially in Sabrang. These interventions can also be promoted along the coastal belt of Bangladesh.

In Hnila, under the project, BDRCS can promote resilient crop farming, homestead farming, slatted houses for livestock rearing, semi-scavenger housing for poultry rearing, resilient fodder farming, agro-forestry, handicrafts, and biofertilizer production.

In Sabrang, homestead farming, slatted houses for livestock rearing, semi-scavenger housing for poultry rearing, resilient fodder farming, seagrass, and seaweed farming, value-added products from seaweed and seagrass, value-added products from mangroves, biofertilizer production, and handcrafts are suitable as climate-resilient livelihood interventions.

Similarly, in Whykong resilient crop farming, homestead farming, slatted houses for livestock rearing, semi-scavenger housing for poultry rearing, resilient fodder farming, agro-forestry, biofertilizer production, and handicrafts are climate-resilient potential livelihood interventions.

However, within a short time (6 months returnable) actionable climate climate-resilient livelihood interventions in all three unions are:

- Slatted houses for livestock rearing,
- Semi-scavenger houses for poultry rearing,
- Fodder farming (Salinity-tolerant and drought-tolerant fodder variety promotion (local-Dhoincha and HYV), and
- Handicrafts.

Value-added products from seagrass and seaweed, as well as pickle and molasses and value chain development from mangroves as NbS (Keora-Sonneratia apetala and Goalpata-Nypa fruticans), can be considered for the Sabrang union only.

The below summary of the potential livelihood options for the study area:

Proposed livelihood options	Name of union	Potential beneficiaries	Entities involved	Timeframe	Resources needed
Resilient crop farming (Introduction of salinity-tolerant and drought-tolerant HYV crop varieties)	Hnila, Whykong	Men	Department of Agriculture Extension	6-12 months	-Resilient varieties -Irrigation facilities during the dry period
Homestead farming (Introduction of	Hnila, Whykong, Sabrang	Men, women, youth, and	Department of	6-12 months	-Resilient varieties

salinity-tolerant and drought-tolerant HYV crop varieties.)		persons with disabilities	Agriculture Extension		-Irrigation facilities during the dry period
Slatted houses for livestock rearing	Hnila, Whykong, Sabrang	Women, youth, and persons with disability	Department of Livestock	3-6 months	-Training on slatted house preparation - Slatted houses for poor families
Semi-scavenger houses for Poultry rearing	Hnila, Whykong, Sabrang	Women, youth, and persons with disability	Department of Livestock	3-6 months	-Training on semi-scavenger house preparation - Semi-scavenger for poor families
Fodder farming (Salinity-tolerant and drought-tolerant fodder variety promotion (local-Dhoincha and HYV)	Hnila, Whykong, Sabrang	Women, youth, and persons with disability	Department of Livestock	3-6 months	-Salinity and drought-tolerant fodder varieties
Agroforestry	Hnila, Whykong	Men, and youth	Department of Forest	Above 12 months	-Training on mixed cropping in agroforestry
Betel leaf farming	Hnila, Whykong	Men, and youth	Department of Agriculture Extension	Above 12 months	-Training on improved betel leaf farming
Sea Grass and seaweed farming	Sabrang	Men, women, youth, and persons with disabilities	World Food Programme (WFP)	6-12 months	-Training on seagrass and seaweed farming -Demonstration input support
Value-added products from seagrass and seaweed (Fertilizer, and	Sabrang	Men, women, youth, and persons with disabilities	Deshojo Bazar, Zahanara Green Agro	3-6 months	-Training on fertilizer, and cosmetics production -Market access

cosmetics) production					opportunity creation
Value-added products from mangroves (pickle and molasses) production	Sabrang	Men, women, youth, and persons with disabilities	Deshojo Bazar, BRAC	6—12 months	-Training on pickle and molasses production -Market access opportunity creation
Biofertilizer production	Hnila, Whykong, Sabrang	Men, women, youth, and persons with disabilities	Department of Livestock	3-6 months	-Training on biofertilizer production. -Cattle rearing support.
Handicrafts	Hnila, Whykong, Sabrang	Men, women, youth, and persons with disabilities	Department of Women and Children Affairs, Department of Social Services	3-6 months	-Sewing machine. -Training on handicrafts
Horticulture (Custard Apple, Sofeda)	Hnila, Whykong	Men, women, youth, and persons with disabilities	Department of Agriculture Extension	Above 12 months	Salinity tolerant seedling

6.2. Conclusion

In conclusion, this study has explored deep into the pressing challenges faced by the impoverished, predominantly female, and vulnerable communities in the study area in the wake of current and impending climate change impacts. These communities find themselves at the mercy of nature's unpredictability, grappling with shifting climatic parameters, and the increasing frequency of sudden and slow onset climate extremes. The implications of these challenges are not merely theoretical; they manifest in profound ways, shaking the very foundations of livelihoods and the environment.

The relentless changes in rainfall and temperature, coupled with the rise in climate extremes such as salinity intrusion, cyclones, and tidal inundation, have left farmers, fishermen, and day laborers vulnerable to food insecurity. These climatic adversities not only lead to declining crop productivity and land degradation but also hinder rainfed agriculture and disrupt fishing livelihoods. The shrinking agricultural and fishing sectors have compelled many to seek alternative sources of income, making day labor a precarious means of subsistence. Furthermore, livestock rearing, once a reliable source of income, has been plagued by the extinction of local fodder varieties due to salinity. Cold waves and heat stress during winter and summer exacerbate the challenges faced by poultry and livestock, increasing disease rates and mortality.

To counter these formidable challenges, a suite of carefully tailored livelihood interventions emerges as a beacon of hope. Climate-resilient crop varieties, salinity-tolerant and drought-tolerant fodder varieties, semi-scavenger and slatted houses for livestock and poultry, handicrafts, and nature-based solutions like seaweeds, seagrass, and mangrove farming have been identified as highly potential strategies. These interventions are not just abstract ideas; they are directly linked to mitigating the climate risks and impacts outlined above.

The feasibility of these interventions is grounded in their alignment with the historical practices of the community. Climate-resilient crop varieties and fodder options cater to the agricultural and livestock heritage of the people, making adoption a natural progression. The introduction of semi-scavenger and slatted houses promises to protect valuable livestock and poultry assets effectively. Handicrafts offer a viable income diversification strategy, particularly for those without access to arable land. Meanwhile, the cultivation of seaweeds, seagrass, and mangroves presents not only environmental benefits but also lucrative market opportunities. Importantly, these interventions are not generic solutions but rather finely-tuned responses to the identified climate risks and their tangible impacts on the community. They provide practical ways to enhance resilience by directly addressing the vulnerabilities and challenges faced by these communities.

In the face of adversity, these proposed livelihood interventions offer more than just optimism; they represent a pragmatic approach to building a more resilient future for the studied populations. Rooted in the historical context of these communities, these strategies are not only feasible but also hold the promise of being highly effective. They stand as tangible solutions, intricately tailored to the unique climate risks and impacts experienced by these vulnerable populations. In sum, they signify a pathway towards a more sustainable and secure livelihood in a changing climate.

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Annex I
Descriptive statistics of the climate adaptive livelihood practices

Variable	Variable description	Mean	Std. Dev	Min	Max
Climate-smart agriculture	Adoption of climate-smart agriculture (Dummy, yes = 1, no = 0)	0.777778	0.41574	0	1
Climate-smart livestock	Adoption of climate-smart livestock (Dummy, yes = 1, no = 0)	0.756757	0.429041	0	1
Climate-smart poultry	Adoption of climate-smart poultry (Dummy, yes = 1, no = 0)	0.884615	0.319486	0	1
Homestead farming		0.786517	0.409766	0	1
Slatted houses for Livestock rearing	Adoption of homestead farming (Dummy, yes = 1, no = 0)	0.71164	0.452999	0	1
Semi-scavenger houses for Poultry rearing	Adoption of semi-scavenger houses for poultry rearing (Dummy, yes = 1, no = 0)	0.695767	0.460082	0	1
Aquaculture	Adoption of aquaculture (Dummy, yes = 1, no = 0)	0.815385	0.387985	0	1
Fodder farming	Adoption of fodder farming (Dummy, yes = 1, no = 0)	0.855204	0.351895	0	1
Agroforestry	Adoption of agroforestry (Dummy, yes = 1, no = 0)	0.868852	0.337562	0	1
Resilient boat for Sea Fishing	Adoption of resilient boat for	0.791971	0.405898	0	1

	sea fishing (Dummy, yes = 1, no = 0)				
Resilient boats for river fishing	Adoption of resilient boat for river fishing (Dummy, yes = 1, no = 0)	0.487324	0.316196	0	1
Betel leaf farming	Adoption of betel leaf farming (Dummy, yes = 1, no = 0)	0.478049	0.327229	0	1
Sea Grass and seaweed farming	Adoption of seagrass and seaweed farming (Dummy, yes = 1, no = 0)	0.357143	0.202535	0	1
Value-added products from seagrass and seaweed	Adoption of value-added product seaweed and seagrass (Dummy, yes = 1, no = 0)	0.377778	0.41574	0	1
Value-added product from mangroves	Adoption of value-added products from mangroves (Dummy, yes = 1, no = 0)	0.351479	0.432155	0	1
Biofertilizer production	Adoption of biofertilizer production (Dummy, yes = 1, no = 0)	0.557576	0.42855	0	1
Biopesticide production	Adoption of biopesticide production (Dummy, yes = 1, no = 0)	0.413043	0.281771	0	1
Small cottage	Adoption of small cottage (Dummy, yes = 1, no = 0)	0.522727	0.499483	0	1
Handicrafts	Adoption of handicrafts	0.842105	0.364642	0	1

	(Dummy, yes = 1, no = 0)				
Horticulture	Adoption of horticulture (Dummy, yes = 1, no = 0)	0.787879	0.40881	0	1
Flood	If people experience flood (Dummy, yes = 1, no = 0)	0.844444	0.362433	0	1
Flash flood	If people experience flash flood (Dummy, yes = 1, no = 0)	0.833333	0.372678	0	1
Strong wind	If people experience strong wind (Dummy, yes = 1, no = 0)	0.888889	0.31427	0	1
Water logging	If people experience waterlogging wind (Dummy, yes = 1, no = 0)	0.857143	0.349927	0	1
Tidal inundation	If people experience tidal inundation (Dummy, yes = 1, no = 0)	0.911765	0.283637	0	1
River bank erosion	If people experience strong wind (Dummy, yes = 1, no = 0)	0.074074	0.261891	0	1
Thunderstorm	If people experience thunderstorm (Dummy, yes = 1, no = 0)	0.789474	0.407682	0	1
Drought	If people experience drought (Dummy, yes = 1, no = 0)	0.944444	0.229061	0	1
Heatwave	If people experience	0.969697	0.17142	0	1

	heatwave (Dummy, yes = 1, no = 0)				
Cold wave	If people experience coldwave (Dummy, yes = 1, no = 0)	0.351852	0.477548	0	1
Landslide	If people experience landslide (Dummy, yes = 1, no = 0)	0.222222	0.41574	0	1
Cyclone	If people experience cyclone (Dummy, yes = 1, no = 0)	0.833333	0.372678	0	1
Migration potentiality	If people are interested in migrating (Dummy, yes = 1, no = 0)	0.941176	0.235294	0	1
Agricultural land ownership	If farmers have agricultural land (Dummy, yes = 1, no = 0)	0.782609	0.412471	0	1
Size of agricultural land	Size of land	19.78621	25.58345	2	160
Ownership of pond/gher	If farmers have pond/gher (Dummy, yes = 1, no = 0)	0.047619	0.212959	0	1
Size of pond/gher	Size of pond/gher	20.66667	31.83639	2	120
Household size	Number of family members (cont.)	4.891	1.655	1	11
Age	Age of the farming household head	50.735	1.718	18	82
Government services	Access to Govt. Extension (Dummy, yes = 1, no = 0)	0.662	0.474	0	1

Inputs	If farmer avails inputs (Dummy, yes = 1, no = 0)	0.397	0.49	0	1
Access to finance	If farmers have access to the bank (Dummy, yes = 1, no = 0)	0.249	0.49	0	1
Livestock index	The index of various livestock	0	1.119	-1.249	9.046
Access to NbS	If people have access to NbS (Dummy, yes = 1, no = 0)	0.662	0.474	0	1
Fishing practices	If people are involved with fishing (Dummy, yes = 1, no = 0)	0.397	0.49	0	1
Hnila	If the respondent belongs to Hnila (Dummy, yes = 1, no = 0)	0.50	0.707107	0	1
Whykong	If the respondent belongs to Whykong (Dummy, yes = 1, no = 0)	0.50	0.707107	0	1
Sabrang	If the respondent belongs to Sabrang (Dummy, yes = 1, no = 0)	0.50	0.707107	0	1