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Watershed Management Plan for the Landscape Area of Teknaf Wildlife Sanctuary

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Watershed Management Plan for The Landscape Area of The Teknaf Wildlife Sanctuary

USAID's Nature Conservation through Livelihoods Improvements (Nature and Life) Project.

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It is our hope that this study will contribute meaningfully to the sustainable management of our vital water resources in Teknaf.

Dr. Shital Kumar Nath
Project Director, Nature and Life Project

Preface

This book is on the **Watershed Management Plan** for the **Landscape Area of Teknaf Wildlife Sanctuary (TWS)**, located in the Southeastern tip of Bangladesh, is currently facing a water management crisis that is causing negative impacts on biodiversity, human livelihoods, and ecological balance due to population growth, climate change, refugee influx, and unplanned development. The Rohingya refugee crisis has made matters worse by tripling the number of people relying on the watershed for their water supply.

The CODEC's Nature and Life Project funded by USAID has undertaken a study to identify the challenges facing the area in developing a watershed management plan from natural, socio-economic, and infrastructural perspectives. The book offers a scope of simple divergences in water accessibility, with affluent individuals exploiting resources and leaving streams dry downstream due to the lack of regulatory mechanisms in addition the discrete spread of aquifers has exacerbated the decline of groundwater levels. The environment is suffering from the loss of forest cover and increasing agriculture within the forests. These factors have led to a decrease in infiltration, an increase in sedimentation, and a compromise in water quality. This degradation, combined with select families' commercial control of water, has created inequality and social discord.

The government has made efforts in terms of projects to address the gravity of the water scarcity situation in communities living near the TWS landscape areas. However, the programs undertaken so far seemed inadequate and poorly coordinated, and there was dissatisfaction with the modality of beneficiary selection and management of the programs. Aiming the issues identified and the ongoing efforts in place and emphasizing the community aspirations regarding services from the watershed, a watershed management plan has been proposed here to distribute water equitably, augment groundwater with artificial aquifers, improve water quality, restore forests for watershed resilience, and develop comprehensive land and water use guidelines to safeguard watershed health in the book. CODEC has always encouraged this type of work since its journey, in 1985.

Our sincere gratitude to the authors of the book, **Professor Dr. Mohammad Mosharraf Hosasain** and **Md Abul Kalam Azad** for their inordinate expertise and leadership in shaping this book and **Dr. Shital Kumar Nath**, Project Director, Nature and Life Project to lead editing the book.

Khursid Alam *Ph.D.*
Executive Director
CODEC

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Abbreviations

AEO	Agriculture Extension Officer
AHP	Analytic Hierarchy Process
ASR	Aquifer Storage and Recovery
BADC	Bangladesh Agricultural Development Corporation
BBS	Bangladesh Bureau of Statistics
BFD	Bangladesh Forest Department
BFIDC	Bangladesh Forest Industries Development Corporation
BOD	Biological Oxygen Demand
BWDB	Bangladesh Water Development Board
CFS	Cubic Feet Per Second
CHTs	Chittagong Hill Tracts
CMCs	Co-Management Committees
COD	Chemical Oxygen Demand
CODEC	Community Development Center
CPGs	Community Petrol Groups
DAE	Department of Agricultural Extension
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DOC	Dissolve Organic Carbon
DoE	Department of Environment
DoF	Department of Fisheries
DPHE	Department of Public Health Engineering
EC	Electric conductivity
ECAs	Ecologically Critical Areas
ERTs	Elephant Response Team
FDMNs	Forcefully Displaced Myanmar Nationals
FGDs	Focused Group Discussions
GEE	Google Earth Engine
GIS	Geographic Information System

GPGs	Good Practice Guidelines
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HYV	High-yielding Variety
ICDDR,B	International Centre for Diarrheal Disease Research, Bangladesh
IPM	Integrated Pest Management
JAICA	Japanese Agency for International Cooperation
KIIs	Key Informant Interviews
LGED	Local Government Engineering Department
LULC	The Land Use and Land Cover
NGOs	Non-Government Organizations
NTFPs	Non-timber Forest Products
NTU	Nephelometric Turbidity Unit
OSM	Open Street Map
PA	Protected Area
PCA	Principal Component Analysis
PFs	Peoples' Forums
PIO	Project Implementation Officer
RAs	Research Assistants
RGB	Red Green Blue
RWH	Rain Water Harvesting
SCRIDP	South Chittagong Rural Infrastructure Development Project
SMW	Sangu-Matamuhuri Watershed
SSWRDP	Small Scale Water Resource Development Project
SWAT	Soil and Water Assessment Tool
TDS	Total Dissolved Solids
TPI	Topographic Position Index
TWI	Topographic Wetness Index
TWS	Teknaf Wildlife Sanctuary
UNO	Upazila Nirbahi Officer
USAID	United States Agency for International Development
USGS	United States Geological Survey

VCFs	Village Conservation Forums
WARPO	Water Resources Planning Organization
WatSan	Water and Sanitation
WDB	Water Development Board
WMC	Watershed Management Committee
WMP	Watershed Management Plan
WUG	Water User Group

Executive Summary

The Teknaf Wildlife Sanctuary, located in the Southeastern tip of Bangladesh, is currently facing a water management crisis that is causing negative impacts on biodiversity, human livelihoods, and ecological balance. This situation has arisen due to population growth, climate change, refugee influx, and development. The Rohingya refugee crisis has made the matter worse by tripling the number of people relying on the watershed for their water supply. The CODEC's Nature and Life Project has undertaken this study to identify the challenges facing the area in developing a watershed management plan from natural, socio-economic, and infrastructural perspectives. The study has revealed stark discrepancies in water accessibility, with affluent individuals exploiting resources and leaving streams dry downstream due to the lack of regulatory mechanisms. The study also found that the discrete spread of aquifers has exacerbated the decline of groundwater levels. The environment is suffering from the loss of forest cover and increasing agriculture within the forests. These factors have led to a decrease in infiltration, an increase in sedimentation, and a compromise in water quality. This degradation, combined with select families' commercial control of water, has created inequality and social discord.

The government has made efforts in terms of projects to address the gravity of the water scarcity situation in communities living near the Teknaf Wildlife Sanctuary. However, the programs seemed inadequate and poorly coordinated, and there was dissatisfaction with the modality of beneficiary selection and management of the programs. Considering the issues identified and the ongoing efforts in place and emphasizing the community aspirations regarding services from the watershed, a watershed management plan has been proposed. The plan aims to distribute water equitably, augment groundwater with artificial aquifers, improve water quality, restore forests for watershed resilience, and develop comprehensive land and water use guidelines to safeguard watershed health. The plan includes the strategic development of community-created artificial aquifers, the protection of riparian buffers, the mapping of streams and aquifers, afforestation, and the creation of prudent land-use guidelines. Implementing this plan requires the formation of vigilant Water Management Committees, standardization, the integration of riparian restoration in water projects, and the use of Geographic Information System (GIS) and Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) for more objective and science-backed planning of projects related to watershed in the area. The plan's evaluation will depend on defined benchmarks, systematic water monitoring, and an adaptable management structure that responds to real-time feedback. This management plan is a clarion call to unite all stakeholders in upholding sustainable watershed stewardship, a crucial prerequisite for TWS's enduring resilience and the prosperity of its communities. It is time for all parties to come together and take action to address this water management crisis before it is too late.

Background

1.1. Teknaf Wildlife Sanctuary

Teknaf Wildlife Sanctuary (TWS) is a protected area (PA) in the Cox's Bazar District of southern Bangladesh. TWS comprises a hill forest area of 11,615 ha (44.85 sq mi). Before being PA, TWS was designated as Teknaf game reserve in 1983, the only game reserve in the country. In 2009, the government of Bangladesh declared the game reserve as PA, designating it as a wildlife sanctuary. TWS is situated in the Teknaf peninsula in the south-eastern corner of Bangladesh. Teknaf peninsula is bounded on the west side by the Bay of Bengal and on the east side by the Naf River, the border between Bangladesh and Myanmar. In between the river and sea, in the middle of the peninsula, lies the Teknaf Hill range. The human settlements lie on the West, North, and East of the hills and valleys cutting the hill range. From an administrative standpoint, the peninsula is known as Teknaf Upazilla, consisting of 5 Unions: Baharchara, Hnila, Sabrang, Teknaf, and Whykong. This vast sub-tropical forest at TWS has several other attractions, such as Nitong Hill, Kudum Cave, Kuthi Hill, etc. The famous Toinga Peak of the peninsula has an elevation of about 1000 feet. Of particular note within the Wildlife Sanctuary is Teknaf Nature Park. This easily accessed area has a shady forest, three small lakes, three hiking trails, an interpretation center, and visitor accommodation.

Once, TWS was rich with extensive tropical mixed evergreen forests. Patches remain, but much of the original forest has been cleared or degraded since the 1990s due to anthropogenic and natural disturbances. TWS is rich in floral and faunal biodiversity. The fauna of the TWS has only been partially studied, but the wider Teknaf peninsula has rich faunal diversity. Some 260 species of birds have been reported, including the impressive and globally vulnerable Great Slaty Woodpecker and Grey Peacock Pheasant. Besides, mammals such as Rhesus Macaque and Hog Badger are available here. TWS is home to the last population of Long-tailed Macaque in Bangladesh. TWS is one of the few places in Bangladesh where Asian elephants can be seen in the wild. Coastal communities and ecosystems here are vulnerable to cyclones and tidal surges.

Despite degradation, TWS is still home to a small population of endangered Asian Elephants, which regularly conflicts with local people. TWS is under Cox’s Bazar South Forest division, consisting of three ranges: Teknaf, Shilkhali, and Whykong, respectively, consisting of 4, 3, and 3 beats. As a protected area (PA), as per PA rules 2017, the TWS is under co-management. In three ranges, there are three co-management committees (CMCs). This CMC is working with the Bangladesh Forest Department (BFD) to change attitudes and conserve elephants in a coordinated way. The CMC have recently been reformed through the Nature Conservation through Livelihoods Improvements (Nature and Life) project, which is under implementation by the Community Development Center (CODEC) and funded by the United States Agency for International Development (USAID).

Despite efforts to establish protected areas like the TWS and Inani National Park, the challenges posing a threat to forests and biodiversity within the region have persisted and been compounded by the influx of Rohingya refugees. This influx has adversely impacted forests and endangered species habitats, profoundly affecting the environment and the livelihoods of local communities. The effect of the Rohingya influx has been particularly acute in Cox's Bazar, including Teknaf and Ukhiya, where over 6000 acres of forest have been degraded, impacting ecologically critical areas. Short-term effects of this influx include escalated local prices for essentials, increased pressure on resources, reduced public services, and heightened competition for jobs.

1.2. Nature and Life Project

The 'Nature conservation through livelihoods improvements (Nature and Life) project' is focused on improving natural resources and conserving TWS ecosystems with the involvement of a successful co-management model and increasing livelihood options to reduce dependency on the forest. The Nature and Life project implements forest landscape restoration and conservation with livelihood improvement of forest-dependent communities at all three (3) forest ranges of the TWS.

The Nature and Life Project of CODEC ensures effective engagement of the Government of Bangladesh and its concerned Agencies, including the BFD and Local Government Institutions such as Union and Upazila Parishads, as well as conservation-focused grassroots organizations, i.e., CMCs. Furthermore, CODEC engages with at the required level different GoB line agencies, including the Department of Agricultural Extension (DAE), the Department of Fisheries (DoF), Livestock Department, the Department of Social Welfare, etc., to ensure adequate livelihood programs host communities. The Department of Environment (DoE) has been coordinated to ensure conservation initiatives in the ecologically critical areas (ECAs) of the Teknaf peninsula and turtle conservation.

The component-wise objectives of the Nature and Life project include

(a) ***Environmental Conservation and Climate Change:*** Restoration of degraded ecosystems in the TWS

(b) ***Livelihood development focusing on WASH facilities and Private Sector Engagement***: Livelihoods development of natural resources dependent on host community households

(c) ***Alternative fuel:*** Targeted host communities adopt less damaging fuel alternatives to firewood.

(d) ***Local capacity building***: Strengthening the capacity of Co-management organizations and their sub-units, e.g., Peoples' Forums (PFs), Village Conservation Forums (VCFs), Community Petrol Groups (CPGs) and Elephant Response Teams (ERTs), Eco-guides, etc. as well as people working at CODEC.

(e) ***Cross-cutting***: Gender, Communication, COVID-19 response, different studies, support to BFD, etc.

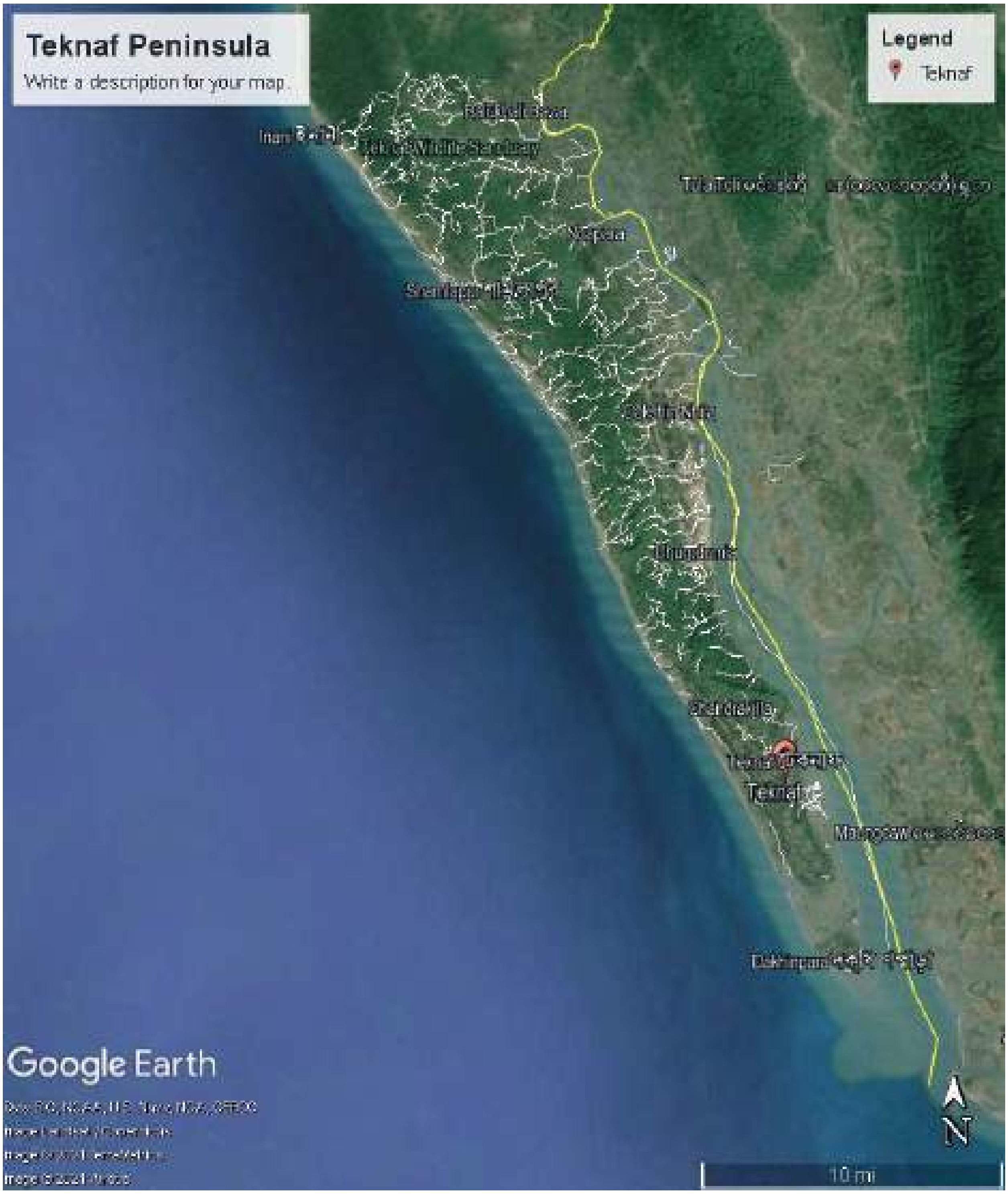
1.3. Watershed and TWS

TWS has elevated hilly topography of different elevation ranges in the middle part of the peninsula, running in the north-south direction. As shown in Map 1, on the east side of the peninsula, the Naf River flows, and on the western side lies the Bay of Bengal. The Naf River estuary is at the peninsula's north tip. There are narrow strips of flat land on the peninsula's east, west, and northern parts, bordering the hilly topography in the middle. The settlements comprise villages, a few small townships, and one municipality – the Teknaf Municipality. Besides the strips of flat lands, mainly used for agriculture, salt pans, and fisheries settlement, there are flat valleys inside the hilly terrain through which the hilly streams originate from the TWS flow, and the lands are also used for farming. There are settlements of tribal communities inside the forest areas. In addition, local communities are also encroaching on the TWS land for settlements, agriculture, and horticulture. Satellite image shows the presence of waterbodies created artificially by erecting dams in hilly streams.

Many streams covering varying sizes of basins flow from the TWS to the east towards the Naf River, to the west towards the Bay of Bengal, and to the north towards the estuary. The degradation of forest cover and changes in land use over the past decades have reduced the water-holding capacity of the TWS forest and its soils, reducing the water flow in the streams. Many streams, which were perennial in the past, have become seasonal and are active only in the rainy season.

Many streams at their downstream locations receive saline water inflow during the tide from the Bay and the river. People try to prevent the inflow of saline water to protect their agricultural land from being affected by salinity. However, salt farmers deliberately allow saline water for salt extraction, which is one of the significant economic activities and, at the same time, the leading cause of increased soil salinity in farming lands. Bangladesh Forest Department has historically been practicing monoculture of commercial timber or fuelwood species as the main plantation species, contributing to the rapid decline in the watershed health. However, the BFD is now inclined more towards mixed plantations in their recent activities.

Streams are the only source of drinking water for wildlife biodiversity. TWS—once rich in wildlife biodiversity, for which it was declared a game reserve in the past—is seeing a decline in wildlife diversity, and watershed degradation is one of the major drivers. Wildlife conservation at TWS will depend mainly on the preservation and restoration of the watershed therein.



Map 1: Teknaf & Ukhiya Peninsula with the TWS watershed area.

Historically, due to patchy aquifers in the TWS watershed and the changes in the climate, people in TWS adjoining areas have been suffering from water scarcity, particularly in the dry season when most of the ponds and makeshift water reservoirs become dry. The streams from the TWS have been the mainstay of meeting water demand for people in the area. However, as the population is increasing, and the Rohingya refugee crisis has put tremendous pressure on the local water resources, the pressure on streams has increased, which leads to competition in accessing the water resources from the stream. Affluent families started erecting dams in the upstream areas to withdraw water by pipes, and anyone can see that pipes are coming out of the forest through the stream banks. Such water withdrawal from upper watershed areas is again accelerating the drying up of the downstream zones of the watershed and creating inequality among the communities in accessing water.

The TWS watershed has been recharging the local groundwater table, which past studies have marked as patchy and discrete, discontinuous in nature. This means there are no continuous aquifers from which people can draw water. In some spots, aquifers are available, and owners of those lands can get water. However, people have erected too many shallow or deep tubewells to draw water from these aquifers, leading to faster depletion.

Development activities in the TWS area, like the construction of the marine drive in the past, the construction of roads and other infrastructure in the hilly terrains, the unplanned erection of dams and sluice gates, unplanned settlements blocking the streams and flowed water flow paths and allocation of land for other land uses have caused significant damage to the watershed components in the past. The invasion of commercial farming and horticulture, besides the subsistence farming of tribal communities, which depend on the intensive use of agrochemicals and pesticides, is another source of water quality degradation.

Climate change is another stressor of the watershed in the area, largely due to the changing rainfall amount and rainfall patterns. The past degradation of forests and land is seeing enhanced susceptibility to landslides due to changing climate, which is becoming a significant threat to the overall morphology and functionality of the watershed.

1.4. Management of TWS Watershed

Currently, there is no organized management for watersheds at TWS. BFD is the government entity entitled to manage the forests, lands, and wildlife within the TWS watershed areas. However, BFD does not have any specific activities concerning the management of the TWS watershed. They mainly try to prevent encroachment, illicit felling, and raising new plantations through different initiatives and projects besides caring for wildlife-related affairs. Non-Government organizations (NGO's) collaborate with BFD under different projects linked to the watershed. Most NGO projects are related to reducing grievances in host communities due to refugee influx. After the 2017 Protected Areas rules, BFD, with help from NGO CODEC under USAID funding, has formed three CMC's in three ranges. However, the CMC's have not yet focused intensely on watershed-related issues.

The Department of Public Health Engineering (DPHE) is not directly associated with managing the watershed. Still, it has a significant stake in it as it is entitled to ensure safe drinking water for the local people. DPHE has been distributing shallow and deep tube wells with pumps among the people involved in their project. They also distribute rainwater harvesting setups, including 3000 L water, to support vulnerable families in becoming resilient against water scarcity during the dry season. However, there is community dissatisfaction regarding the mechanism of beneficiary selection for tube wells and rainwater harvesting systems as well as extra cost over DPHE fees that the people are charged by the people selecting them. DPHE is also piloting with World Bank funding to establish a rural water supply system using a single surface water treatment plant for several villages by erecting dams on the stream. They plan to operate the facility for a few years and train the local people under the leadership of Union Parishad to manage the plant using funds collected from the people who are getting connections from the plant. As connections are given to one household for every five families, people complained regarding accessibility, indicating a managerial and administrative gap. DPHE has also established a water reservoir at camp 26 in the hills under the jurisdiction of BFD to store rainwater and treat it to supply the camp and some parts of Ukhiya. It has plans for similar projects for Teknaf.

The Department of Agricultural Extension (DAE) supports farmers' agricultural endeavors. In Teknaf, the DAE is grappling with issues of providing irrigation support. Bangladesh Agricultural Development Corporation (BADC) is responsible for the irrigation projects, but due to the smaller basins, they do not have much presence in Teknaf upazila. They operate from their district office in Cox's Bazar.

The Local Government Engineering Department (LGED) has been deeply involved with activities and projects related to the watershed of TWS as the streams come out of the hills. They are erecting rubber dams and other tidewater control structures. The Water Development Board (WDB) is responsible for the polders and coastal embankments. They also operate their district office in Cox's Bazar, and WDB seems to play indirect roles in the watershed-related affairs.

The Upazila Nirbahi Officer (UNO) office oversees the Water Management Committee at the Upazilla, but contrary to its name, the committee's activity is limited. It is responsible for permitting the application of low-cost electricity connections for irrigation pumps.

Teknaf Municipality is severely suffering from the water crisis, and its water security is linked to the health and management of the TWS watershed. However, its participation in water management seems inadequate. Currently, it is dependent on unreliable and low-quality groundwater, and they have a project in the pipeline to use hilly stream-based water treatment to meet future demands.

Union Parishad is becoming important in water management through its Water and Sanitation (WatSan) committee. This committee is responsible for beneficiary selection and channeling funds for local governance, including water governance.

Under the unfolding water insecurity and watershed degradation, resilience and adaptation will depend on coordinated management of the watershed and water withdrawal management, which requires a coordinated and structured management system.

1.5. Objectives

The forest restoration and conservation activities done so far under the Nature and Life project are expected to positively influence the watershed's components and awareness among people of the watershed. CODEC expects to design more focused activities considering local awareness and aspirations to guide CMCs for the conservation and restoration of the watershed in the backdrop that the Teknaf peninsula is one of the most water-vulnerable areas in Bangladesh, with the population suffering from water crisis, specifically during the dry season. The specific objectives of this watershed study are the following –

1. Conducting inception meetings with project stakeholders and initial site visits to gather initial information and data required for,
   a) Developing a detailed watershed map for the PA,
   b) Mapping and assessment of water discharge and quality of water from streams within the PA, including groundwater levels and quality, rainfall trends, etc.,
   c) Developing the baseline for water harvesting structures and water demand in the PA,
   d) Assessing community awareness of the watershed, knowledge of its status, associated challenges, and aspirations from it.
2. Conduct a macro-level assessment of watershed areas within the PA to understand its characteristics, focusing on streams flowing in the PA to make a digital watershed map.
3. Identify hotspots for interventions in the PA based on the assessments for implementation support from the project through CMC.
4. Develop a watershed management plan for the PA, focusing on conserving the headwater region and improving riparian buffers for increased water discharge and improved water quality.
5. Propose a monitoring framework for the watershed of the PA to monitor its health.

Methodology

2.1 Description of the Study Area

2.1.1 Climate and Weather

The climate of the TWS (generally warm and humid) is characterized by three seasons – winter, summer, and monsoon rains. There is heavy dew during winter when rainfall is low. The water condensation is thus distributed throughout the year in different forms and greatly influences plants and monsoon rains (Alam et al., 2014). According to the Bangladesh Bureau of Statistics (BBS), the average annual rainfall in Teknaf is 2960 mm, with maximum rainfall in July (1003 mm) and minimum in January-March. The sanctuary enjoys a moist tropical maritime climate, and rainfall is frequent and heavy during the monsoon season (May to October), ranging between 130 mm and 940 mm (BBS, 2011). The temperature may range from 16.3ºC in January to 33.6ºC in May. The standard minimum and maximum normal temperature in this region, 1981-2010, is 22.1ºC and 30.2ºC (BBS, 2022). In contrast, humidity is high in the TWS throughout the year, with monthly average humidity varying from monsoon rains, ranging from 27.6% in April to 98.6% in August (BBS, 2011).

2.1.2 Topography

The topography of TWS is very undulating, covered with a linear hill range with an uneven surface. Still, the elevation is below 300 m and does not change much, and the east side slope is steeper than the west side. (Moslehuddin et al., 2018), gently sloping to rugged hills and cliffs running down the central part of the peninsula, with a north-south length of nearly 28 km and an east-west width of 3-5 km (Choudhury, 1969).

The Piedmont plains, located at the foothills, are characterized by gentle slopes and are commonly inhabited by human settlements. Covering 31% of the total land area, these plains reach a maximum elevation of 10 m, predominantly situated on the hills' western, eastern, and southern sides, creating a continuous belt running from north to south across the peninsula. (Moslehuddin et al., 2018). The sandy beaches cover 3,155 hac, accounting for 9.03% of the total area, and are situated on the peninsula's western side adjacent to the Bay of Bengal. The highest mean elevation in Teknaf is approximately 55 m, while in the Teknaf and Whykong unions, it is estimated at 31 m. Conversely, the lowest average elevation is found in the Sabrang and Hnila unions, measuring 5 m (Hassan et al., 2018).

The range has several projections running towards east and west and interspersed by valleys, gullies, and streams. These are crossed by numerous streams flowing down to the Naf River in the east and the Bay of Bengal in the west. Most of the streams are seasonal and dry up during the off-monsoon season. The hills of the Sanctuary are composed of upper tertiary rocks (Pliocene and Miocene epoch) with three representative geological series: Surma, Tipam, and Dhupitila. (Choudhury, 1969). The soils vary from clay to clayey loam on level ground and from sandy loam to coarse sand on hilly land. (Choudhury, 1969; Uddin et al., 2013).

2.1.3 Landform

The TWS consists of gently sloping to rugged hills and cliffs running down the central part of the peninsula (Mollah et al., 2004). Physiographically, the Teknaf peninsula is mainly comprised of hills, a piedmont plain, a tidal floodplain, and a beach, with a minor area of coral beach. These areas cover approximately 80% of the total landmass. The hill area covers 14,602 ha, accounting for 41.8% of the total area, and is divided into medium-high hills (6940 ha) and medium-low hills (7436 ha), with varying heights and slopes.

The slopes of these hills range from steep (30–50% slopes) to excessively steep (>70% slopes). The hill ranges, interrupted by streams and valleys, are oriented from north to south and developed over sedimentary rocks. The Piedmont Plain covers 3034 ha (8.6% of the total area) alongside the hills, mainly on the western side, but is found sporadically on the eastern and south sides of the mountain, which is subject to flash floods during the rainy season. The tidal floodplain runs from north to south through the peninsula, located between the hills and the Naf River, and comprises 6838 ha of land (19.57% of the total area). The area consists of broad, high, and low ridges and depressions. Numerous canals divide the landscape, some of which are subjected to tidal flooding. Most areas become mildly inundated with rainwater during the rainy season and occasionally suffer flash floods during heavy rainfall. Beaches cover 9.03% (3155 ha) of the total area and lie on the west side of the peninsula along the sea. Coral Beach is a minor area (1%) located approximately 12 km from the mainland. It is located on St. Martin’s Coral Island. (Moslehuddin et al., 2018).

2.1.4 Forest and Land Use

TWS is among Bangladesh's oldest and largest PAs and has a rich biodiversity. The Divisional Forest Office of Cox's Bazar (South) regulates the forest in 3 ranges (Teknaf, Whykong, and Shilkhali range) and 11 forest beats (Teknaf, Mochoni, Hnila, Madhya Hnila, Rajarchara, Mathabhanga, Shilkhali, Shamlapur, Whykong, Raikheong, and Monkhali). In the forest reserve, there are about 45 officers and employees of the BFD. (BFD, 2006). The forested areas in the Teknaf Peninsula first became a reserve forest in 1907, referred to as the Teknaf Game Reserve. (Aziz & Decosee, 2009; Ullah et al., 2022)The forest cover in TWS is broadly classified as a mixed tropical evergreen and semi-evergreen forest, covering 11,610 hectares in total. (Green, 1987; Moslehuddin et al., 2018).

Teknaf Wildlife Sanctuary has historically supported mixed evergreen and semi-evergreen forests, which have been substantially altered over time due to heavy biotic pressure. (Uddin et al., 2013). The forest is broadly classified as a mixed tropical evergreen and semi-evergreen forest. (Das, 1990). The vegetation originally consisted of tall, mixed evergreen trees in deep valleys and shaded slopes dominated by unique Garjan (*Dipterocarpus* spp.) trees. However, the hills are mainly denuded and dominated by Sun grass (*Imperata cylindrica*), herbs, shrubs, and brushwood. Tropical evergreen forests are found in deep valleys where wet conditions exist with shade. Tropical semi-evergreen forests predominate on the hills and flatlands. Evergreen species are more frequent in the lower stories; the main upper story has a high proportion of deciduous species that lose their leaves during the dry season. However, some places have experienced good natural regrowth, particularly of ground flora and the middle story, because of favorable climatic and edaphic conditions, thereby enhancing the inherent conservation value of the forest. (Moslehuddin et al., 2018).

The TWS has identified 535 angiosperm species (wild and cultivated) from 103 families and 370 genera. (Uddin et al., 2013). In Magnoliopsida (dicots), Fabaceae is the largest family, represented by 38 species, while in Liliopsida (monocots), Poaceae is the most prominent family, represented by 29 species. Only one species represents each of the 31 families. Of 535 species recorded here, herbs are represented by 178 species, 110 by shrubs, 150 by trees, 87 by climbers, and ten by epiphytes, including parasites. Nineteen species, including one gymnosperm (*Gnetum oblongum*) listed as threatened in the Red Data Book of the country, have also been detected in this sanctuary. (Khan et al., 2001).

The region has long reserved the forest; therefore, no heavy industries, large factories, or even large-scale logging facilities exist. (Tani & Rahman, 2018). Due to a lack of livelihood opportunities and a comparatively higher poverty level than other regions in the country, the local people highly depend on the natural forest and its resources. (Moslehuddin et al., 2018). Even with the lack of large-scale deforestation drivers, anthropogenic pressure from the local community is causing deforestation. Previous studies have reported fuelwood harvesting, cash crop cultivation by small farmers, and settlement encroachment are the main deforestation drivers causing continuous forest conversion in the past few decades. (Alam et al., 2014; Tani, 2018; Ullah et al., 2020; Ullah et al., 2022; Ullah & Tsuchiya, 2018).

2.1.5 Population

Because TWS is situated on a peninsula, the surrounding settlements are located alongside the PA boundary. According to the previous household census (BBS, 2011), the total population of Teknaf Upazila was 264,389, comprising 46,328 households, and according to the latest population census (BBS, 2023)The total population of Teknaf is 333,840, with 66,597 households of an average size of 4.98. The literacy rate (7^+ years) is 64.35%.

2.1.6 Agriculture

Households located inside the TWS are more intensively engaged in agriculture, whereas those located outside are mostly involved in fishing and business for income generation. (Tani, 2018). Only 5.5% of the land of the Teknaf peninsula is under cultivation, having a cropping intensity of 136%, which is well below the national average of 193% (Moslehuddin et al., 2018). Teknaf's major agricultural crops are rice, wheat, jute, pulses, vegetables, and spices. Aman rice occupies the most significant area, followed by Aus and Boro varieties.

The crops that are very commonly grown are betel nuts and betel leaves. Both require a lot of irrigation and are water-intensive crops. The crops usually grown in the upazila include local Aus, High-yielding variety (HYV) rice, wheat, maize, vegetables, pulses, oilseeds, potato, tobacco, cotton, spices, etc. Rahman et al. (2014) reported that agriculture in Teknaf significantly increased after 1990 following extensive clearing of forests to create a huge settlement. Agricultural productivity is lower in Teknaf than in many other parts of Bangladesh because of conventional crop varieties and the lack of know-how. As a result, this peninsula is considered a food-deficit area (Moslehuddin et al., 2018).

2.1.7 Wildlife

The sanctuary harbors a great diversity of tropical semi-evergreen flora and fauna. The TWS contains 55 mammals, 286 birds, 56 reptiles, 13 amphibians, and 290 plant species. (BFD, 2006; Khan, 2008). It is also the last habitat for the Asian elephant (*Elephas maximus*), whose population varies from 15 to 100 (IUCN, 2004). Additionally, large Indian civets (*Viverra zibetha* and *Viverricula indica*) are found in the TWS, the only recognized site of these animals in Bangladesh. (Alam et al., 2013). It is home to many species of avifauna, which depend on good undergrowth and forest cover. Various non-timber forest products (NTFPs), including medicinal plants, bamboo, canes, sun grass, fish, and wild animals, are obtained from the forests.

2.1.8 Refugee Crisis

Forcefully Displaced Myanmar Nationals (FDMNs) indicate the Rohingya refugees who had been fleeing Myanmar to evade persecution in their homeland. The displacement and flow of these refugees have been happening over the decades. Before 2017, the Rohingya had faced several waves of forced displacement due to oppressive actions by Myanmar's authorities and communal violence. In 1978, approximately 200,000 Rohingya fled to Bangladesh. The aftermath of the uprisings for democracy and the 1990 election saw the displacement of another 250,000 Rohingya. The aftermath of the uprisings for democracy and the 1990 election saw the displacement of another 250,000 Rohingya. In 2012, communal riots in Rakhine state prompted an additional 200,000 to flee. However, the crisis reached an unprecedented scale in 2017 when 740,000 Rohingya escaped to Bangladesh following a brutal military crackdown in response to an attack by the Arakan Rohingya Salvation Army.

The refugees who came to Bangladesh before 2017 have been living in registered camps in Ukhiya, and Teknaf has already been stressing local resources, including forests and water. The 2017 influx has taken the refugee population to around 1.3 million, with a high birth rate compared to the 0.6 million people living in Ukhiya and Teknaf. This has caused the sudden conversion of more than 6000 acres of forest land in TWS and National Park areas in Ukhiya, which has been marked as a severe episodic degradation of the watershed in the area.

Following the influx, the refugees razed the entire forest to bare soil in pursuit of fuelwood collection, aggravating the deterioration of the watershed's health. Supplying drinking water for these 1.3 million additional people is pushing the water security of the local 0.6 million people to the brink of collapse. Hence, a sustainable watershed management approach for the area is a burning need to address all governess related to services from the TWS watershed.

2.2 Review of Literature

Numerous small to medium streams flow across TWS; more than 40 are delineated using the Digital Elevation Model (DEM). The streams flow through an undulating landscape with a linear hill range of elevation up to 300m, mainly towards the Naf River in the east and the Bay of Bengal in the west. These streams, though numerous, are mostly seasonal and dry up during the off-monsoon season. They intersect with valleys and gullies, shaping the terrain. The hill ridges divide the streams to the eastern aspect and western aspect, oriented from north to south, interrupt the landscape and are formed over sedimentary rocks. The landscapes are prone to severe soil erosion due to anthropogenic factors degrading the watershed's health. Though the watershed of TWS is vulnerable, few studies have taken place to identify and mitigate those factors. To understand the problems and to upgrade the watershed health of TWS, a literature review with studies of watersheds for similar kinds of physiographic places has been tabulated.

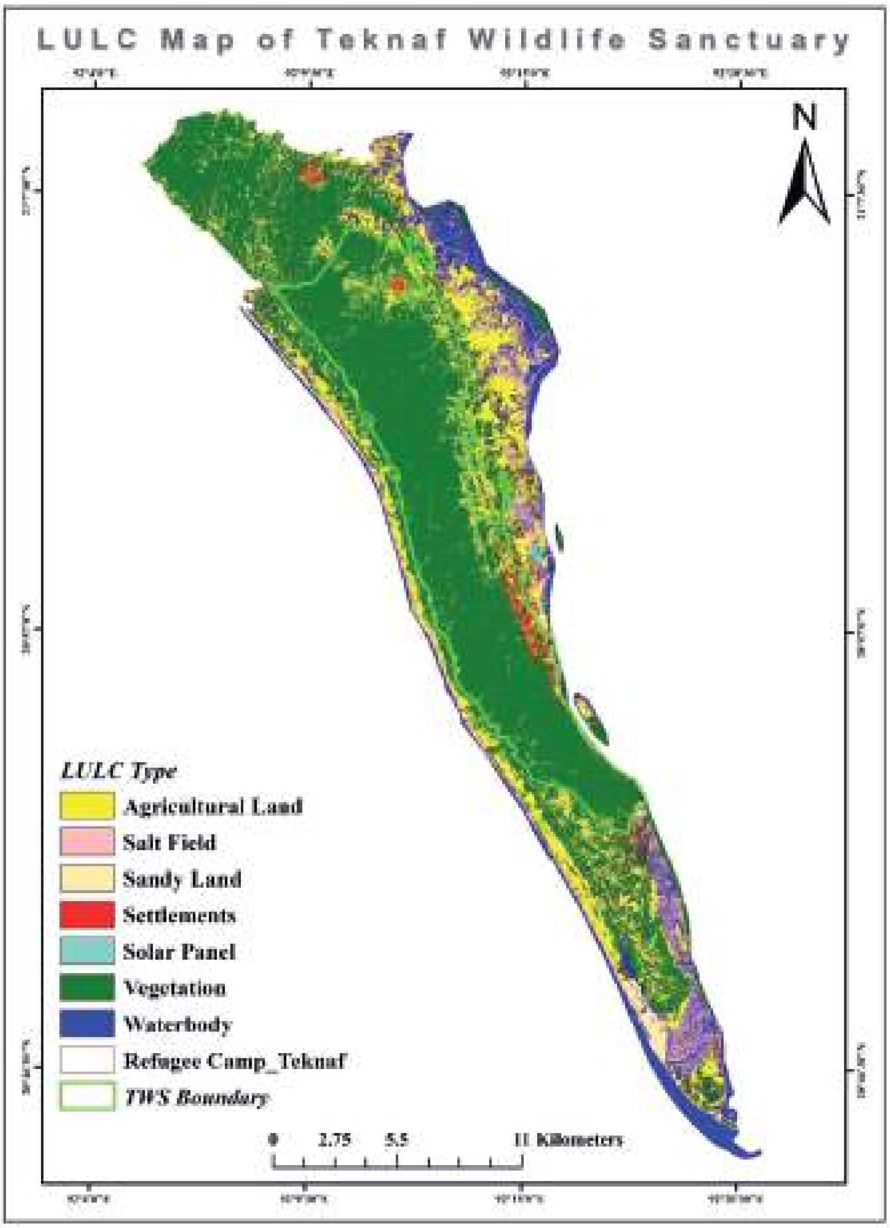
S/N	Title	Area	Objectives	Tools/Methods	Reference
1	Deforestation effects on biological and other essential soil properties in an upland watershed of Bangladesh	Upland watersheds of Chittagong and Chittagong Hill tracts.	To assess the impact of deforestation on soil biological and other important physicochemical parameters in the Chittagong region	pH meter, digital conductivity meter, loss on ignition method, the micro-Kjeldahl method, substrate-induced respiratory assay, the soil monolith and pitfall trap method, SPSS 16.	Sirajul Haque et al., 2014
2	The use of watershed geomorphic data in flash flood susceptibility zoning: a case study of the Karnaphuli and Sangu River basins of Bangladesh	Karnaphuli and Sangu River basins	To evaluate various morphometric parameters with flash food susceptibility at the watershed level and develop a flood susceptibility map for the area	Flash flood susceptibility mapping, using morphometric analysis, hydrological flood models	Adnan et al., 2019
3	Flash flood susceptibility assessment using the parameters of drainage basin morphometry in SE Bangladesh	Cox's Bazar, Bandarban, and a relatively small part of Chittagong		Topographic Wetness Index (TWI) and Topographic Position Index (TPI) through overlay analysis	Alam et al., 2021
4	Micro-watershed Delineation and Potential Site Selection for Runoff Water Harvesting Using Remote Sensing and GIS in a Hilly Area of Bangladesh	Khagrabill, Ramgarh upazila and part of Fatikchari Upazila, Chittagong	Selecting a suitable location of RWH structure for micro-watershed through all possible combinations of methodologies and criteria.	ArcGIS hydrological Tools, SRTM DEM (automatic delineation), and Google Earth (manual-delineation),	Islam et al., 2020
5	Evaluation of soil-vegetation interaction effects on water fluxes revealed by the proxy of model parameter combinations			Soil and Water Assessment Tool (SWAT)	Lotz et al., 2023

S/N	Title	Area	Objectives	Tools/Methods	Reference
6	Streamflow characteristics of the Sangu-Matamuhuri watershed in the Southeastern part of Bangladesh	Sangu-Matamuhuri Watershed (SMW) in Chittagong Hill Tracts (CHTs)	To determine water yield, specific water yield, rainfall-runoff ratio, peak discharge, To find temporal runoff for Sangu-Matamuhuri drainage areas, To construct a flow duration curve to understand its low and high flow dynamics.	Arc hydro tool in ArcGIS 10.5	Rudra & Alam, 2023
7	Comparisons of Watershed Delineation of River Network Representation and Morphometric Analysis in Karnaphuli River Basin, Chittagong, Bangladesh: A study with Different Digital Elevation Models (DEM)	Karnaphuli River Basin, Chittagong, Bangladesh	To find out, "Which form of digital elevation model offers realistic surface morphology and morphometry results?"	Arc-hydro tool in ArcGIS 10.5 software	Roy et al., 2022
8	Watershed prioritization for soil and water conservation aspect using GIS and remote sensing: PCA-based approach at northern elevated tract Bangladesh	the northern part of Bangladesh	To conduct the watershed morphometric study. Principal component analysis (PCA) for watershed prioritization. Propose soil erosion and water preservation measures	ArcGIS and Arc Hydro tool	Arefin et al., 2020
9	Evaluating Integrated Watershed Management using multiple criteria analysis—a case study at Chittagong Hill Tracts in Bangladesh	Bandarban Sadar, Chittagong, Bangladesh	To establish a framework for evaluating and implementing alternative IWM practices in Bangladesh's CHT.	Analytic Hierarchy Process (AHP), including sensitivity analysis	Biswas et al., 2012

2.3 Land Use and Land Cover Mapping

The Land Use and Land Cover (LULC) map was generated (Map 2) using the Google Earth Engine (GEE) platform. The images of Teknaf Upazila from January to February 2024 were collected from Sentinel-2 MSI: Multi-Spectral Instrument, Level-2A, with a resolution of 10m×10m.

Training points from the Red, Green, and Blue (RGB) imagery for seven different LULC types: Agricultural Land, Settlements, Waterbody, Vegetation, Salt Field, Sandy Land, and Solar Panel were selected and classified to make the map accordingly.



Map 2: Land Use Land Cover (LULC) Map of Teknaf Wildlife Sanctuary

Table 1: Distribution of Land Use and Land Classes (LULC) in Teknaf

SL.	LULC Type	Area (km^2)	Area (%)
1	Vegetation	185.15	58.41
2	Agricultural Land	61.88	19.52
3	Waterbody	40.62	12.81
4	Salt Field	11.68	3.68
5	Sandy Land	9.71	3.06
6	Settlements	7.57	2.39
7	Solar Panel	0.37	0.12
	Total	**316.98**	**100.00**

The major LULC classes in Teknaf Upazila 2024 are vegetation, agricultural land, water bodies, and salt fields. The details of land use and land cover in this area are shown in Table 1 and Figure 1. Vegetation, including forests, comprises 185.15 km^2 (58.41%) of the total area in Teknaf, and almost 61.88 km^2 (19.52%) of the total area has been used for agricultural purposes, including paddy, seasonal crops, spices, betel leaf, vegetables, and others. Approximately 11.68 km^2 (3.68%) of the total land of Teknaf is currently being used for salt production, which is increasing daily. The region's water bodies cover 40.62 km^2 (12.81%) of the land. Settlements in Teknaf, such as refugee camps, buildings, and other built-up areas, cover almost 7.57 km^2 (2.39%).

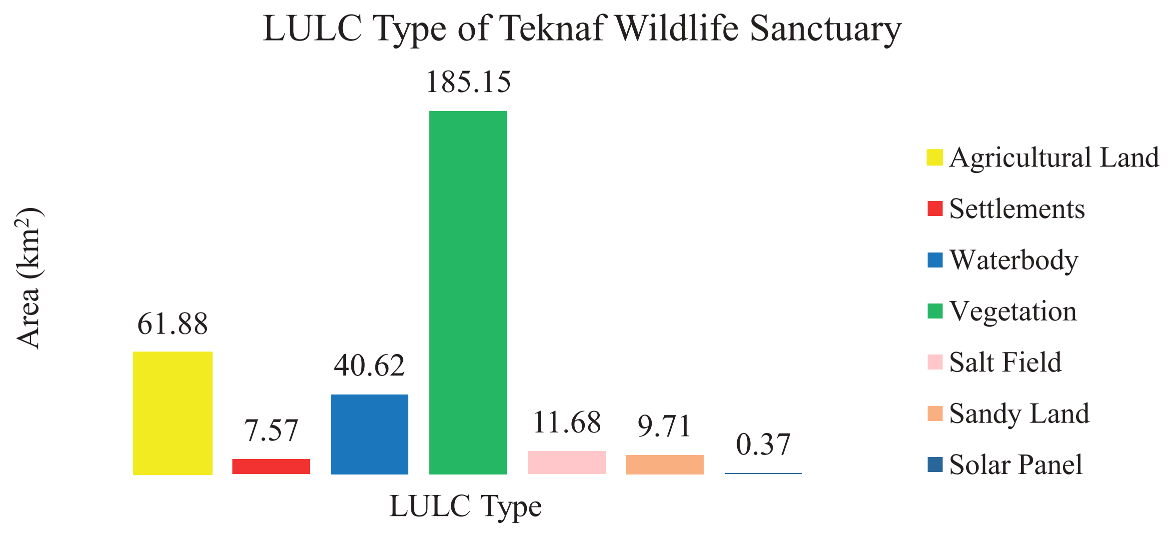
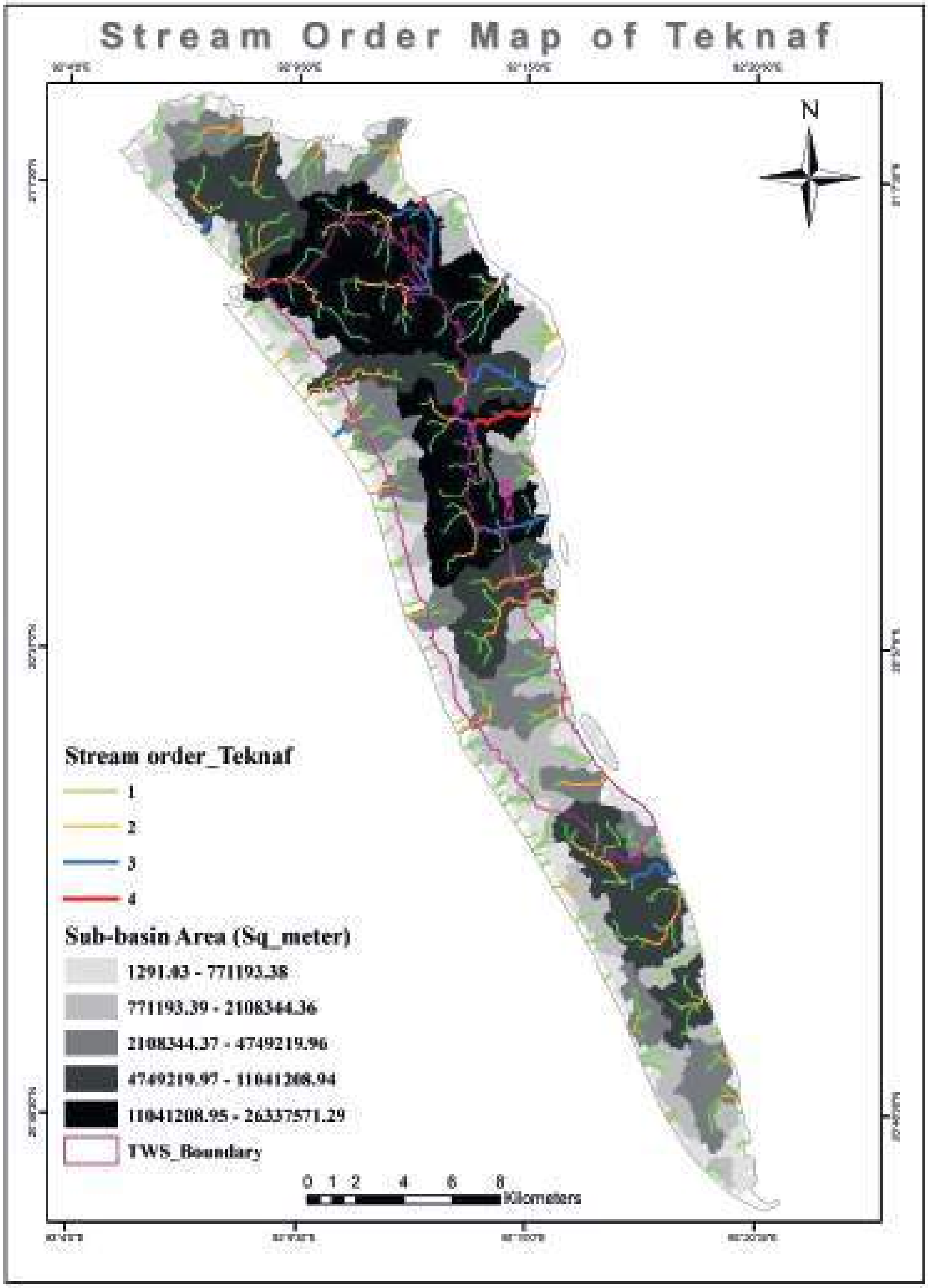


Figure 1: Area of Teknaf covered by different LULC Types

To ground-truth the classification, a field investigation was performed on the different land covers of Teknaf. After comparing the ground truth points, the classification showed an overall accuracy of 80.6%. The Kappa (K) statistic was 0.762, which indicates a well-performed and satisfactory classified LULC.

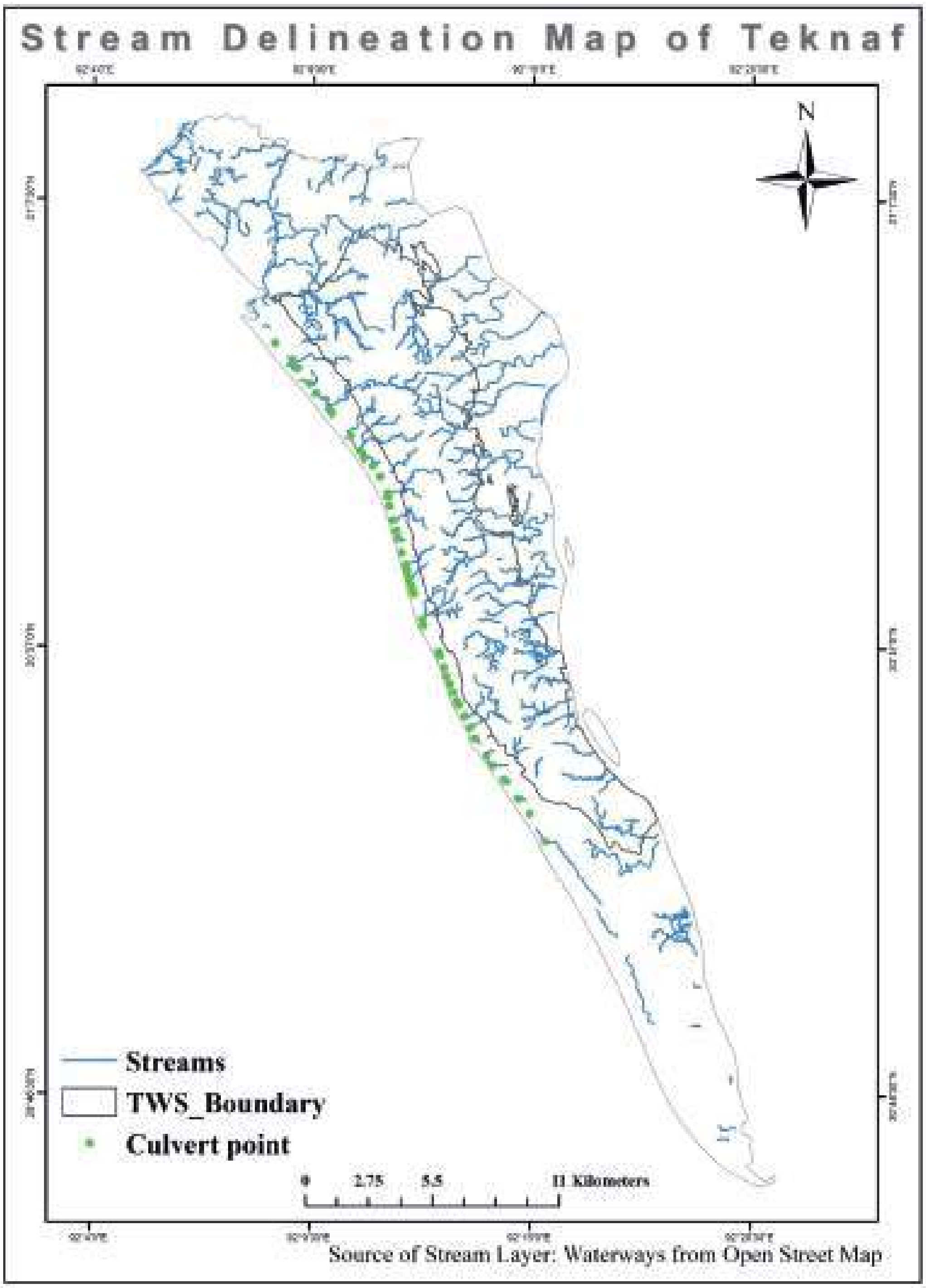
2.4 Stream Mapping

SRTM 1-arc global Digital Elevation Model (DEM) of 30m resolution was retrieved from the USGS (United States Geological Survey) Earth Explorer for watershed preprocessing in ArcGIS 10.8. The generated stream order map for Teknaf Upazila is shown in Map 3. The highest stream order (4) was found for two streams a, indicated by red on.



Map 3: Strahler Stream Order Map of Teknaf

Using the Open Street Map (OSM) waterways layer, a Stream delineation map for Teknaf Upazila is generated and shown in Map 4. It also shows the location of culverts on Marine Drive Road, which cross-cuts the western aspect streams flowing to the Bay of Bengal. Approximately 45 culverts were recorded on Marine Drive Road using Garmin GPSMAP 64s GPS.



Map 4: Stream Delineation Map of Teknaf showing Culvert points on Marine drive

Establishing Riparian Buffer Zones or Vegetated Filter Strips is critical to integrated management plans. It attenuates runoff and associated pollutants before reaching surface and under ground water sources by infiltration, absorption, uptake, filtering, and deposition.

Depending on site-specific conditions, buffer widths ranging from (3 to 200) m are effective widths. (Castelle et al., 1994). However, water quality protection would range from 30m for Capability Classes I, II, and V to 40m for Capability Classes II and IV and 53m for Capability Classes VI and VII. (Narumalani et al., 1997). Here, the buffer zones were delineated using a spatial distance for the streams using widths of 30m (Map 5).

Once the riparian buffer zones were delineated using the OSM waterways layer, the LULC was extracted and used to identify those areas where the establishment of filter strips would be recommended.

An assessment of these buffer zones about their land cover (Figure 2) reveals that much of the streams overall, 26.6 km^2, is protected by streamside vegetation (63%). Unfortunately, many areas along the streams have agricultural land (19%) and salt fields (4%), which can be the prime source of water quality degradation. In the case of settlements (2%), it would be difficult or economically inefficient to develop buffer zones (e.g., moving buildings or demolishing refugee camps). Therefore, the riparian buffer zones can be created in agricultural areas. More than 19% or 4 km^2 of the area consisted of agricultural and salt fields is thus characterized as 'critical.' As these 'critical' areas are adjacent to agricultural fields, water resources management strategies must focus on the establishment of riparian zones to minimize the impact of non-point source pollution.

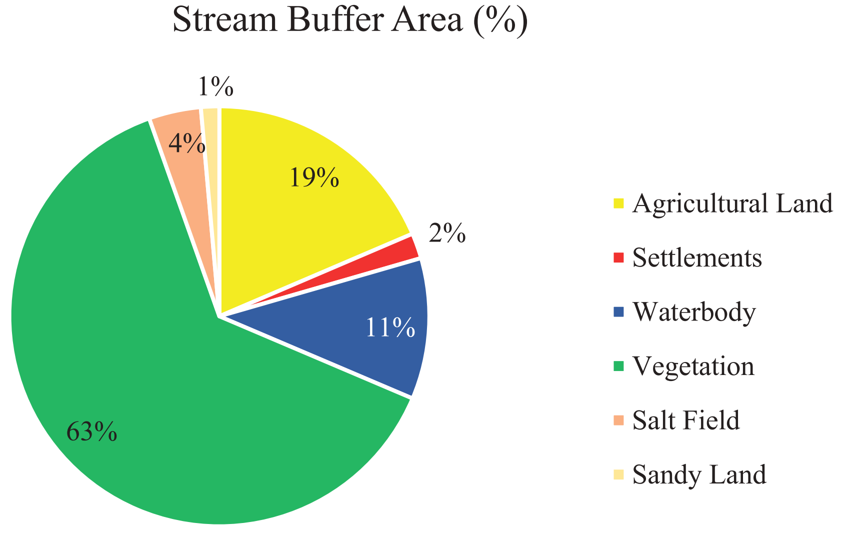
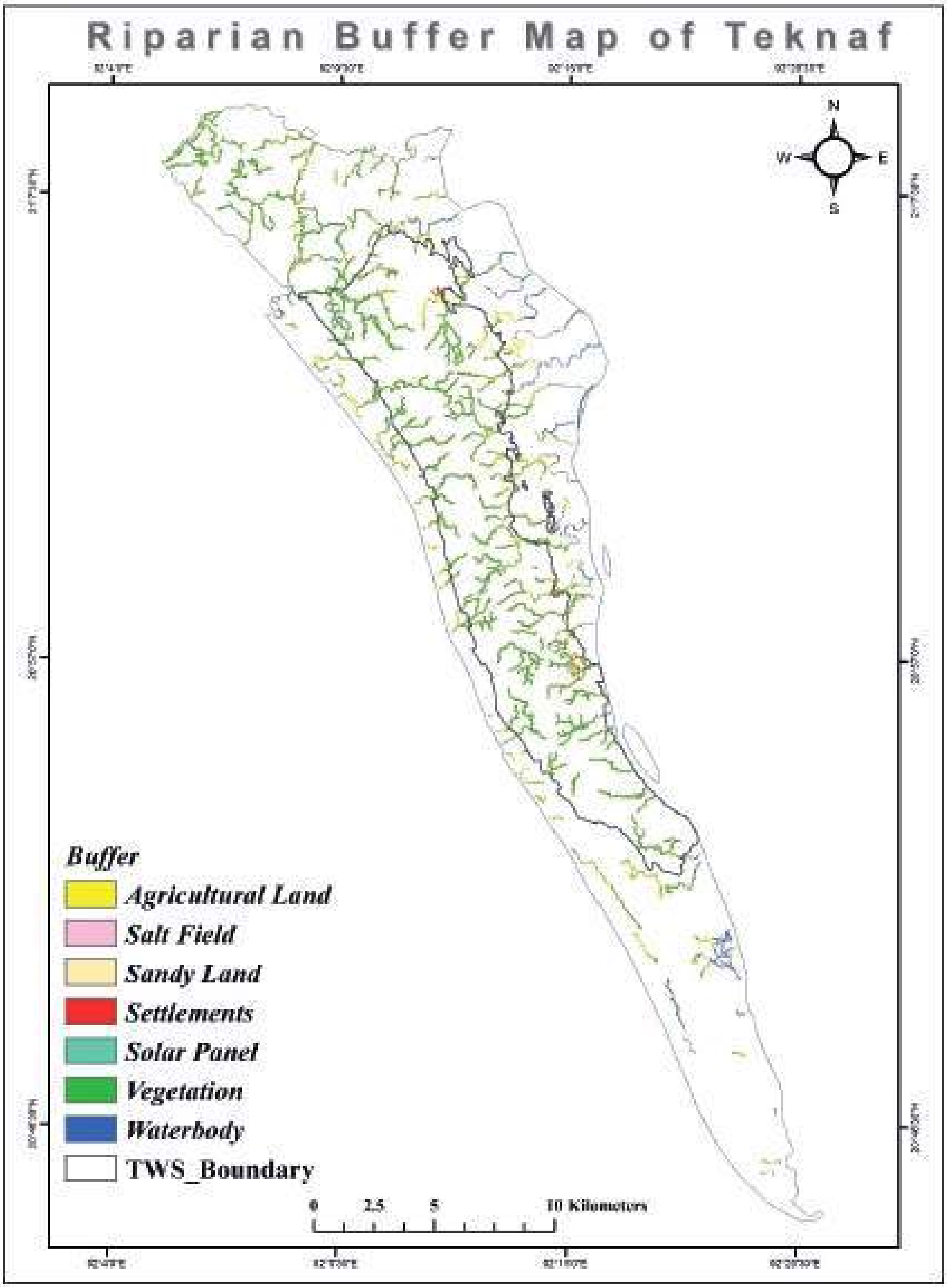


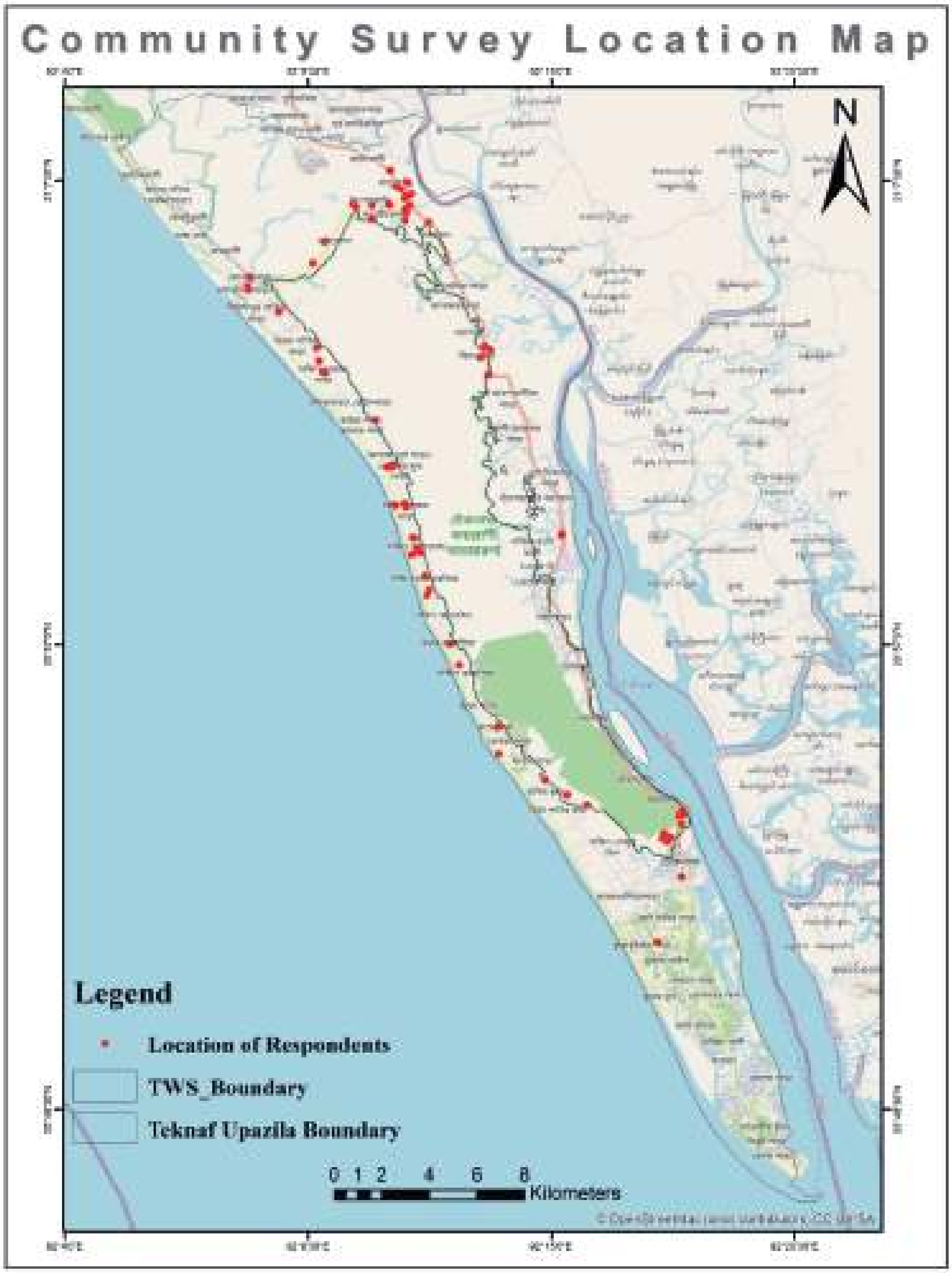
Figure 2: Stream Buffer Area (%) in Teknaf



Map 5: Riparian Buffer Map of Teknaf

2.5 Social Survey

A total of 141 respondents were surveyed from five unions: Baharchara, Sabrang, Hnila, Teknaf Sadar and Whykong. Houses of the VCF members of Teknaf under different beats of forest division were visited to conduct social survey and in some place members from nearby VCFs gathered together to participate in the survey. Map 6 shows the location of the respondents who participated in the survey.



Map 6: Community Survey Location Map

2.5.1 Focused Group Discussions (FGD’s)

FGD is a vital part of the management plan for the planning and design process aimed at involving the local stakeholders in the Project development and execution phases of the Project cycle. Focus Group Discussions were scheduled for 21 to 25 February 2024 in different locations as per the community and stakeholders' demands. Enumerators were made to transact work over the project area, observe the potential present situation of the project area, and identify social features. They also selected easily accessible venues for conducting stakeholder meetings and consultations with local people. The schedule, number of participants by gender, and type of participants are presented in the Table below and discussed more clearly.

Here are some steps commonly used in conducting FGD’s in a social survey:

1. **Planning and Recruitment:** Determine the purpose of the FGD, identify the target population or specific groups for participation, and recruit participants who represent diverse perspectives or experiences relevant to the research topic.

2. **Moderator Guide Development**: Prepare a structured guide with open-ended questions or topics to guide the FGD discussion. The guide should cover key areas of interest and allow participants to express their opinions freely.

3. **Setting and Logistics:** Arrange an appropriate venue for open discussion. Ensure that it is comfortable, private, and free from distractions. Set up chairs or tables in a circle or semi-circle to facilitate participant interaction.

4. **Introduction and Icebreaker**: Begin each FGD with introductions, during which participants share their names, backgrounds, and any relevant information about themselves. Use an icebreaker activity or question to create a relaxed atmosphere and encourage participation.

5. Facilitation: The moderator plays a crucial role in facilitating the discussion by actively listening, probing deeper into responses when necessary, encouraging all participants to contribute, managing time effectively, and ensuring everyone's perspective is heard.

6. Recording: Record FGD sessions using audio recorders (with participant consent) or assign note-takers who accurately capture essential points raised during the discussion.

7. **Analysis:** Transcribe audio recordings or carefully review notes taken during the FGD session. Analyze themes emerging from participants' responses using coding techniques such as content analysis or thematic analysis.

8. **Reporting:** Summarize findings from multiple FGD sessions into a comprehensive report that presents critical themes identified along with direct quotes or illustrative examples from participants' discussions.

It is essential to ensure ethical considerations throughout the process by obtaining informed consent from all participants, maintaining confidentiality of personal information shared during discussions, and providing an opportunity for debriefing after each session if needed.

Table 2: The list of FGDs is arranged at different places near TWS.

FGD Date	Place	Number of Participants
21 February 2024	North Naittong para	5
22 February 2024	Teknaf	15
22 February 2024	Mainuddin Memorial College	15
23 February 2024	Marish Bonia Boro Dayle, Mathavanga	8
23 February 2024	Hajom para	7
23 February 2024	Ejaj	7
24 February 2024	Horikhola	6
24 February 2024	Jahajpura Ecopark	5
24 February 2024	Laturikhola, Whaykong	8
25 February 2024	Shilkhali	15
25 February 2024	Whykong	12
	12 FGDs	**9 (Average participants)**

2.5.2 Questionnaire survey

A community survey was conducted between 21-25 February 2024 in all Unions of Teknaf Upazilla involving the CMC members and local people living near three forest ranges on TWS. The respondents were selected by adopting a saturation sampling technique. In this approach, the respondents were interviewed based on availability, and the accumulated data was verified daily to see the responses' saturation. If the reactions from additional respondents stop adding anything new to show discernible changes in the descriptive statistics, the survey is considered to reach saturation, and data capturing from additional respondents is stopped.

The survey utilized a semi-structured questionnaire to capture various responses on different aspects of Watershed, Watershed Management, Water Use, Water Availability, and Water security-related issues pertaining to the TWS. The survey was administered using the KOBO toolbox on Android devices, ensuring a diverse and representative sample. A total of 11 Research Assistants (RAs), comprising graduate students from the Institute of Forestry and Environmental Sciences, University of Chittagong (IFESCU), were employed to conduct the survey. The interviews of respondents were conducted by RAs, mainly in the respondents' locality. In some cases, the respondents from different areas were gathered for CMC-related meetings by CODEC, where the RAs interviewed them. Various factors, such as mixing respondents from the CMC members and the community who are not beneficiaries of the Nature and Life Project, were used to select initial respondents. Respondents from both genders, diverse age and occupation classes, and varying levels of interactions with the watershed were included. While checking for saturation, we also evaluated the representativeness of these groups in the sample. After reaching saturation, the final sample comprised 141 respondents. Their distribution is shown in Map 6, which shows representations around the TWS. On the eastern side of TWS, the distribution was not even as the respondents were gathered for two meetings – one at Teknaf and the other at Whykong.

2.6 Institutional Survey Through Key Informant Interviews (KIIs)

Ten KII's were conducted with key stakeholders from various sectors, including LGED, DPHE, BFD, CMC, PF, NGO, Agriculture Extension Officer (AEO), and Project Implementation Officer (PIO). These interviews offered expert opinions and detailed information on the stakeholders related to water and the watershed in Teknaf, the challenges facing these entities, and their roles in watershed management in the area.

2.7 Water Quality Assessment

Collecting water samples from a stream requires careful planning and adherence to proper sampling techniques to ensure accurate and representative results. Here are the steps involved in collecting water samples from a stream:

1. **Equipment Preparation**: Gather all the necessary equipment, including clean sample containers, sampling bottles, measuring tapes, labels, and any additional tools required for specific tests.
2. **Site Selection**: Choose a representative spot along the stream free from pollution sources such as industrial discharge or sewage outlets. Avoid areas near stagnant water or areas affected by recent rainfall.
3. **Pre-sampling Procedures**: Before use, clean all equipment thoroughly with non-chlorinated water. Wear disposable gloves to prevent contamination of the sample.
4. **Sample Collection:** Stand facing upstream and submerge the open sample bottle into flowing water while maintaining its orientation for a few seconds to allow flushing of contaminants on or inside the bottle. The water samples were collected for physicochemical parameters from a depth of 0.6 m from the surface using the grab method. The samples were collected 10 ± 2 m into the stream from the bank, i.e., mid-axial during the low tide. For an accurate assessment of effluent qualities, the samples were collected carefully from ten points (Figure 1). The plastic bottles were washed thoroughly with 10% HNO_3 and then distilled water before collecting the sample to ensure it was completely free from any undesirable materials. During sampling, the sample bottles were first washed with the sample. After taking samples, the bottles were labeled accurately by mentioning the name and location of the sampling sites, date, time of collection, etc. The collected water samples were carefully brought and preserved in a refrigerator for laboratory analysis.
5. **Sample Preservation**: For certain tests that require analysis within a specific time frame (e.g., bacterial analysis), add appropriate preservatives like sodium thiosulfate or coolers with ice packs to maintain low temperatures during transport.
6. **Sample Handling and Storage:** Label each sample container accurately with location details, date, time of collection, and any relevant information about potential pollution

sources nearby. Store the samples in coolers until they can be transported to the laboratory for analysis.

7. **Field Parameters Measurement (optional):** If field parameters like pH, temperature, and dissolved oxygen levels are required immediately after collection, measure them using handheld instruments at the sampling site before preservation.
8. **Documentation**: For future reference, keep detailed records of all sampling procedures, including field measurements and preservation methods used for each sample.
9. **Transportation to Laboratory**: Transport the samples as soon as possible after collection while keeping them chilled in coolers with ice packs if required by analytical protocols or regulations governing your specific study area.
10. **Analysis:** Once a sample is taken, the sample's constituents should be adequately maintained as collected. For proper arrangement of the water quality parameters and making the sample representative, pH, TDS, and temperature were recorded immediately. Once a sample is taken, the constituents of the sample should be adequately maintained as collected. For proper arrangement of the water quality parameters and making the sample representative, pH, TDS, and temperature were recorded immediately.

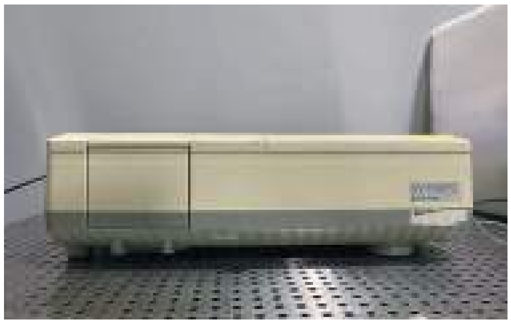
Table 3: Analytical Methods of Water Quality Parameters.

Parameter	Name of Instrument	Method of Analysis/Model
Temperature	Multiparameter meter	YK22DO
Dissolved Oxygen	Multiparameter meter	YK22DO
pH	pH meter	HannaHI-255
Alkalinity	Tritematric instrument	APHA method
Total Hardness	Tritematric instrument	APHA method
Chloride	IC	HIC-10A(super), Shimad Zu, Japan
TDS	Portable Multi-meter	SENSION(™156)
COD	Tritematric instrument	APHA method
BOD	Tritematric instrument	APHA method
PO_4	UV-Visible Spectrophotometer	UV-1650PC (Shimad Zu), Japan
SO_4	IC	HIC-10A(super), Shimad Zu, Japan

Picture (a): Multiparameter meter

Picture (b): Tri-thematic instrument

Picture (c): P^H meter; Hanna HI-255



Picture (d): UV-Visible Spectrophotometer

Picture (e): Portable Multi-meter; SENSION(™156)

Picture (f): HIC-10A(super), Shimad Zu, Japan

Picture: (e-f): Instruments used for Water Quality Assessment.

2.8 Water Discharge

Water discharges through stream flow for different streams have been measured using the Float Method. The apparatuses used were a measuring tape, a stopwatch, a meter stick to measure depth, and three apparent buoyant objects such as sticks or twigs. Calculations of discharges were measured in Cubic Feet Per Second (CFS) flow rate.

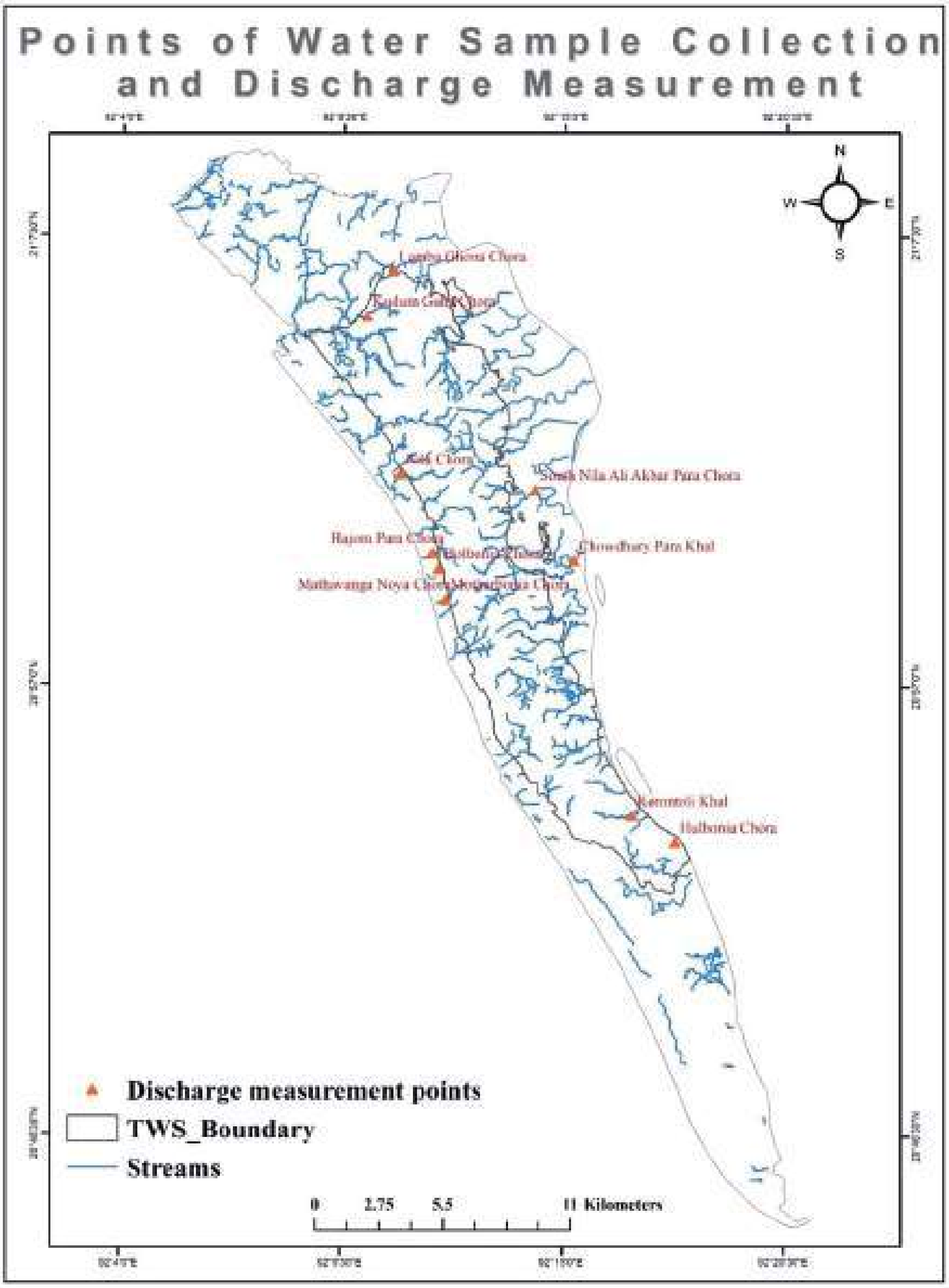
CFS = A x V

Where,
A (Area) = Width of Channel (feet) x Depth of Water (feet).
V (Velocity) = Distance Traveled/Time to travel (feet traveled divided by seconds).

While measuring, after choosing a suitable channel section with minimum turbulence, the beginning and end of the distance the floating object traveled was measured (recommended is 20 feet minimum). The floating object was thrown into the stream upstream of the upstream marker, and the time needed for the object to travel to the downstream marker was recorded by stopwatch (minimum recommended travel time is around 20 seconds). The process is repeated three times, and the average of three measurements for time and distance traveled were taken for calculations. The width of the stream and its depths across the downstream marker section were taken respectively using meter tape and the meter scale. It was kept in mind that the surface velocities are typically higher than the average overall channel velocity. To account for this, we take the surface velocity measured and multiply it by 0.85 to adjust the overall velocity to be more representative of the slower velocities under the surface.

2.9 Water Balancing: HEC-HMS-Based Model

We tried to use the Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) platform from the US Army Corps of Engineers to develop a watershed model for TWS. However, data availability, specifically on discharge from the streams, was temporally not rich, and we have only single measurements for a limited number of streams. Within this study's timeframe and budgetary scope, it was impossible for the team to go beyond that. We propose collecting temporally segregated discharge data from a broader geography within the watershed to build on the modeling we tried to make the watershed management plan more quantitatively rich and objective.



Map 7: Points of Water Sample Collection and Discharge Measurement

Findings from the Watershed Survey

3.1 Demographic Profiles of Survey Respondents

3.1.1 Spatial Distribution

A total of 141 households were surveyed from five Teknaf unions: Whykong, Baharchara, Teknaf Sadar, Hnila, and Sabrang. The majority of households were surveyed in Whykong (35%) and Baharchara (34%) (Figure 3). Sabrang's coverage was less as this union is a bit away from the TWS area.

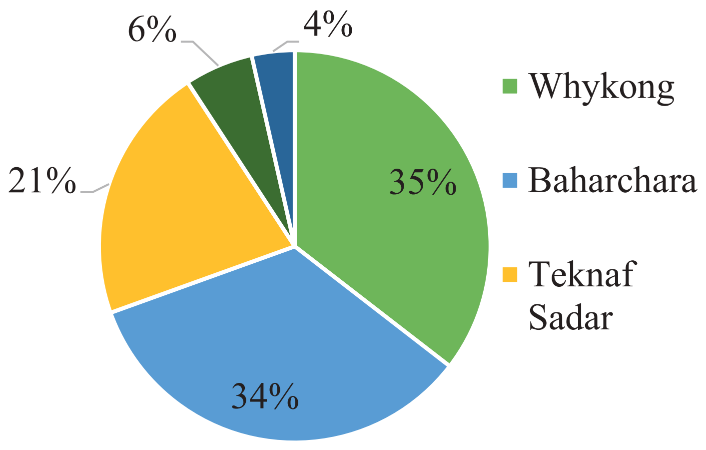


Figure 3: Spatial Distribution of the Respondents

3.1.2 Gender

The majority of the total respondents were female (54%), as they like to share their opinions without hesitation (Figure 4). Around 46% of the respondents were male. The gender mix obtained in the survey almost evenly represented the inclusion of both genders.

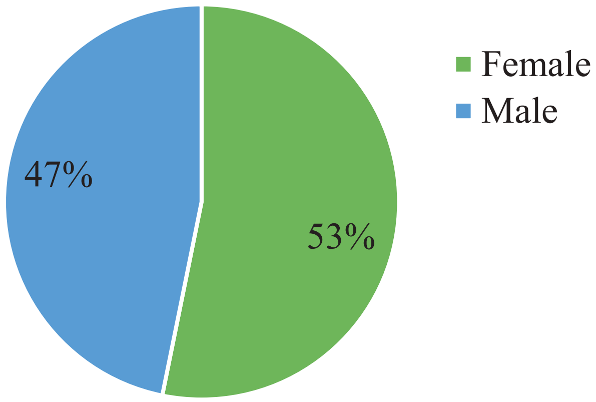


Figure 4: Gender of the Respondents

3.1.3 Age

We have classified the age of respondents into six age classes. The total number of respondents was 141; among them, the maximum number of individuals was 32-41 years, which is 33% of the total respondents. The other age classes are <=20, 21-31, 42-52, and 53-63 years, comprising 6%, 32%, 23%, and 4%, respectively (Figure 5). Only 2% of respondents were from the age range 63-73. The age distribution reflected the excellent representation of old and young generations to unearth past and present watershed situations.

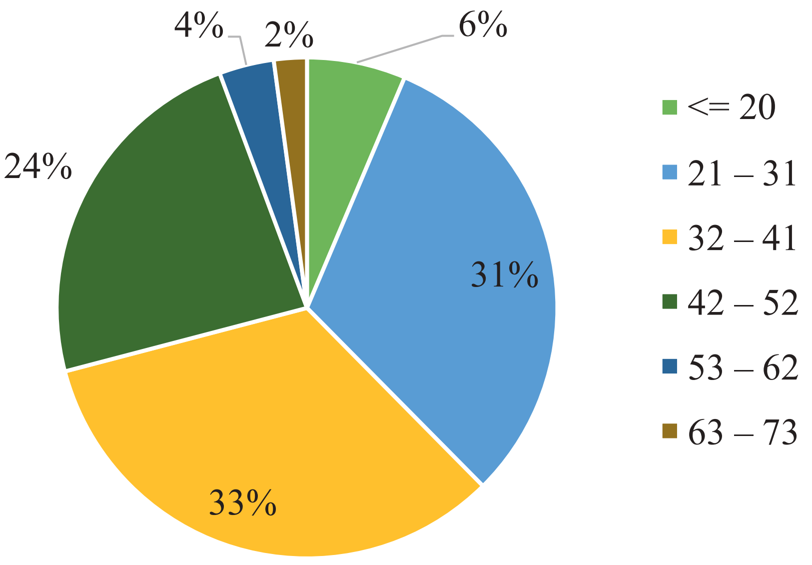


Figure 5: Age Range of the Respondents

3.1.4 Education

The mean value of the years of schooling was 5.52, indicating that the education level of the beneficiaries of the Nature and Life project and other respondents was relatively low. This also reflects the communities' lower awareness and unsustainable use of water resources.

3.1.5 Occupation

The graph (Figure 6) shows the main occupation of the respondents. Most of the respondents (18%) were unskilled laborers who work on daily wages. Around 17% of the respondents were involved in business. Homemakers account for 16.31% of those surveyed. Farmers are the fourth largest group at 13.48%. Skilled laborers make up 7.80%, and private service workers make up 9.22%. The remaining respondents are self-employed workers, teachers, students, fishermen, government employees, and remittance workers.

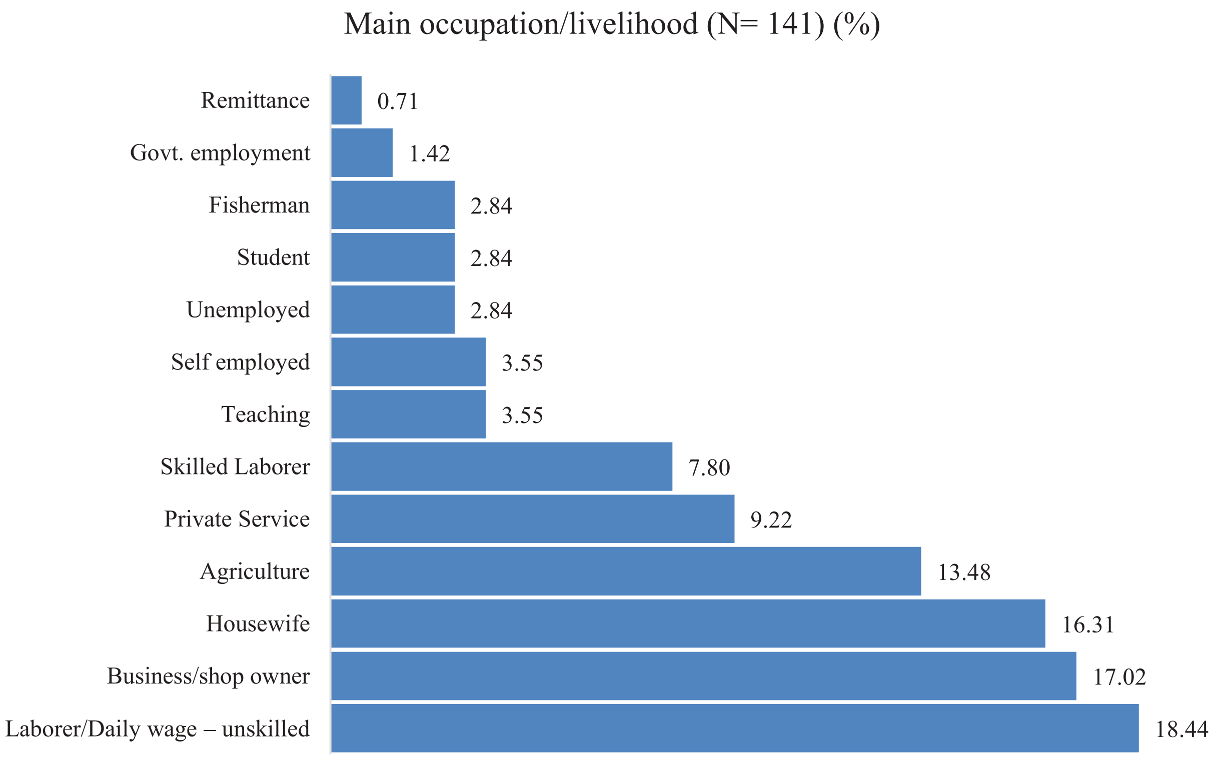


Figure 6: The Main Occupation of the Respondents

3.1.6 Dwelling

This graph (Figure 7) shows that the house of 66.67% of the respondents was Kacca (temporary), i.e., mostly made with mud or bamboo, whereas the house of 24% of respondents were Semi-pucca (semi-temporary), and only 9% of the respondents had Pucca or permanent dwellings.

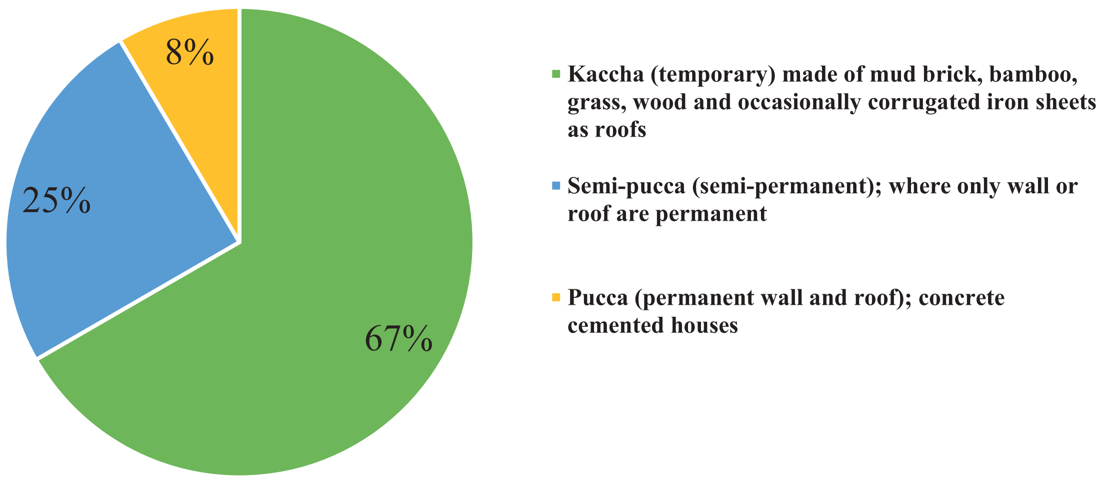


Figure 7: Dwellings of the Respondents

3.1.7 Income

Average monthly income for 54% respondents ranges from BDT 10,000 to BDT 20,000, and 35% respondents earn less than BDT 10,000 in a month. On the other hand, around 7% of the respondents usually earn BDT 20,000 to BDT 30,000. Few of the respondents earn more than BDT 30,000 (Figure 8). This indicates a low level of income for the people of TWS.

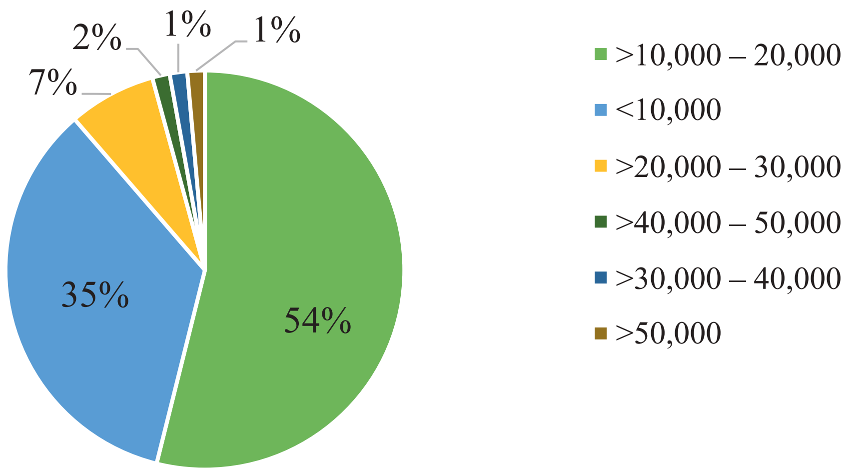


Figure 8: Ranges of Income of the Respondents

3.2 Household Water Use

3.2.1 Purpose of Water Use

This graph (Figure 9) shows water usage by purpose. Almost everyone (141 respondents) uses water for drinking, and a vast majority (97.16%) use it for domestic needs. Irrigation comes in at 42.55%, meaning less than half the people surveyed use water for agricultural purposes, while water usage for livestock only accounts for 11.35%.

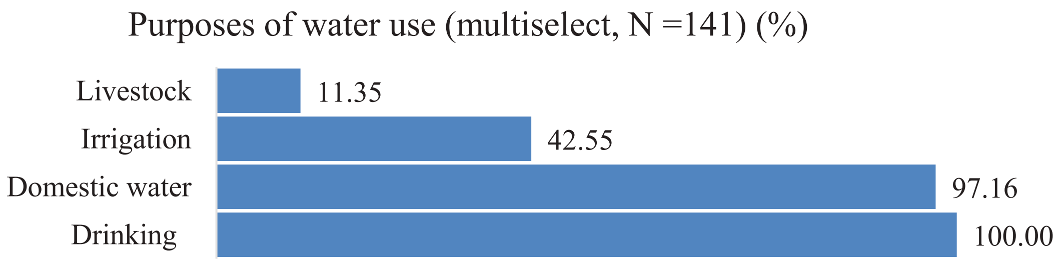


Figure 9: Purposes of Water Use

3.2.2 Places of Bathing

The diagram (Figure 10) shows the percentage of people who use different bathing places. Among the respondents, 52.48% of the people surveyed used to bath in bathroom, which likely means they have access to pipeline water and 48.23% of the people surveyed get their bathwater from a tubewell. The remaining of the respondent bathe in pond, stream and canal.

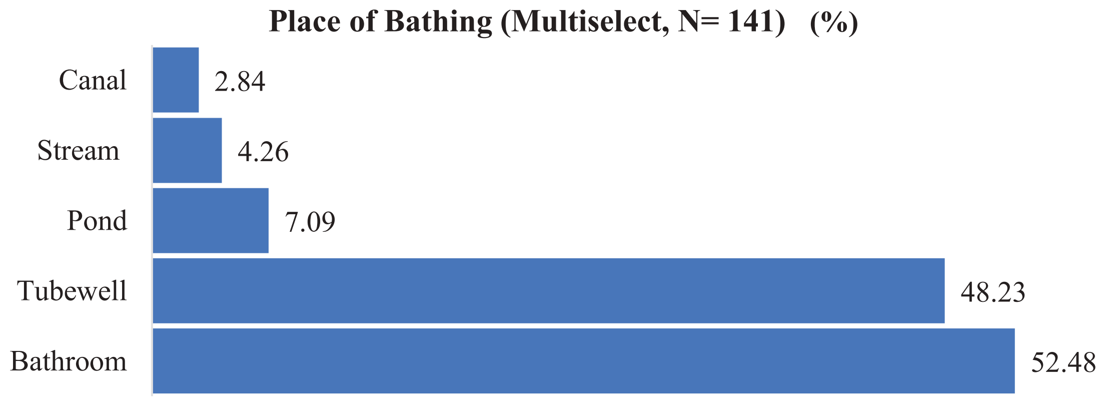


Figure 10: Places of Bathing

3.2.3 Primary Sources of Water Use

Figure 11 shows that the majority of the respondents rely on direct or stored tubewell water as their primary source for various purposes – Drinking (85%), Bathing and washing (74%), Cooking and utensils (83%), irrigation (75%) and Livestock (85%). Ponds have emerged as the least preferred source of water for varying purposes. Other surface sources, including streams and canals, as well as dug wells and ring wells, had much lower preference than groundwater but were preferred over ponds. Canals and streams meet substantial demand for irrigation water (15%) and water for bathing and washing (>10%).

These observations clearly indicate the intense dependency of the communities living in the vicinity of TWS on groundwater resources and, hence, on the service from the TWS watershed in recharging those groundwater aquifers. On the other hand, the results clearly indicated issues with ponds and other stagnant water sources. In watershed planning and management, emphasis must be placed on addressing the concerns related to surface sources to make water sourcing more sustainable. A large-scale program to create surface water reservoirs is necessary to meet the local demand for irrigation water. Measures to keep the canals and streams are necessary to make these sources meet substantial water demand for varying purposes besides being sources of large-scale water treatment plants for centralized piped water supply.

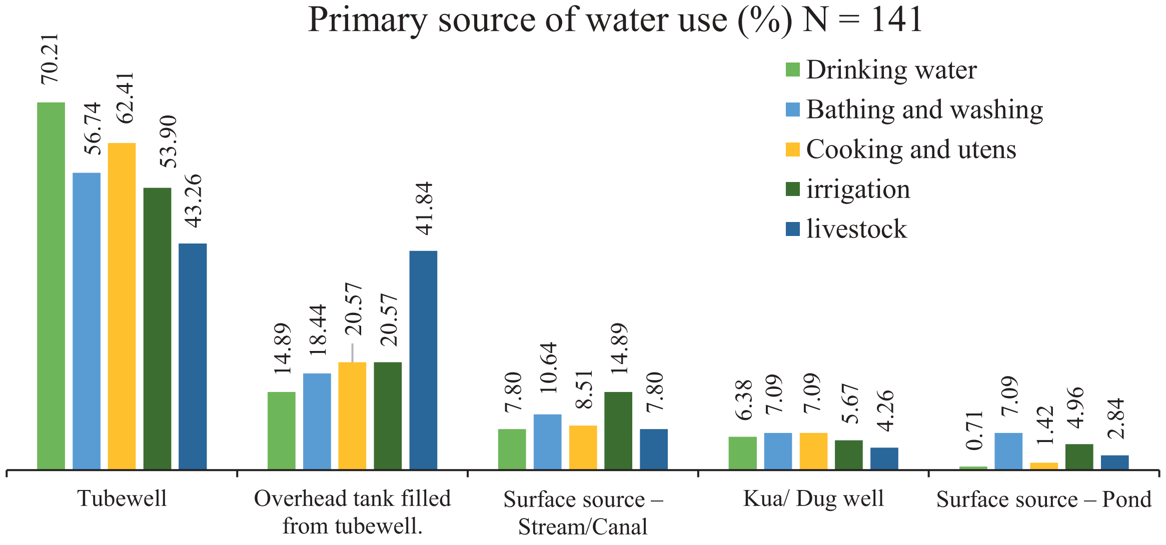


Figure 11: Primary Sources of Water Use

3.2.4 Alternative Sources of Water Use

Different sources are used for the varying needs of people living in the Teknaf peninsula, depending on availability and access, as shown in Figure 12. For all purposes, the majority are dependent on groundwater – drinking (68%), Bathing and washing (28%), Cooking and related (57%), irrigation (32%), and Livestock (43%) - through shallow or deep tubewells. Surface sources are used for a sizeable portion of bathing and washing as well as irrigation. Irrigation water is used from more diverse sources. Dug and ring wells have become an adaptive measure for many during the dry season when water scarcity kicks in. Overall, high dependency on groundwater indicates the high dependency on the watershed ecosystem services from TWS and suggests the need for conservation and restoration of the watershed through proper management.

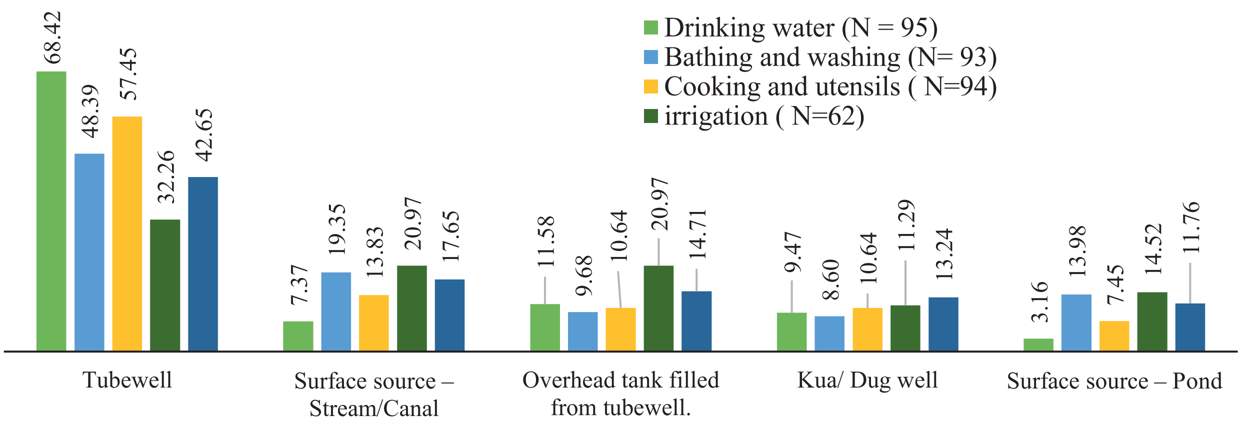


Figure 12: Alternative Sources of Water Use

3.2.5 Household Water Quality Issues by Sources

A range of issues related to the quality of water from the significant sources of water for people of the Teknaf peninsula living in the vicinity of TWS has been found (Figure 13). There was no clear trend that indicated variations in the quality issues from source to source. The occurrence of iron in water was the primary water quality of the majority of the sources, followed by bad taste and odor. Color and salinity have also been reported as issues for both groundwater and surface water sources.

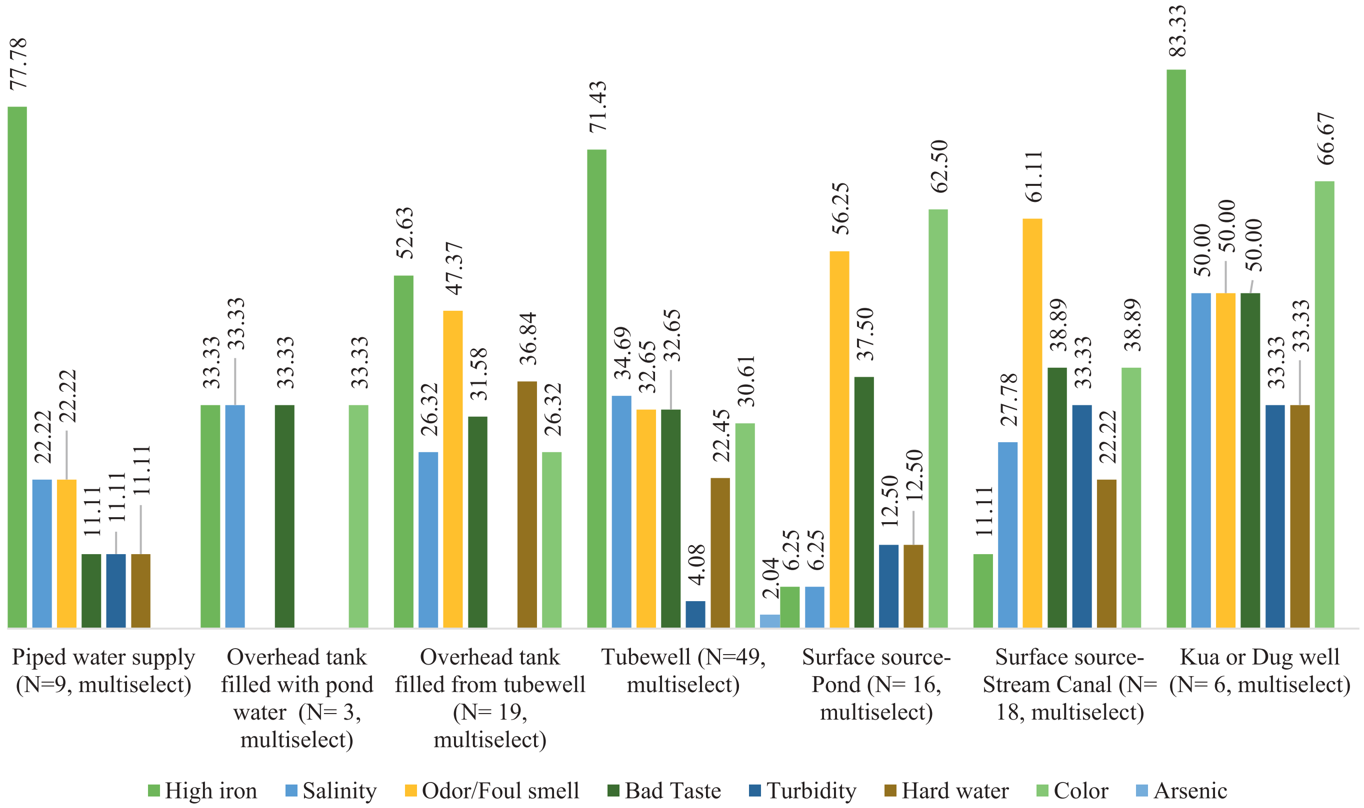


Figure 13: Household Water Quality Issues by Sources

3.2.6 Temporal Changes in Household Water Quality by Sources

The respondents were asked about the temporal changes in water quality of different sources. Figure 14 depicts the perceptions of the respondents. The respondents felt piped water (60%) and tubewell water (50%) maintained consistent quality. For overhead tanks, the perception of the respondents differed: 20-40% believed pond-filled tanks' water quality improved seasonally, while 10% each thought quality worsened. Both tubewell-filled tank water and tubewell water themselves had roughly half perceiving unchanged quality, with 20% each for seasonal increases or decreases. Surface water sources like ponds (40%) and streams/canals (35%) were viewed as declining seasonally, with a smaller portion believing permanent worsening. Respondents' perceptions of dug well water quality were mixed, with a third each finding consistent, seasonally improving, or declining water quality.

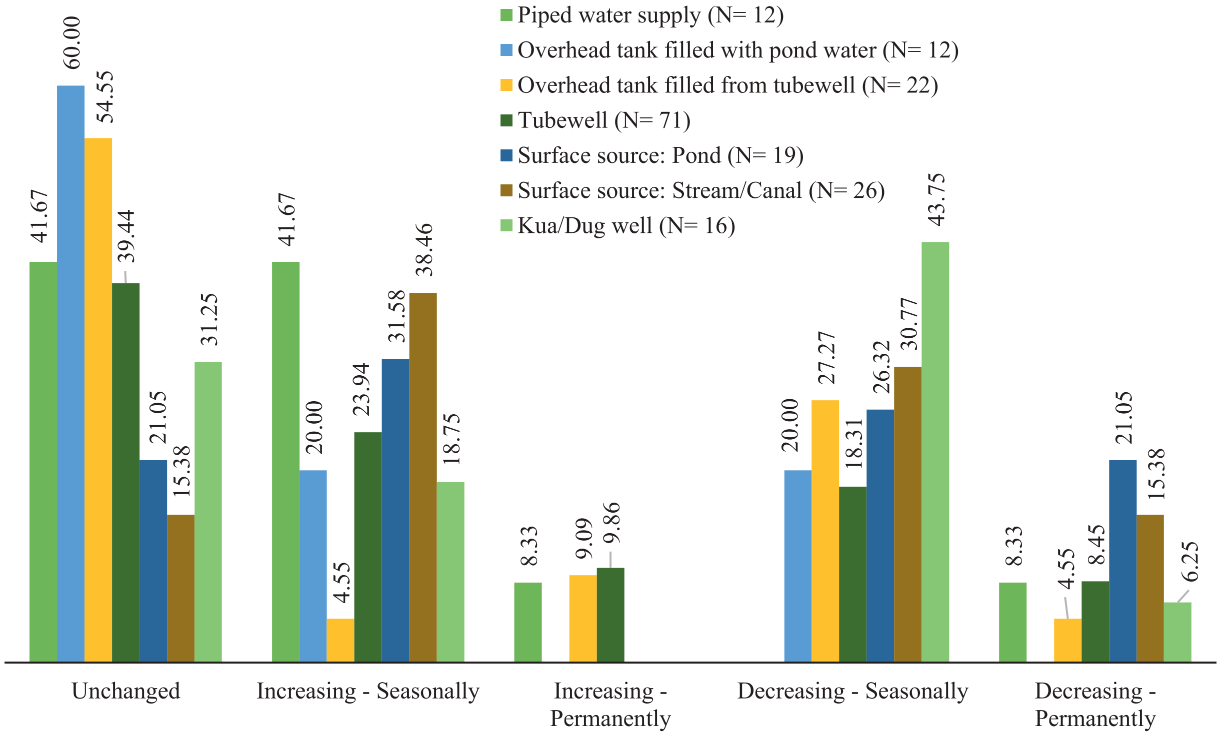


Figure 14: Temporal Changes in Household Water Quality by Sources

3.2.7 Ranking of Water Quality for Water Used from Different Sources

The respondents were asked to rate different water sources based on the type of uses. According to Table 4, piped water ranked highest for bathing, cooking, and washing utensils (averaging above 4.0 on a 0-5 scale), though drinking water may require treatment. Overhead tanks filled with pond water were best for irrigation (5.0) but lower for domestic uses (around 3.5). Tubewells and tubewell-filled tanks offered moderate quality across all uses (averaging around 4.0). Surface water (ponds and streams/canals) received the lowest rankings (averaging below 3.0 for most uses), while kua/dug wells showed mixed scores (averaging around 3.4). Overall, piped water was preferred for domestic purposes, while surface water sources were the least suitable.

Table 4: **Ranking of Water Quality of Different Sources on a scale of 0-5. (0 = Very poor, 5 = Very good)**

Household Water Source	Bathing & Washing	Cooking & utensils	Drinking water	Irrigation
Piped water supply	4.43	4.52	4.29	4.56
Overhead tank filled with pond water	3.50	3.33	2.50	5.00
Overhead tank filled from tubewell	3.90	3.45	3.55	4.00
Tubewell	4.06	4.15	4.03	4.45
Surface source - Pond	3.67	3.64	2.40	4.20
Surface source - Stream Canal	2.74	2.52	2.13	2.93
Kua or Dug well	3.29	3.45	3.26	3.46

3.2.8 Salinity Intrusion

Around 20% of the respondents agreed that the salinity is increasing in the Teknaf peninsula. Though a majority of the respondents (46%) couldn't specify the reasons for salinity intrusion, another big portion of the respondents (46%) found that tidal flooding is responsible for that (Figure 15). A small portion of the respondents (4%) thought that sluice gate management issues and bringing saline water by other farmers are responsible for the salinity intrusion.

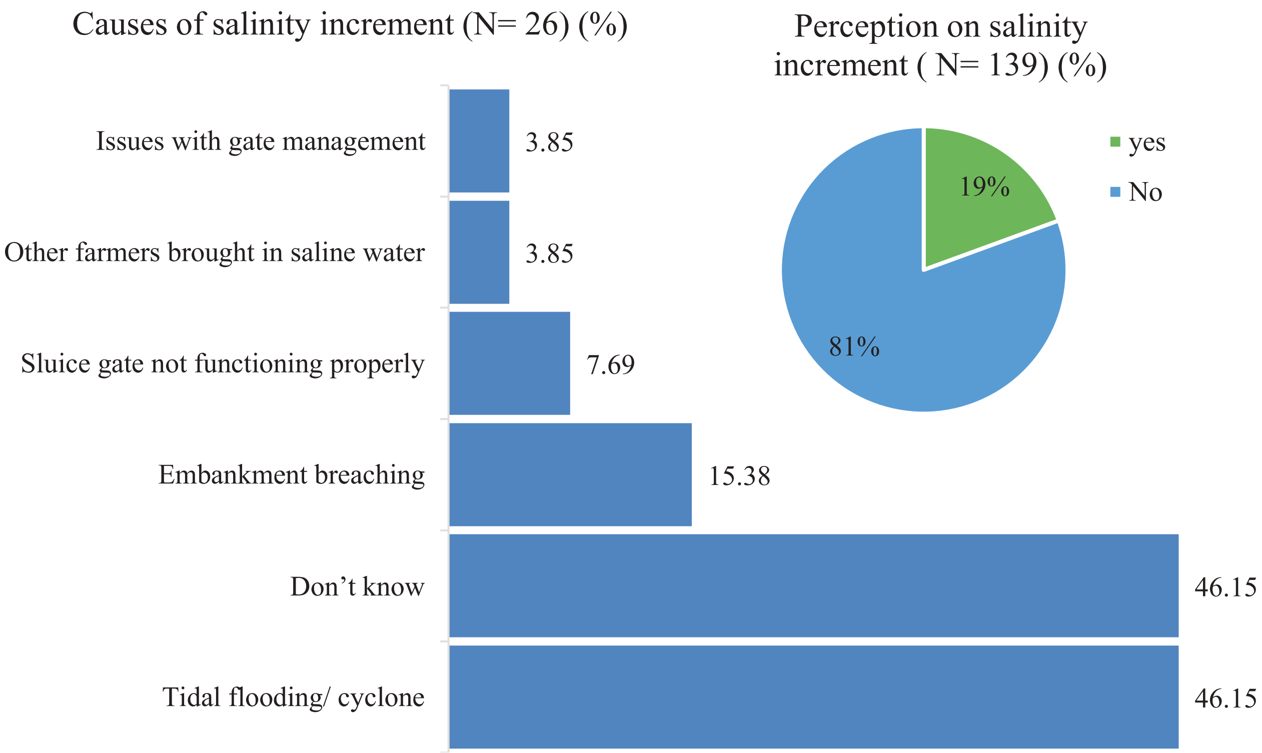


Figure 15: Perception and Causes of Salinity Intrusion

3.2.9 Effect of Disaster on Different Water Sources

Despite Teknaf is a coastal area, only 24% of the respondents thought that natural disasters area affecting water sources (Figure 16). On the other hand, 76% of them didn't agree on it.

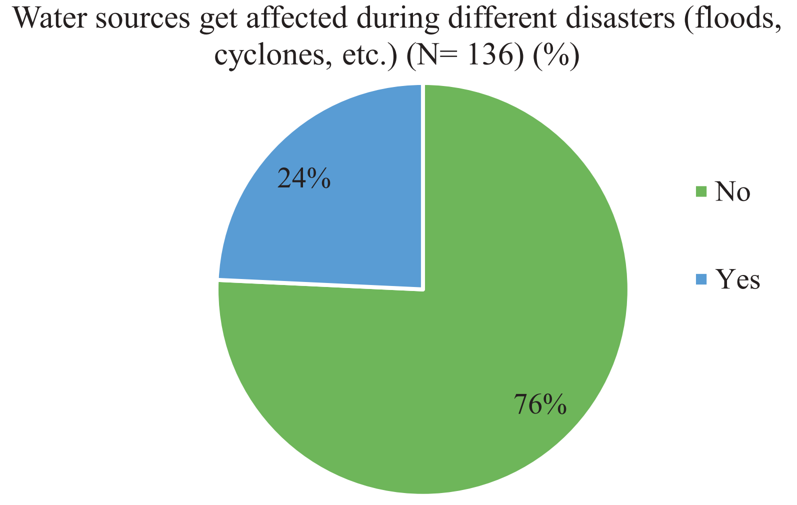


Figure 16: Perception of Disaster Effects on Water Sources

Table 5: Usability of Water Sources After Disaster on a Scale of 0 (usable) to 5 (unusable)

Water source	Mean value
Pond	0.75
Tubewell	2.04
Stream	1
Canal	3

3.2.10 Effect of Disaster on Different Sources of Water

Floods and cyclones were the predominant disasters affecting water sources in the TWS watershed areas, impacting all water sources. The load-shedding of electricity is a problem for pump-based tube wells, and for some tube wells and streams/canals, salinity is an issue. Other issues mentioned were turbidity, heavy rain, and contamination due to landslides.

3.2.11 Reasons for Changes in Irrigation Water Availability

The respondents identified an array of environmental, seasonal, and anthropogenic factors affecting irrigation water availability, including deforestation and sedimentation, the operation of brickfields, excessive groundwater extraction by deep tube wells, construction of embankments, and sluice gate mismanagement. Seasonal variability, particularly changes in rain patterns and dry seasons, was significant for canal water. Lake and pond water availability was affected by natural elements like heat and rain, as well as human pressures, including population growth and land use changes that encroach on existing water bodies. For groundwater accessed via pumps, challenges such as the lowering of the water table, reduced rainfall, and geological barriers were paramount, emphasizing a complex interplay of factors diminishing water accessibility for irrigation across different sources.

3.2.12 Reasons for Changes in Irrigation Water Quality

Respondents highlighted diverse reasons affecting water quality in various sources for irrigation, like color, odor, germs, and salinity in canal water, indicating organic contamination and chemical pollutants in canals. Irrigation water from lakes and ponds faces quality degradation due to domestic uses, throwing litter, and pollution, reflecting direct anthropogenic impacts. Groundwater extracted via pumps is chiefly compromised by high iron levels and, in some cases, salinity influences, possibly from ocean water intrusion.

3.3 Agriculture Water Use

3.3.1 Involvement in Agriculture

Among the surveyed respondents, around 47% engaged in agricultural activity (Figure 17). Whereas around 53% of them reported no involvement with agricultural activities.

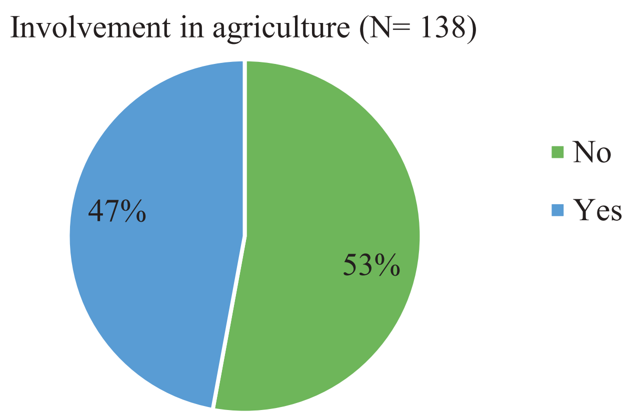


Figure 17: Respondents' Involvement in Agriculture

3.3.2 Perceived Impacts of Natural Hazards on Agriculture

The perception regarding the impacts of natural hazards on different agricultural crops among people in the local community is shown in Table 6. They scored the impacts on a 6-point scale.

Table 6: Perceived Impacts of Natural Hazards on Agriculture

Crop type	Flood	Cyclone	Drought	Storm surge
Boro rice	3.00	2.88	2.64	2.29
Aus/Aman	4.22	4.22	1.56	2.72
Vegetable	3.37	3.14	1.85	2.65
Both Salt and Paddy	5.00	5.00		
Fruit	1.33	2.60	1.33	1.80

*0-None, 1 – very less, 2- less, 3- medium, 4 – high, 5 – very high, 6 – No idea

3.3.2.1 Impact of Flood on Agricultural Activities

Figure 18 shows the perceived impact of floods on three different crops: Boro rice, Aus/Aman rice, and vegetables. As for the graph, 72% of the respondents reported a "Very high" impact of the flood on Aus/Aman rice, followed by Boro rice (26%) and vegetables (29%). This graph highlights variations in perceived flood impact across different crops.

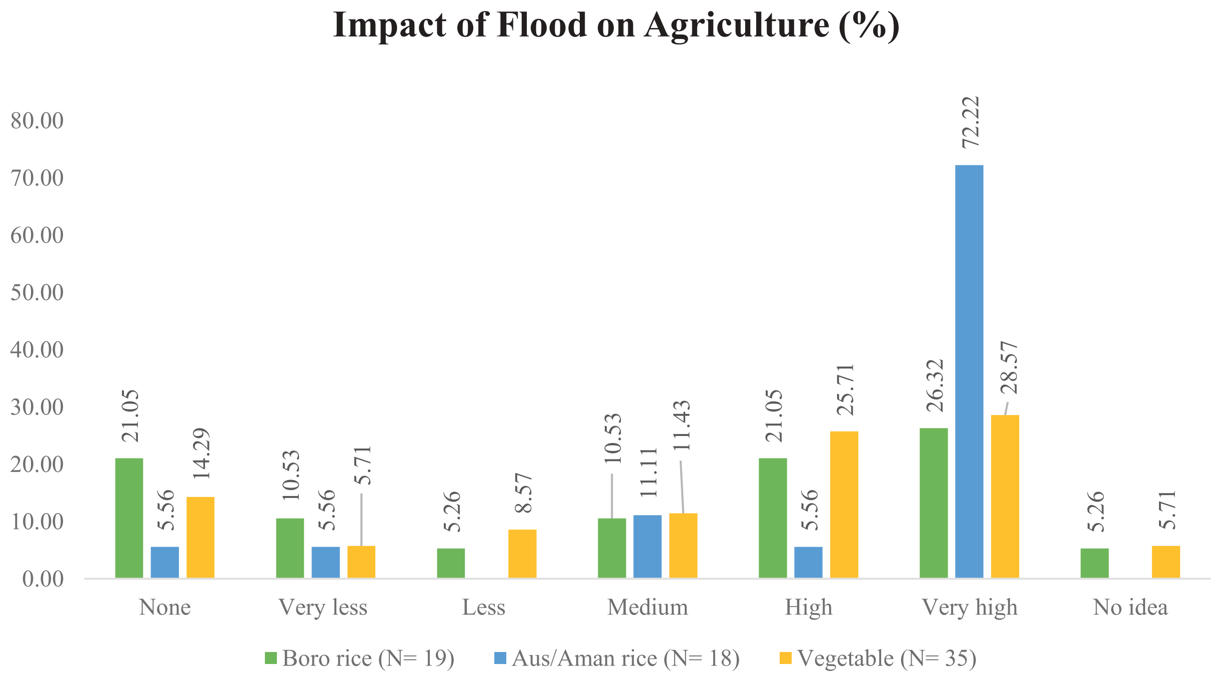


Figure 18: Perception of Flood Impact on Agriculture

3.3.2.2 Impact of the Cyclone on Agricultural Activities

Aus/Aman rice is supposed to be more affected by cyclones than Boro rice or vegetables. Around 75% of the respondents reported that the impact of cyclones on Aus/Aman rice is “very high,” followed by vegetables (35%) and Boro rice (13%) (Figure 19). In contrast, one-fourth of the respondents stated the “none” impact of the cyclone on Boro rice.

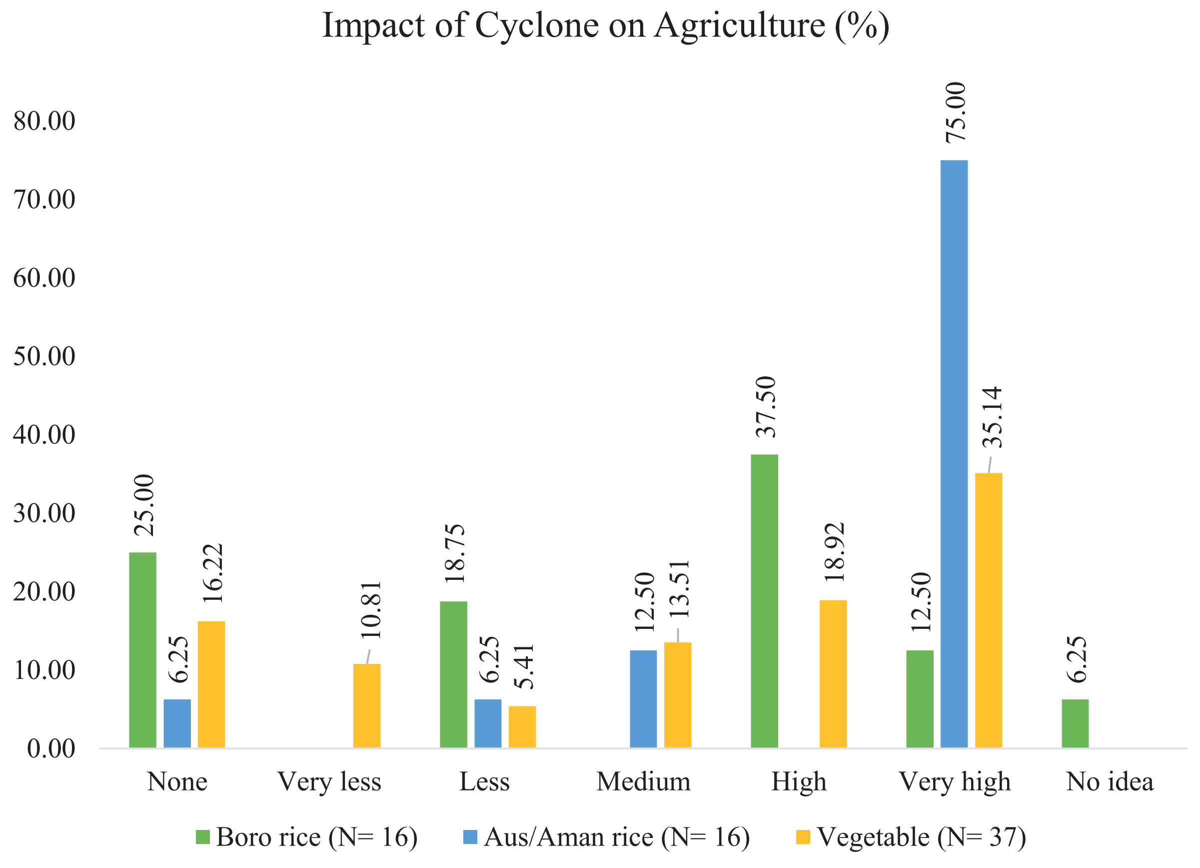


Figure 19: Perception of Cyclone Impact on Agriculture

3.3.2.3 Impact of Salinity on Agricultural Activities

More than half of the respondents said that the impact of salinity on vegetables is “none,” whereas 44% and 29% of the respondents thought the same for Aus/Aman rice and Boro rice, respectively (Figure 20). On the other hand, around 21% of the respondents found a “very high” impact of salinity on Boro rice.

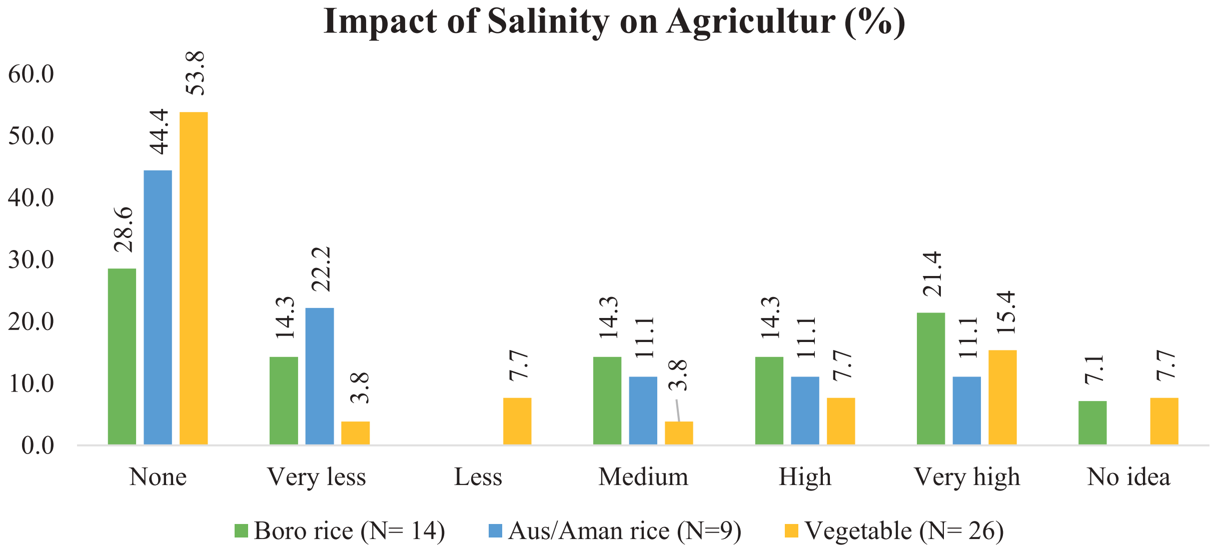


Figure 20: Perception of Salinity Impact On Agriculture

3.3.2.4 Impact of Drought on Agricultural Activities

In the case of the impact of drought, the responses were highly variable. Around 46% of the respondents stated the “less” impact of drought on Boro rice. Contrarily, 23% of them reported “none” and “medium,” with a small portion (8%) of “very high” in the case of Boro rice (Figure 21). Again, around one-third of the respondents reported “none” when asked about the drought's impact on vegetables, whereas 23% of them said it had a “very high” impact on vegetables.

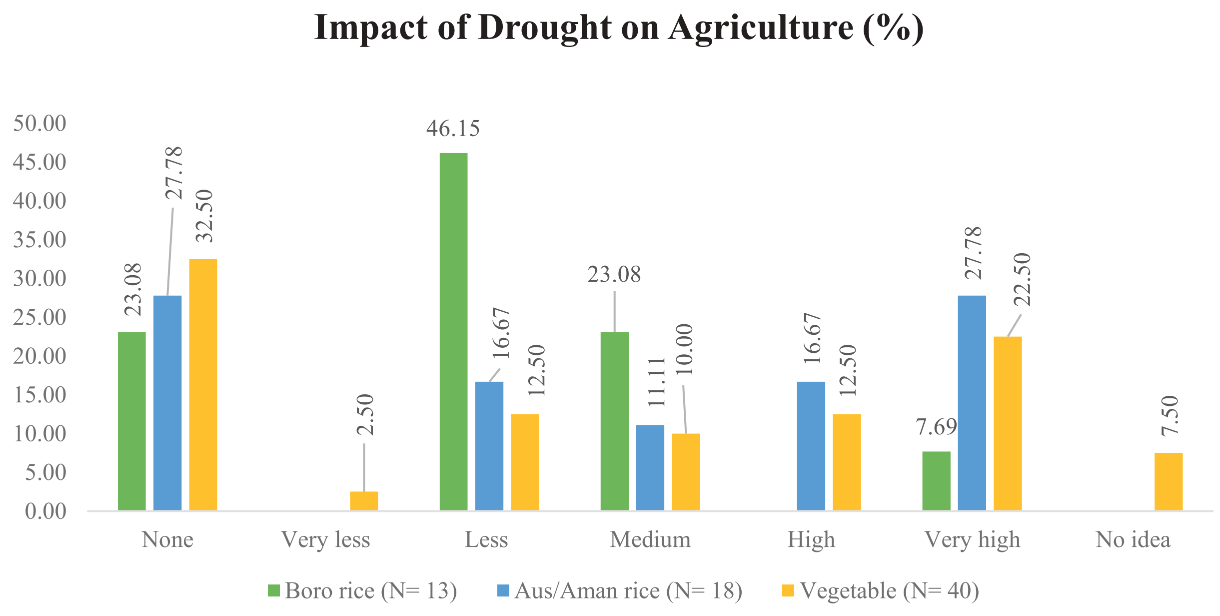


Figure 21: Perception of Drought Impact on Agriculture

3.3.2.5 Impact of Storm Surge on Agricultural Activities

According to the respondents, the impact of the Storm surge on agriculture is not significant for any crop. For all of the crop types, Boro rice, Aus/Aman rice, and vegetables, the majority of the respondents said "none" when asked about the impact of the storm surge. In contrast, around 40% and 23% of the respondents reported a "very high" impact of storm surge for Aus/Aman rice and vegetables, respectively (Figure 22).

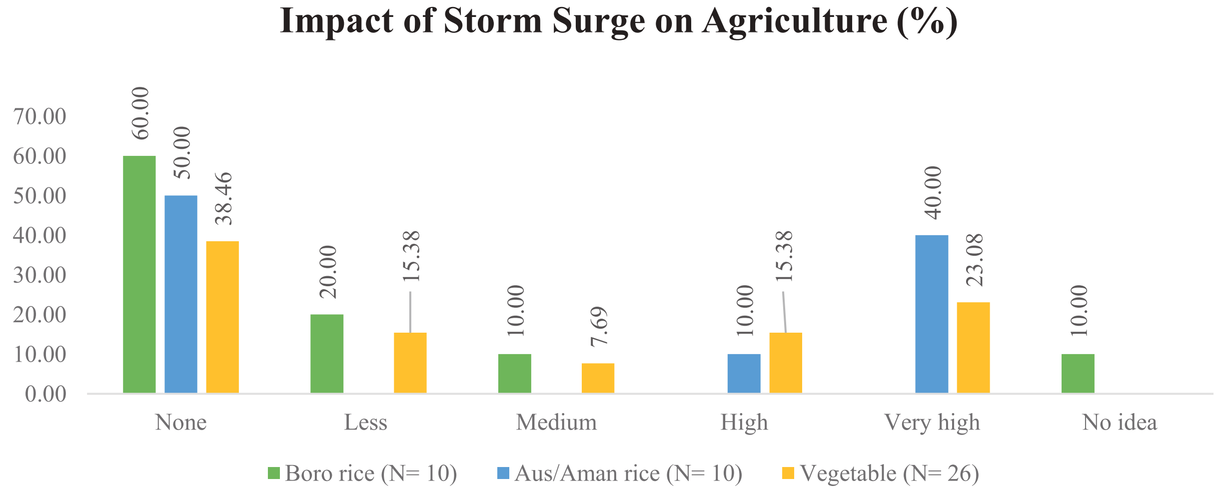


Figure 22: Perception of Storm Surge Impact on Agriculture

3.3.3 Number of Crops Cultivated

Almost half of the respondents are involved in agricultural activities. The study found that nearly half of them grow double and single crops in a year (Figure 23). Only a tiny portion (12.50%) of the respondents had the opportunity to grow three cops in a year.

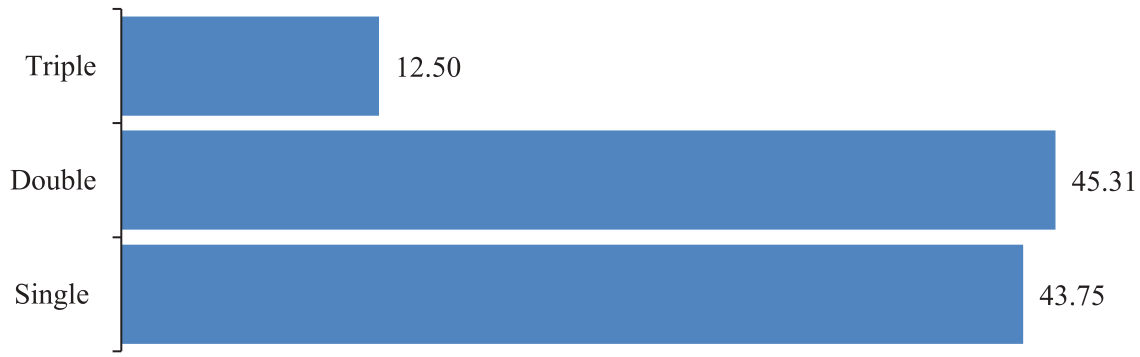


Figure 23: Number of Crops Cultivated in a Year

3.3.4 Uses of Different Sources for Irrigation Water

Irrigation water is crucial for agriculture. Figure 24 shows how respondents used different sources of water for irrigation purposes. Of the surveyed respondents, almost all of them reported that they use public tap/standpipes for irrigation water, whereas all of them also reported that they don't use rivers as the source of irrigation water. From the other sources, a significant portion of the respondents (64%) talked about using artificial reservoirs for irrigation water. On the other hand, around 36%, 29%, 23%, and 20% of the respondents used shallow tubewell, lake or pond, deep tubewell, and canal/stream to irrigate their crops, respectively.

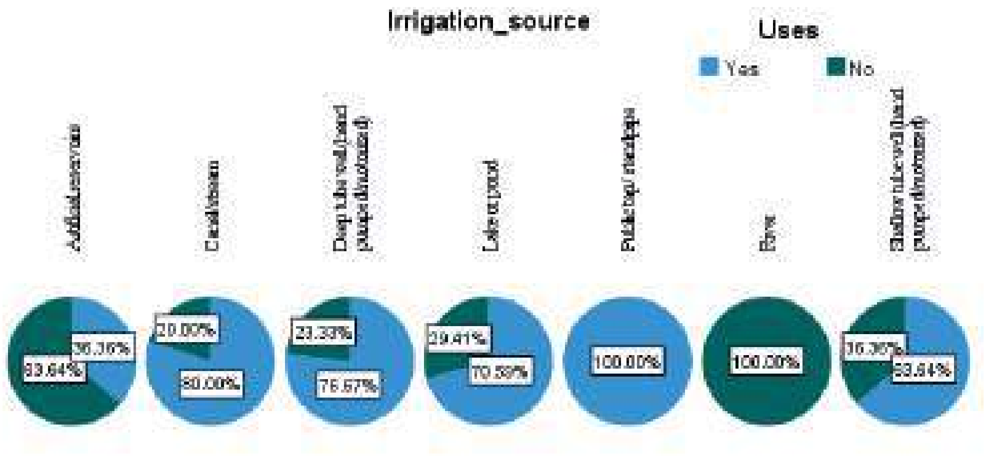


Figure 24: Uses of Different Sources of Irrigation Wate

3.3.5 Location of the Irrigation Source

The cost of irrigation water, influenced by the distance from the water sources, has an impact on the overall agricultural production. The respondents were asked about the distance between different irrigation sources and their land. The majority (83%) of them said that they have a lake/pond near their land as a source of irrigation water, followed by deep tube well (50%), canal/stream (42%), artificial reservoir (33%), and shallow tube well (29%). On the other hand, 71% of respondents reported shallow tube wells as a bit far from their land but still within the village. Similarly, 50% reported public tap/standpipes, and 38% reported canal/stream with the same distance (Figure 25). Finally, 33% of the respondents stated that artificial reservoirs and public taps/standpipes were far outside of the village, followed by canals/streams (21%) and deep tube wells.

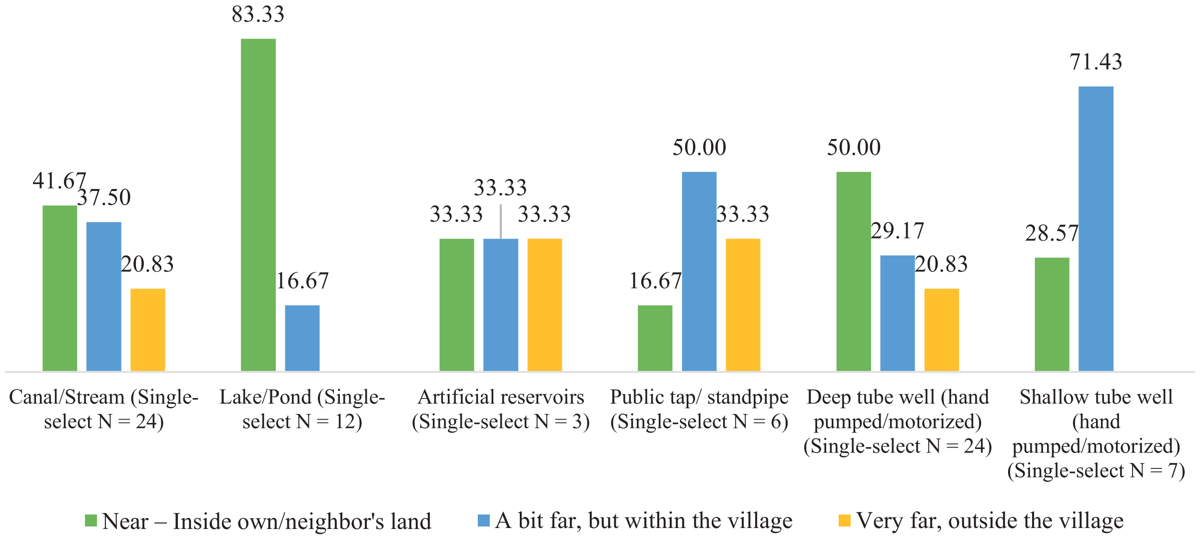


Figure 25: Distance of Different Irrigation Sources from the Respondent

3.3.6 Challenges Faced in Accessing Irrigation Water

Irrigation water is crucial for a good yield from agriculture. Respondents, involved in agricultural activities, were asked if they face challenges to irrigate their crops along with the types of challenges. The Figure 26 depicts that 88% of the respondents reported to face challenges to fetch irrigation water. Among the reasons, Quarrels/conflicts with neighbors (71%) was the most significant challenge followed by verbal abuse of people controlling irrigation water sources.

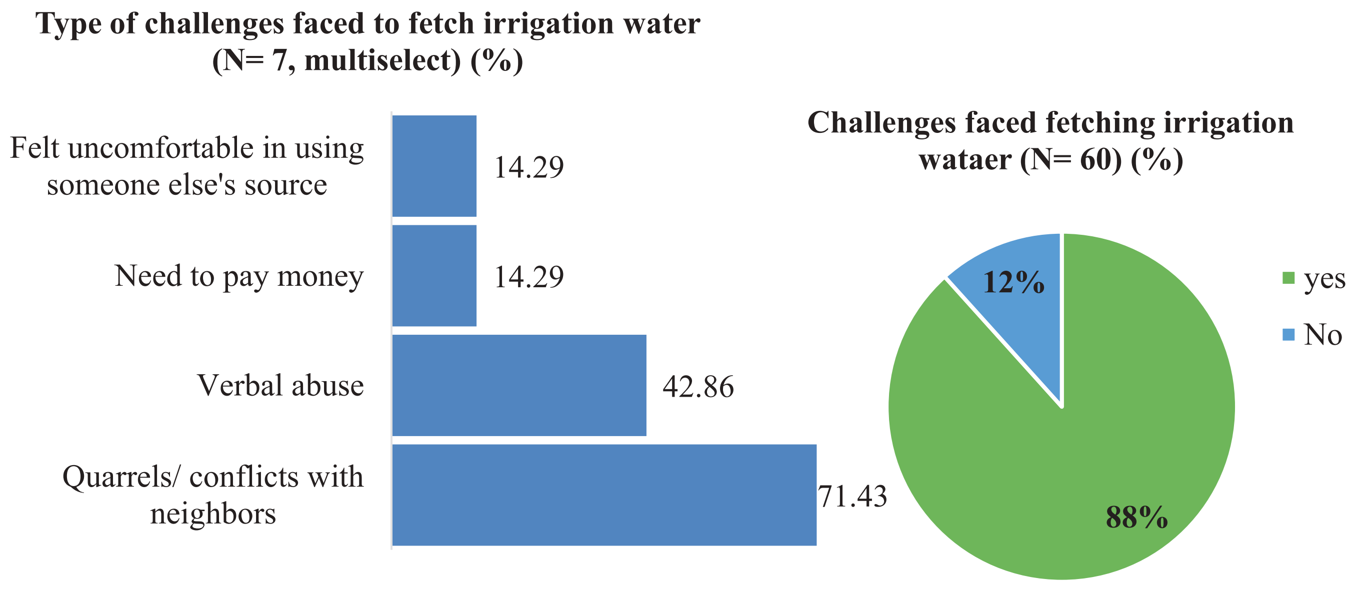


Figure 26: Challenges Faced in Accessing Irrigation Water

3.3.7 Measures Taken to Address Irrigation Water Fetching Challenges

A large portion of the respondents (57%) stated that, to address the challenges of accessing irrigation water, they remain silent or take no action. On the other hand, 29% and 14% of them reported improving mutual understanding and buying water to address the challenges.

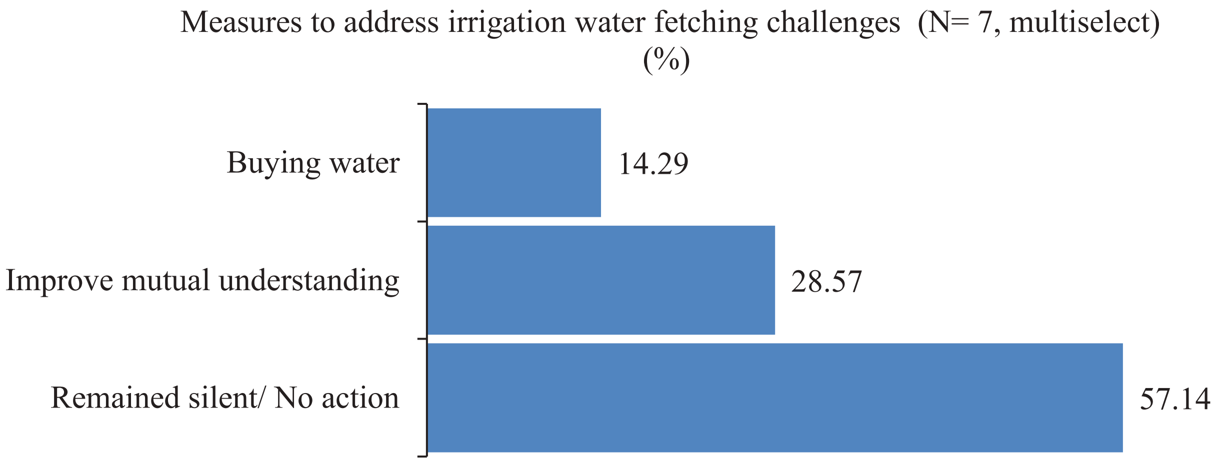


Figure 27: Measures Taken to Address Irrigation Water Fetching Challenges

3.4 Water Demand

3.4.1 Demand for Drinking Water

The water demand per liter per household per day, as reported by the respondents, ranges from a minimum of 2 liters to a maximum of 50 liters. The mean daily water demand is approximately 7.54 liters, while the most frequently reported value, the mode, is 3 liters per day. The data show a higher frequency of lower demand values, with 36 responses indicating a demand of only 3 liters per day, followed by 26 responses for 5 liters per day and 14 responses for 2 liters per day. This distribution suggests that a significant number of respondents experience very low water demand per capita, pointing towards scarcity among the surveyed population. Most of the households, 96 of 141, have a drinking water demand of 5 liters per day or less, indicating a predominant low water demand in this sample may be due to high water scarcity affecting the poor households. In larger and affluent families, the demand tends to be higher, as indicated by other categories with lower frequency.

Table 7: Demand for Drinking Water (L/hh/day) in Teknaf area

Water Demand per household (Liters/Day)	Frequency (136 out of 141)
≤ 5	96
5 – 10	9
10 – 15	18
15 – 20	5
> 20	8
	136

3.4.2 Demand Versus Supply of Drinking Water as a Percentage of Demand

The range of supply as a percentage of demand for drinking water in Teknaf was 1% to 100%, with the modal percentage being 5%, reflecting the commonality of severe undersupply. The mean supply level, heavily influenced by a large number of low values, would be significantly below the midpoint of the range, indicating a general insufficiency in meeting drinking water demand among the respondents. The most alarming observation is that a vast majority, 80 respondents, experienced a supply of less than 40% of the demand. Among the respondents, 18 reported a total 100% supply meeting demand, whereas only one respondent reported supply within the 80-100% range and one within the 40-60% range. No respondents fell into the 60-80% category.

3.4.3 Water Demand for Cleaning and Washing

The demand for water for cleaning and washing ranged from 5-800 L per household per day. The mean daily demand is approximately 140 liters, and the modal demand is 50 liters. The distribution suggests that a significant majority of respondents survive on relatively low daily water demand for cleaning and washing, with a few excessive water uses for cleaning and washing.

Table *8*: Supply as a percentage of Demand for Drinking Water in the Teknaf area

Supply as % of Demand	Frequency (100 out of 141)
100%	18
80-100%	1
60-80%	0
40-60%	1
<40%	80

3.4.3

Table 9: Demand for cleaning and washing water (L/hh/day) in Teknaf area

Daily Water Demand (liters/hh/day)	Frequency
<10	2
10-50	42
50-100	29
100-200	31
200-400	15
>400	17

3.4.4 Perception of Water Scarcity

Out of 141 respondents, 140 reported their perception regarding water shortage issues, with almost two-thirds confirmed experiencing water shortages, indicating a significant concern within the community regarding water availability (Figure 28).

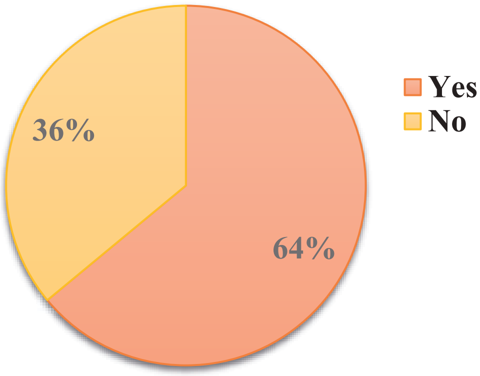


Figure 28: The perception of Respondents on the Water Scarcity

3.4.5 Temporal Aspect of Water Shortage

Responses on water shortage seasonality were obtained from 70 out of 140 who responded to the perception question. Their responses reveal that 71% of them experience seasonal water shortages while the remaining 20% face permanent water scarcity, highlighting the need to address fluctuating water availability throughout the year (Figure 29). In terms of the actual period of the year when they suffer water scarcity, ***February to June,*** i.e., the dry period of the year before rain, emerges as the time frame where many respondents suffered water shortage, with one large group mentioning ***February to April*** and the other group ***March to June*** highlighting these as critical periods.

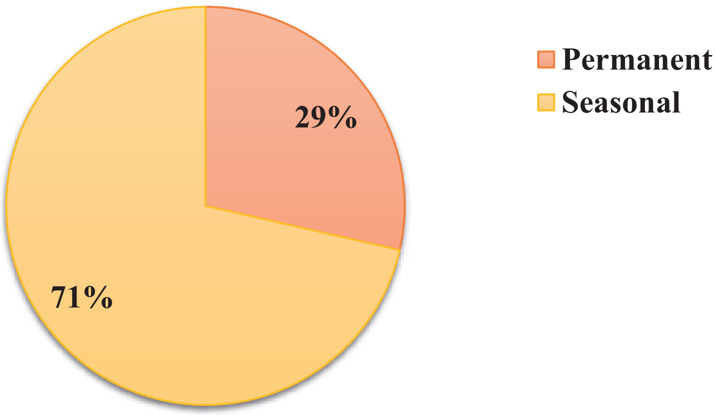


Figure 29: The Temporal Aspect of the Water Shortage

3.4.6 Water Shortage Intensity Over Time

Figure 30 shows the intensity of water shortage in TWS over time. Among 100 respondents who face a shortage of water for domestic use, 78% revealed that water shortage is increasing day by day, but according to 10% of the respondents, it is decreasing. Half of the remaining respondents said that the water shortage problem fluctuates seasonally, and the other half seemed to be unchanged.

3.4.7 View on Water Scarcity

Figure 31 shows the views of 70 respondents on water scarcity in TWS. The majority of respondents (62%) believe that water scarcity is primarily a supply-side or source-related issue, suggesting they believe there are not enough sources of water, especially in the dry season, available in TWS. In contrast, 4% of respondents believe water scarcity is primarily a demand-related issue. This means they think that there is enough water available, but factors like water consumption or inefficient water management are causing problems. The remaining 34% of respondents believe that water scarcity is caused by a combination of both demand and supply-side factors.

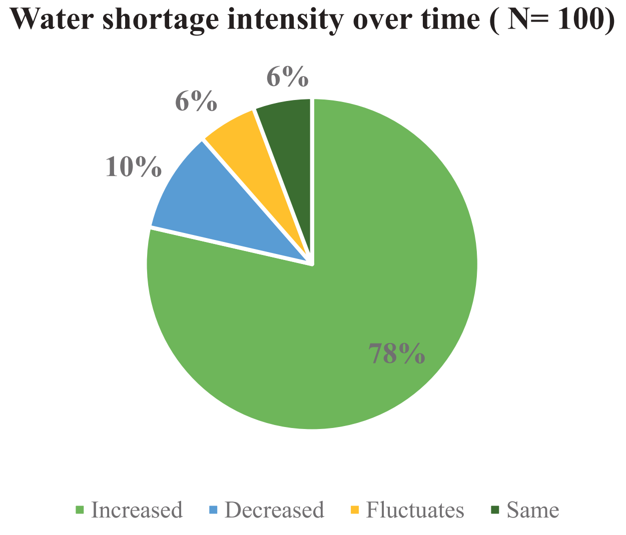


Figure 30: Water Shortage Intensity Over Time.

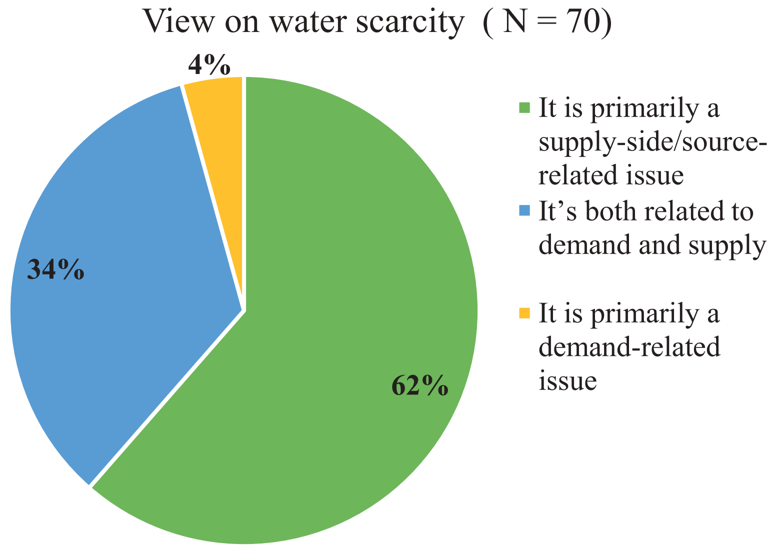


Figure 31: View on Water Scarcity.

3.4.8 Primary Reasons for Water Shortage

Figure 32 displays the factors contributing to water scarcity TWS. The prevalent reasons identified are groundwater depletion (68.12%) and the decline in precipitation (50.72%). Increasing temperature and reduction in water source output (drying up) were mentioned as causes of water scarcity by 46.38% of respondents. Other causes of water scarcity include the intrusion of salinity (24.64%), increased demand due to population growth (23.19%), and the filling of water bodies such as ponds, canals, etc. Natural calamities (20.29%) and inadequate water supply infrastructure (15.94%) were also noted as contributors to the water shortage issue. According to 11.59% of respondents, lack of supply line or pipe maintenance or damage causes water scarcity in TWS, and 10.14% identified Rohingya influx as a cause. A smaller portion of respondents pointed out deforestation (1.45%), local geology (1.45%), competition for water among different sectors (1.45%), and poor water quality (4.35%) as factors impacting the shortage of water.

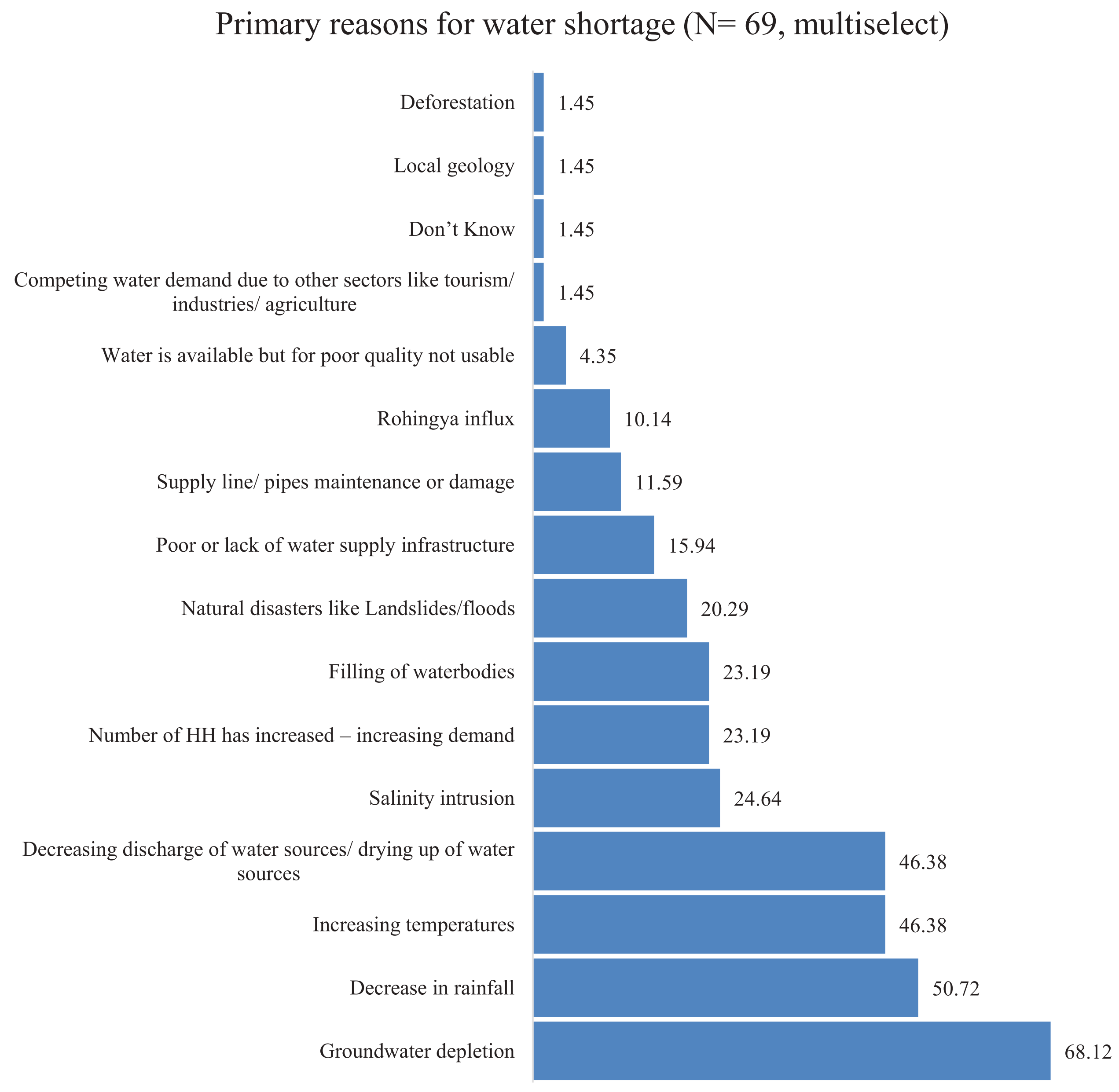


Figure 32 Primary Reasons for Water Scarcity

3.4.9 Problems You Face Related to Water Scarcity

The respondents identified a multitude of problems they faced due to water scarcity, highlighting issues across daily life and agricultural practices. Key concerns are drinking water scarcity, with many mentioning the need to transport water from distant sources, the unreliability of future water availability, and the labor-intensive process of fetching water. The quality of water is also a significant worry, with numerous mentions of high iron content, salinity, and bad odor affecting its usability. Agriculture is heavily impacted, with respondents noting the detrimental effects on cultivation, irrigation shortages, and the overall threat to food security. Groundwater depletion and the dry season exacerbate these challenges, with water levels dropping and sources drying up, leading to increased hardship in accessing water for household and agricultural needs. Additionally, the economic burden of securing water, infrastructure issues like damaged or distant tubewells, and environmental factors such as deforestation and pollution further compound the water scarcity crisis experienced by the community.

Table 10: Problems faced by households due to water scarcity in Teknaf area

Cause of Water Scarcity	Frequency (number of respondents)
Drinking Water Scarcity/Shortage	17
High Iron Content in Water	13
Water Availability Issues in Dry Season	11
Groundwater Depletion/Level Depression	6
Hygiene and Sanitation	6
Irrigation and Agricultural Issues	5
Distance and Accessibility Problems	5
Water Quality Issues (Other than Iron)	4
Economic Constraints	3
Infrastructure Problems	3
Seasonal and Weather-Related Issues	1

3.4.10 Migration Due to Water-Related Issues

Figure 33 displays findings from a survey conducted among 132 individuals in TWS regarding their awareness of people relocating due to water-related issues. According to the results, a large majority, accounting for 80% of respondents, confirmed knowing someone who has moved because of water problems. In contrast, 20% of respondents stated that they are not acquainted with anyone who has relocated for water-related reasons. These findings suggest that water scarcity plays a role in driving migration trends in TWS.

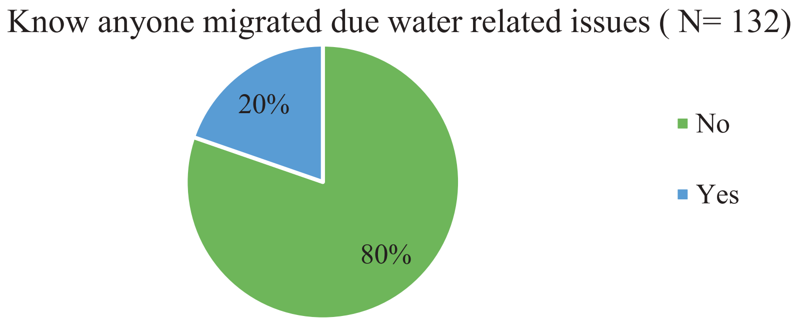


Figure 33: Migration due to water-related issues

3.5 Watershed of TWS

3.5.1 Status of Watershed Components of TWS

Table 11 summarizes the scores indicating the status of various watershed components of TWS on a scale from -5 (worst) to +5 (best). While hills score highest (1.69), indicating the presence of hills in TWS contributes moderately to the health of the watershed, followed by rivers (1.41), indicating a good ecological state, natural depressions like ponds or wetlands have the lowest score (-1.80), suggesting they're in the worst condition. This could be a cause for concern for the overall health of the watershed. The remaining components, including headwater regions (0.50), springs (0.72), streams (0.23), canals (0.71), and soil or groundwater surface (0.91) and wildlife (0.81), fall somewhere in fair condition. Streams score near zero (0.23) means the streams in TWS are likely in neither a good nor bad ecological state. This mix highlights areas where the watershed thrives and areas needing attention.

Table 11: Status of watershed components of TWS: rating between -5 to +5

Watershed component	Mean rating
Hills	1.69
Headwater region	0.50
Springs	0.72
Streams	0.23
Canlas	0.71
Rivers	1.41
Natural depressions	-1.80
Soil/ground surface	0.91
Wildlife	0.81

3.5.2 Current Health and Restoration Need of TWS Watershed

Table 12 shows the current health of the overall watershed and the need for restoration efforts with higher scores indicating better health or a greater need for restoration. The current health of the overall watershed is 2.40 which indicates moderate to poor health value and rate for the need of watershed restoration at TWS is 4.65 meaning restoration efforts are highly needed.

Table 12: Current health and restoration need of TWS watershed: scale of 5

Item	Mean rating
Current health of the overall watershed	2.40
Need for watershed restoration	4.65

3.6 Water Management

3.6.1 Status of Natural Water Resources

Table 13 presents an overview of the mean ratings for the status of various natural water resources, ranging from -5 (worst) to +5 (best). Groundwater resources, including dug wells (1.57) and deep tube wells (3.03), exhibited the highest mean ratings, indicating a generally better-perceived condition compared to surface water resources. Surface water resources showed mixed results, with rivers (1.39) having a positive rating, while canals (-0.30) and hilly streams (-0.25) scored lower. Overall, surface water resources had a mean rating of 0.00. These findings suggest a potential need for further investigation into the factors influencing the status of surface water resources in this area.

Table 13: Status of Natural WaterResources: rating between -5 to +5

Natural water resource	Mean
Surface Hilly stream	-0.25
Surface Canal	-0.30
Surface River	1.39
Surface Overall	0.00
Ground Dug well	1.57
Ground Deep tubewell	3.03
Groundwater overall	1.27
Springs fountain	1.60
Spring shed	0.82
Riparian zone	-0.06

3.6.2 Water-Related Project

The majority of the respondents (79%) stated that there is no water related ongoing project in Teknaf peninsula (Figure 34). Only 21% of them reported to know about any water related ongoing project.

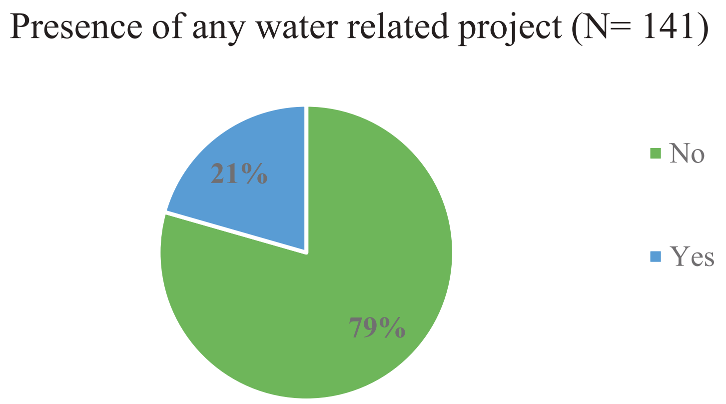


Figure 34: Presence of any Water-Related Project

3.6.3 Water Management Group in The Community

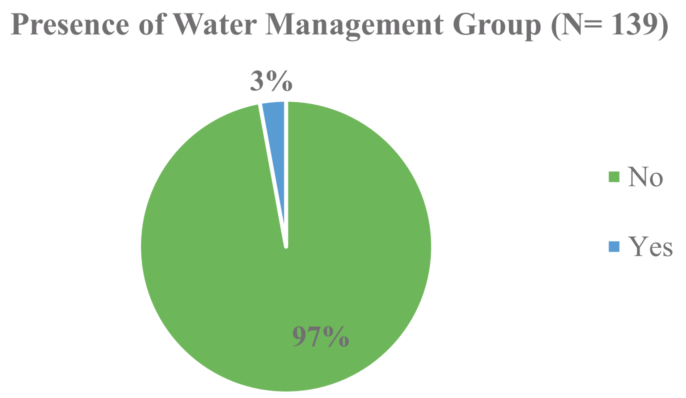


Figure 35: Presence of Water Management Group

Water management group comprising local people would play a pivotal role to address water related challenges of any area. But only 3% of the reported to know about the presence of any water management group (Figure 35). In contrast, 97% of them stated about no presence of any water management group.

3.7 Water Discharge

The survey was conducted almost at the end of the dry season (The last week of February), and as such, there was low water flow in the stream. And it was not possible to measure discharges of all streams in the area. Still, we could discern from Table 14 that the stream health is variable, with some streams having very good discharge even at the end of winter (Chowdhury Para Khal: 136 CFS) while many have virtually very low flow (2-3 CFS in Hnila Chora, Holbonia Chora, and Hulbonia Chora) indicating the degraded condition. We need to consider, however, that the streams are variable in size, and water extraction at different locations of the stream is a factor of its proximity to the locality nearby, which all are reflected in the discharge measurements.

Table 14: Discharge Rate at Different Canals in Teknaf

Sl.	Name of stream	Location	Discharge rate (CFS)
1	Chowdhury Para Khal	N: 20.99886 E: 92.25397	136.00
2	Motherbonia Chora/khal	N: 21.01087 E: 92.19164	28.80
3	Hajom Para Chora	N: 21.00169 E: 92.19553	25.31
4	Ali Akbar Para Chora, S. Hnila	N: 21.02622 E: 92.23771	23.22
5	Lamba Ghona Chora	N: 21.11120 E: 92.17873	9.00
6	Mathavanga Noya Chora	N: 20.98360 E: 92.20082	8.44
7	Kerontoli Khal	N: 20.89956 E: 92.27845	4.80
8	Hnila Chora	N: 21.03234 E: 92.18205	3.15
9	Holbonia Chora	N: 20.99556 E: 92.19797	3.09
10	Hulbonia Chora	N: 20.88935 E: 92.29620	2.18

3.8 Water Quality Assessment

3.8.1 Turbidity

Turbidity refers to the haziness of a liquid caused by the presence of suspended particles. Riverbank erosion, runoff from land, or the presence of algae and other microorganisms are the main causes of high turbidity in water. In this experiment, we noticed that the water collected from Pond and Pat kua (Ring well) had elevated turbidity levels. Among the six sources, the turbidity level of Pond Water (21 NTU) and Pat Kua Water (23 NTU) crossed the standard level of turbidity for irrigation (10 NTU) and drinking water (5 NTU). Water samples collected from Tubewell (2.5 NTU) and Artesian aquifer (4.5 NTU) showed the lowest level (Figure 36). Water samples taken from Tubewell and Artesian Aquifer are excluded from hilly erosion, runoff or debris, and wastewater. So, the turbidity level of under ground water is low.

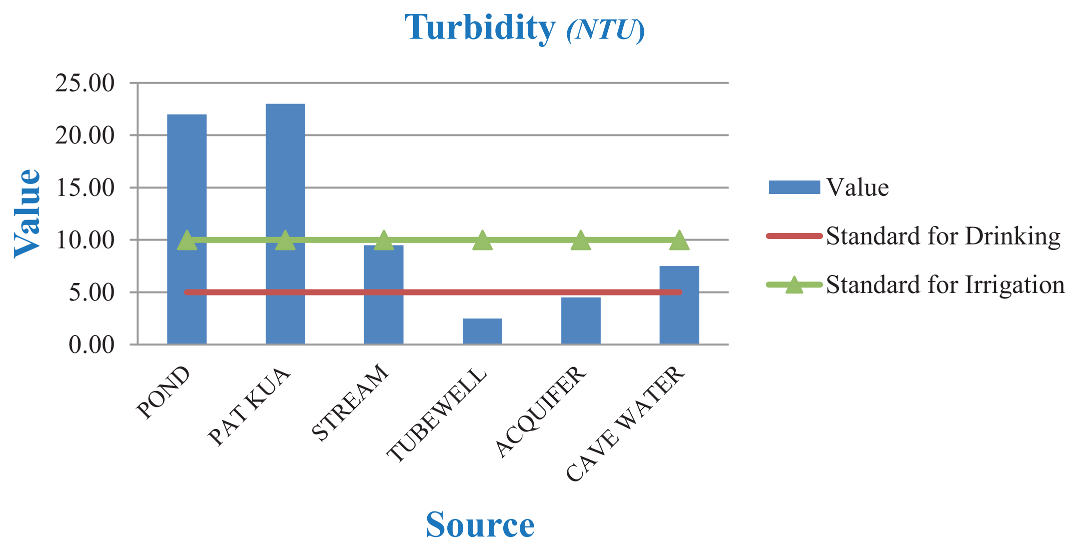


Figure 36: Average Turbidity level in different sources of TWS

3.8.2 Electric Conductivity (EC) at 25°C

Conductivity refers to the measurement of water's capability to pass electrical flow. This ability is directly related to the presence of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides, and carbonate compounds. In this study, the highest conductivity in tubewell is 500 µs/cm, and this level is under the standard level (2200 µs/cm). EC of all sources of water is falling well below the specified limit. EC is well positioned due to the absence of external ions in the TWS water sample.

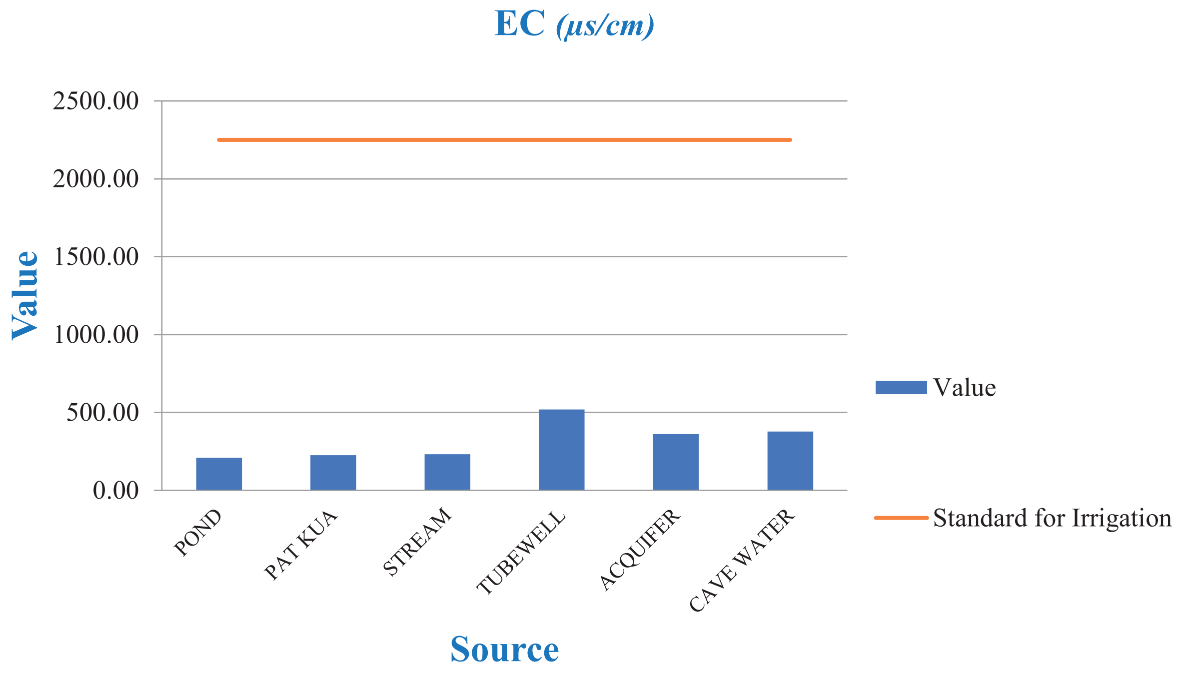


Figure 37: Average Electric Conductivity level in different sources of TWS

3.8.3 Total Dissolved Solid (TDS)

Total Dissolved solid refers to any salts, metals/non-metals, or other organic/inorganic substances that are present in water in a dissolved form. In this study, the highest TDS (257 mg/l) was found in tubewell water, whereas the lowest TDS level (112 mg/l) was found in the Pat Kua. All these levels are under the standard level (1000 mg/l). It is necessary to write that there is no reason to worry about the TDS level at present, but the government should be cautious in the future. High levels of certain types of dissolved solids can cause health and environmental problems.

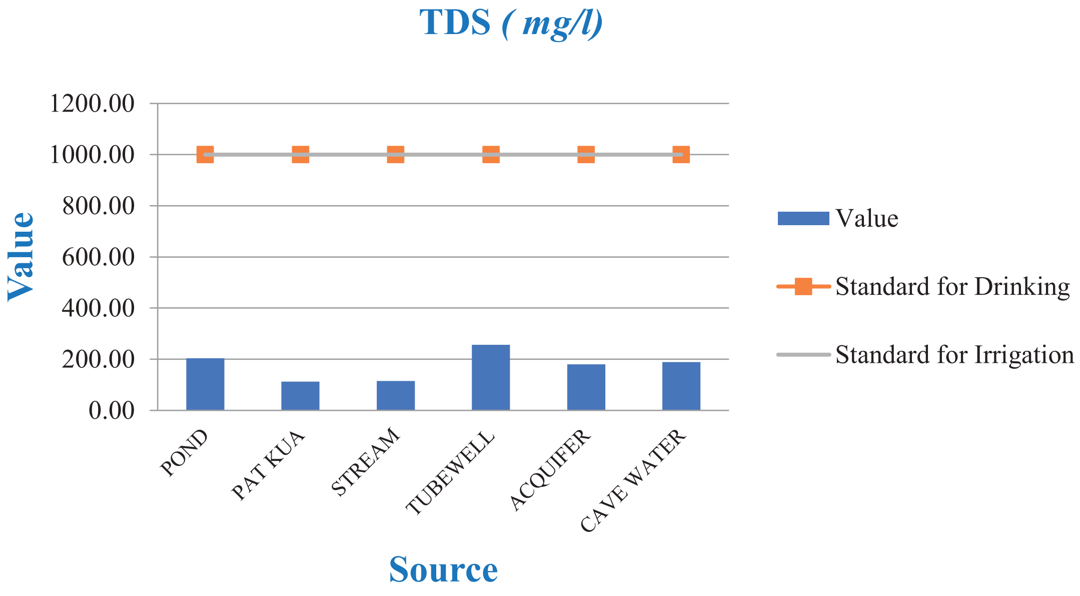


Figure 38: Average TDS level in different sources of TWS

3.8.4 pH

The pH of water denotes the solubility and biological availability of chemical constituents such as nutrients and heavy metals. The water collected from Pat Kua and caves has a higher P^H value. These water samples may have bicarbonates, carbonates, hydroxides, or alkalis. These mineral deposits also increase the alkalinity of the water. These substances can come from various sources like rocks and minerals in natural environments, industrial activities, or even household products.

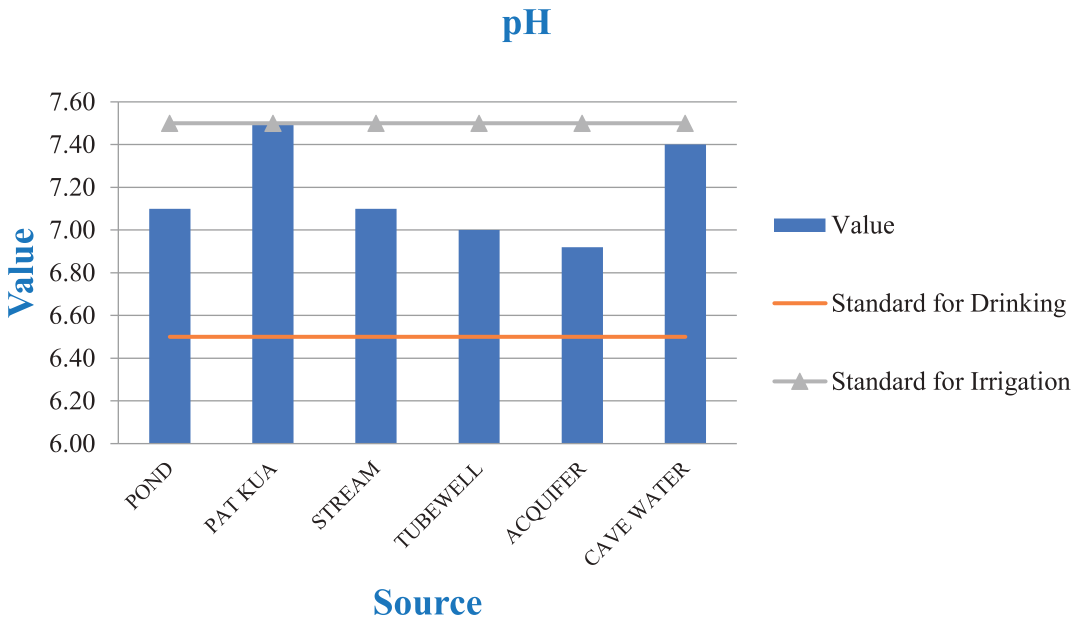


Figure 39: Average pH level in different sources of TWS

3.8.5. Dissolved Oxygen (DO)

Dissolved oxygen (DO) is the concentration of how much oxygen is dissolved in the water. The amount of dissolved oxygen in a stream or pond can tell us a lot about its water quality. All aquatic animals need DO to breathe. Low levels of dissolved oxygen (less than 3 mg/l) (hypoxia) or no oxygen levels (anoxia) can occur when excess organic materials, such as large algal blooms, are decomposed by microorganisms.

Testing of water samples in this research revealed that the DO content was accurate. All samples contained DO content between 4-5mg/l. Only the amount of DO in the artesian aquifer is lower than the limit. But for drinking purposes, artesian aquifers are easily drinkable. However, there is no oxygen in the groundwater because there is no interface with the atmosphere. There may be CO_2, which comes from the carbon cycle. The oxygen could come from the photosynthesis if the water contains algae.

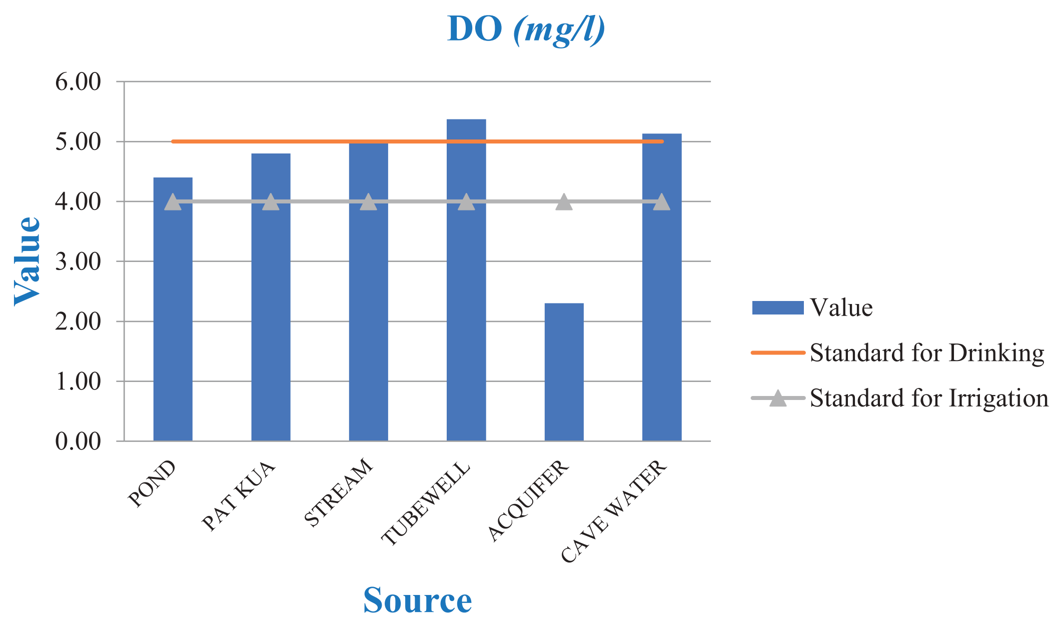


Figure 40: Average DO level in different sources of TWS

3.8.6 Biological Oxygen Demand (BOD)

It is the amount of oxygen required by the micro-organisms to decompose the organic matter under the presence of oxygen**.** The study revealed that the BOD levels in the samples were acceptable, except for Pat Kua *(Ring well: 3mg/l)*. During the site visit, it was noticed that water stored in Pat Kua was uncovered and not maintained in hygienic condition. As a result, organic matter originates from various sources like human waste; food waste can be easily mixed with water. This results in heightened microbial and higher BOD levels as microorganisms consume oxygen while breaking down organic compounds. BOD in pond water is 2.2 mg/l, which is higher than other sources like stream tubewell, aquifer, etc (0.2 mg/l to 0.5 mg/l) but generally better than ponds or impoundments in different areas. As water is very scarce in this region, the local people refrain from any activity that creates any kind of garbage or pollution in the pond water. Therefore, the water quality of the pond in this area was relatively good.

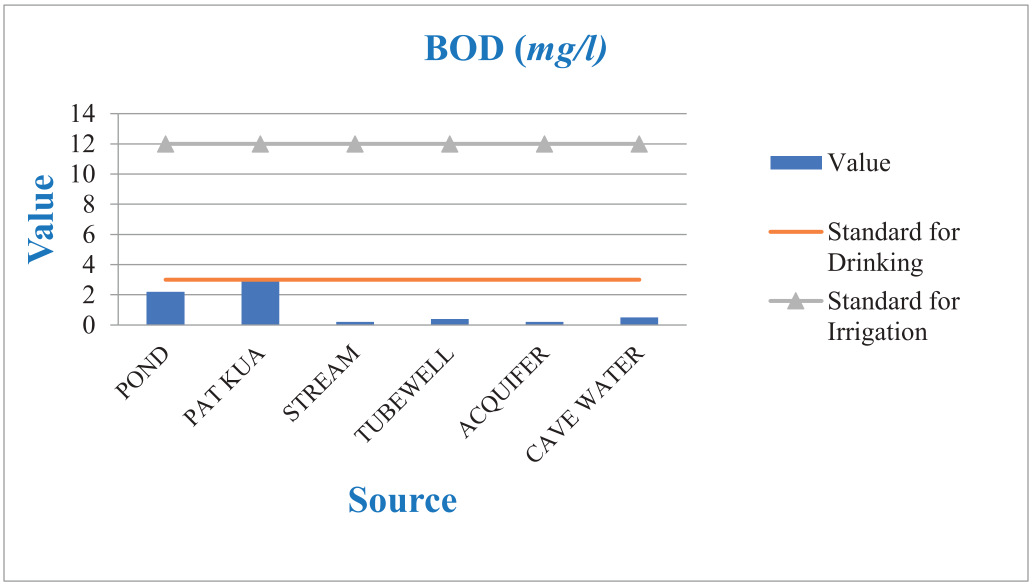


Figure 41: Average BOD level in different sources of TWS

3.8.7 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand is the total amount of oxygen required to break down the organic matter by chemical oxidation. It is an important water quality parameter because, similar to BOD, it provides an index to assess the effect discharged wastewater will have on the receiving environment. From the study, we found that the chemical oxygen demand (COD) of all sources was below the standard line (25 mg/l). Among the sources, Pat Kua showed the highest COD level (4.7 mg/l). Water gathered and stored in Pat Kua is not covered and not maintained properly. As a result, the accumulation of animal feces, solid waste, soluble organic compounds, residual food waste, oils, etc., increases the decomposition and release of dissolved organic Carbon (DOC).

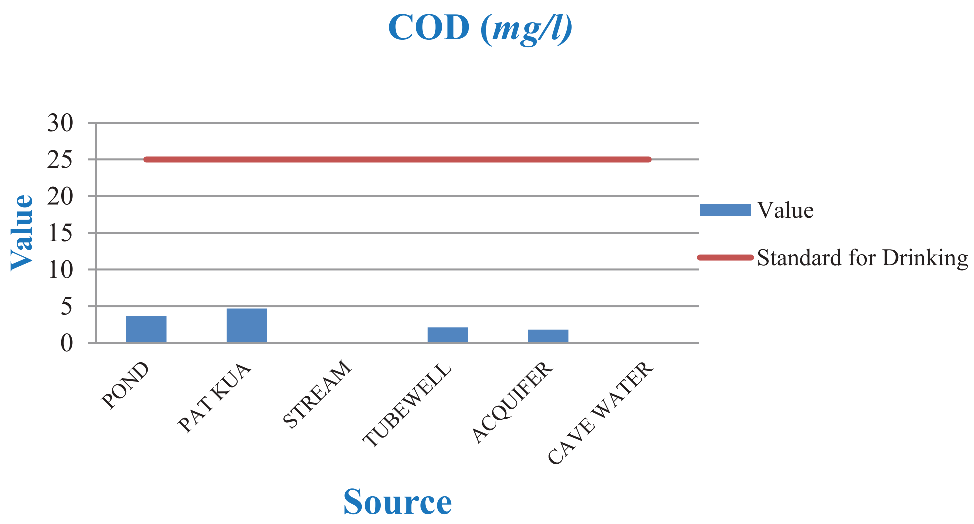


Figure 42: Average COD level at different points among three different source

3.8.8 Phosphate (PO_4^-)

Phosphate levels in artesian aquifer (3.5 mg/l) significantly increased among six water sample sources. It can speed up eutrophication (a reduction in dissolved oxygen in water bodies caused by an increase of mineral and organic nutrients) of rivers and lakes. Anthropogenic sources like use of fertiliser or natural source like aquifer sediments may be causes of elevated phosphate level in artesian aquifer.

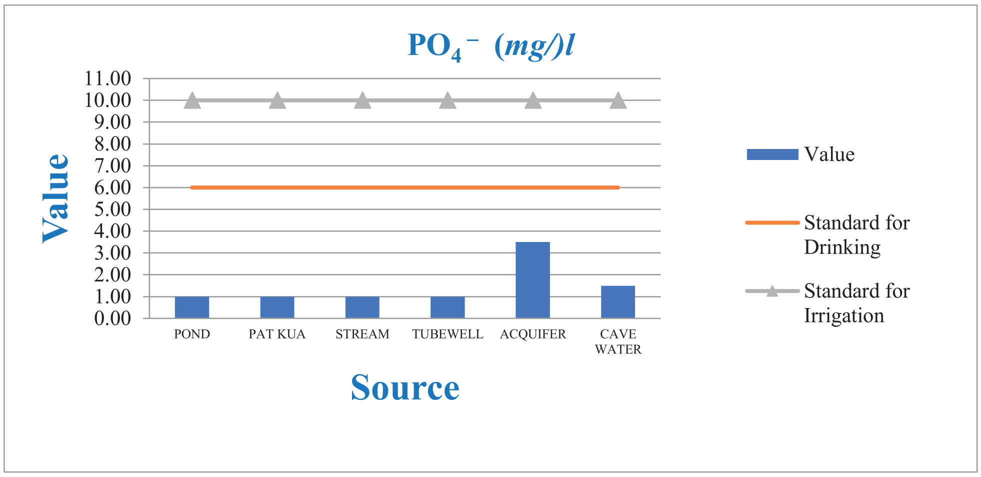


Figure 43: Average PO_4^- level in different sources of TWS

3.8.9 Nitrate (NO_3^-)

Nitrates are essential plant nutrients and a common pollutant in both surface and groundwaters. Excess amounts of NO_3^- can deteriorate water quality and create significant water quality problems. NO_3 ions can easily leach down by the root zone in soils, reach the ground, and mix with surface waters. All the water samples collected from Teknaf upazila showed more or less amount of nitrate ion, which is very alarming. Among these, tubewell water (2.0 mg/l), pat kua (1.8 mg/l), and pond water (1.50 mg/l) showed significant results. Nitrogen fertilizers that are applied to the land mainly leach from the fertilizers and mix with river water and groundwater. Although these values are far from the standard limit of nitrate, the amount is not very low. Due to its use in agriculture, it is slowly mixing with groundwater. So, we need to reduce the use of nitrogen fertilizers by at least fifty percent as soon as possible.

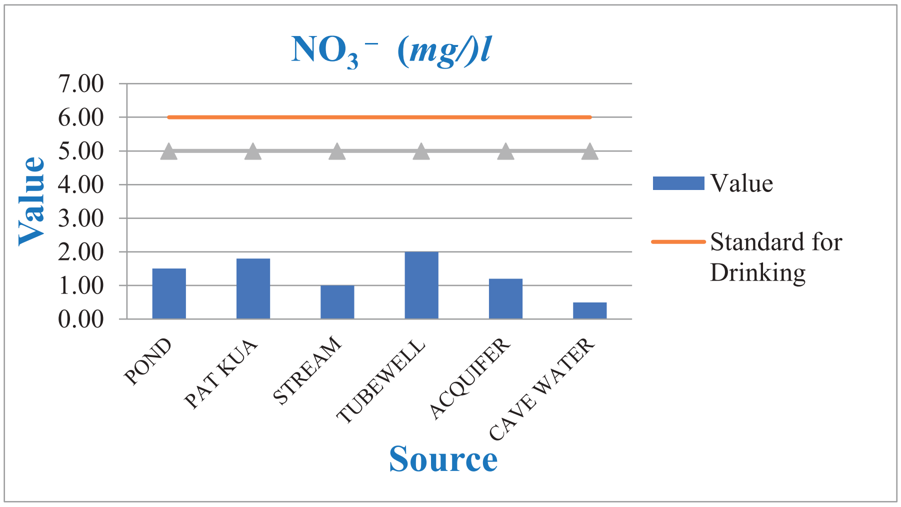


Figure 44: Average NO_3^- level in different sources of TWS

3.8.10 Comparison among Drinking Water Sources

The people of Teknaf upazila meet the demand for water by installing deep and shallow tube wells in different places after the water availability in the stream has decreased recently. In those places where tube well water is not available, they collect water through an ancient method of digging holes in the ground and placing rings there. Those who cannot afford to install deep tube wells usually collect water by sitting. At present, drinking water needs are being met by storing rainwater. Apart from government agencies, some private development organizations have taken up rainwater harvesting projects.

Table 15: Comparison of different Water Quality Parameters of Drinking Water Sources.

Source	Turbidity (NTU)	pH	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Salinity (ppt)	EC (µs/cm)	TDS (mg/l)	SO_4^- (mg/l)	PO_4^- (mg/l)
Tube well	2.5	7.0	2.3	0.42	2.11	0.045	520	258	23.5	5.5
Pat Kua	23.1	7.5	4.80	2.2	3.7	00	235	112	104	1.0
Kua	22	7.45	4.1	3.2	4.8	0.1	215	107	89	1.0
Rainwater Harvester	3.5	6.72	7.8	0.2	0.1	00	30.1	14.1	4.0	1.0
Artesian Aquifer	4.5	6.9	2.3	0.2	1.82	0.1	362	180	36	3.4
Standard (DPHE)	10.00	6.5-8.5	>=6.00	0.20	4.0	0.00	1200.0	1000	400	6.0

After testing various samples of unde rground water of Teknaf Upazila, we can conclude that a relatively high level of pollution has been found in kua *(well water)* and Pat kua *(Ring well water)*. Water from these two sources is readily available, but due to improper storage, evidence of various contaminations has been found in the water. BOD, COD, sulfate, nitrate, carbon dioxide, etc., were found in excessive amounts in the water of kua *(well water)* and Pat kua *(Ring well water)*. If someone drinks water from these sources without any purification process, then there will be a chance of contracting various waterborne diseases.

On the other hand, rainwater, which is readily available but expensive to conserve, is the purest and least polluted. Rainwater contains the least Nitrate, Sulphate, Phosphate, BOD, and COD; even carbon dioxide is not found much in it.

3.9 Community Perception (FGD Summary)

Twelve FGDs at different localities near the TWS have unearthed the major watershed and water-related themes facing the community and the pain points they suffer. The significant findings from the FGDs reflect the community's perception of the TWS watershed and the local community’s dependency on it. The findings have been summarized into six thematic areas:

3.9.1 Reduction and Accessibility of Water Sources

- **Perennial Streams:** Participants noted a significant reduction in the number of perennial streams, attributing this to water harvesting in the upper watershed areas, which prevents water from reaching downstream locations.
- **Groundwater Accessibility:** There is a notable decrease in groundwater levels, with wells needing to be dug deeper each year, sometimes reaching depths of 1000 to 1500 feet. Despite these efforts, the water extracted is often salty, impacting its usability.
- **Local Water Storage Adaptations:** In response to water scarcity, locals have innovated by creating deep trenches to store rainwater, demonstrating a grassroots approach to water conservation and accessibility.

3.9.2 Water Quality Concerns

- **Contaminants:** Across various water sources, there are repeated concerns about water quality, explicitly mentioning issues with color, odor, salinity, and germs. High iron content was particularly emphasized, impacting both taste and safety.
- **Seasonal Variability:** The quality of water sources also fluctuates with the seasons, exacerbating the difficulty in accessing potable water year-round.

3.9.3 Socio-Economic Factors in Water Access

- **Commercialization of Water:** There's a burgeoning business around water, where those who own wells or have access to cleaner water sell it, often at high prices, capitalizing on the scarcity.
- **Economic Burden on the Poor:** The cost of water or the infrastructure to access it (like long pipes) places a significant financial burden on less affluent community members, exacerbating social inequalities.
- **Community Solutions:** Suggestions were made for community-managed water distribution systems to democratize access and reduce disparities.

3.9.4 Infrastructure and Sustainable Management

- **Inadequate Infrastructure:** The existing water supply infrastructure, including tube wells and rainwater harvesting systems, is often deemed insufficient or unsustainable, lacking in maintenance and capacity.
- **Proposed Improvements:** Participants advocate for better infrastructure planning, like re-excavating old ponds and establishing more robust rainwater harvesting systems, emphasizing long-term sustainability over ad hoc solutions.

3.9.5 Environmental Degradation and Its Impact

- **Environmental Mismanagement:** Deforestation, improper waste disposal, and construction activities are cited as significant contributors to the degradation of water sources, affecting both availability and quality.
- **Climate and Seasonal Effects:** The impacts of climate change and seasonal shifts further strain the water sources, with particular challenges during dry seasons and unexpected changes during rainy seasons.

3.9.6 Governance and Community Engagement

- **Need for Transparent Management:** The distribution of resources like rainwater harvesting tanks is reportedly influenced by local politics, suggesting a need for more transparent and equitable governance.
- **Community-Driven Solutions:** There is a strong call for community engagement in water management decisions, including the establishment of localized water committees and the inclusion of community voices in the planning and implementation stages.

3.10 Perception of Key Informants (KII summary)

3.10.1 Community Management and Water Conservation Initiatives

- ***CODEC's Co-Management System:*** CODEC has established a co-management system by forming three CMCs Teknaf Wildlife Sanctuary, Teknaf, Shilkhali, and Whykong, and forming 128 Village Conservation Forums (VCFs) to engage local communities directly in conservation efforts.

- ***Water-Related Activities:*** Projects under CODEC's initiative address the critical need for sustainable water management, including the revival of non-functional tube wells, pond re-excavation, new tube well establishments, and rainwater harvesting, aiming to mitigate the water scarcity issues faced by local communities.

3.10.2 Challenges in Water Infrastructure and Agricultural Irrigation

- ***Inadequate Infrastructure:*** The interviews reveal a gap in irrigation infrastructure development, particularly highlighted by the absence of Bangladesh Agricultural Development Corporation's activities in Teknaf. This gap underscores the need for more targeted infrastructure development to support local agriculture.

- ***Water for Agriculture:*** The AEO's insights illuminate the struggles of farmers with irrigation during dry seasons, emphasizing reliance on diminishing groundwater resources and stream water, which are not always reliable or sustainable sources.

3.10.3 Impact on Agriculture and Local Economy

- ***Crisis in Agricultural Water:*** The AEO pointed out that water scarcity directly impacts agricultural output, with specific reference to the damage of demonstration plots due to inadequate water supply.

- ***Economic Activities Around Water:*** There's a note on the emergence of water-related businesses where individuals sell access to water, indicating an economic adaptation to water scarcity but also raising concerns about equitable access and sustainability.

3.10.4 Water Quality Concerns and Health Implications

- ***Varied Water Issues Across Regions:*** Engineer Faruk from DPHE highlighted differing water crisis levels in various unions, suggesting a nuanced and location-specific approach to addressing water issues.

- ***Concerns Over Water Quality:*** Issues like high iron content, salinity, and alkaline water not only affect the usability of water but also pose potential health risks, necessitating urgent attention to water treatment and quality assurance.

3.10.5 Governance, Policy, and Stakeholder Engagement

- ***Need for Coordinated Management:*** There's a strong emphasis on the necessity for inter-ministerial coordination to align various departments and stakeholders to address the complex, interlinked issues of water management and irrigation effectively.

- ***Local Engagement and Solutions:*** The discussions reflect a need for more robust local engagement and empowerment in water management decisions, suggesting that community-driven approaches could be more adaptive and sustainable.

3.10.6 Environmental Concerns and Sustainable Resource Management

- ***Impact of Environmental Degradation:*** The Forest Ranger's input sheds light on how infrastructure development and deforestation are affecting natural water catchments, pointing to a broader environmental crisis that exacerbates water scarcity.

- ***Conservation and Restoration Efforts:*** There is mention of the potential for forest conservation and species-specific plantation strategies to restore natural water balances, emphasizing the link between environmental health and water resource sustainability.

4.0 Identification of watershed management issues

Based on the survey results, KII observations and FGD outcomes, digital watershed map generation, field observation, and community survey, the primary main points related to watershed and water management in the TWS area have been identified as summarized in Table 16.

Table 16: Identification of watershed management issues at TWS.

Sl	Observation	Source	Management issue	Comment
1.	In winter, affluent individuals transport water to their homes using pipes from upstream areas, where they accumulate water by constructing dams. This process necessitates a significant investment.	-FGD -KII -Field observation	-A significant amount of water is wasted due to the absence of a stopcock at the end of the pipes. -There is a notable social disparity in accessing water, with inequitable distribution among the population. -The lack of water flow downstream is leading to the drying and subsequent demise of streams.	-Ensure equitable water access. -Water Management Committee Formation -Erect a dam on the streams at the valley to give access to a maximum number of people. -BFD seems to have no action in this regard.
2.	A JAICA survey of the discrete and patchy nature of aquifers in Teknaf, influencing the water availability. Water is localized, often controlled by a handful of families who commercialize access. This caused the concentrated installation of numerous tube wells in limited spaces with aquifers, exacerbating the region's water management challenges.	-KIIs -FGDs -Field observation	-Rapid depletion of GWT -No idea about how these aquifers are recharged and the point of their recharge -Inequality in water access -Uncontrolled water business	-Recharge points are to be located and conserved -Mark all such hotspots of aquifers and rings under joint management for equitable and sustainable access.
3.	Due to the lowering water table in the area, DPHE routinely fails to achieve its target of establishing tubewells. In 2023, they could establish 145, including 60	-KIIs -FGDs -Field observation	- Contractors are not interested in taking installation contracts as they face difficulty and delays due to lowered water table and patchy nature of the aquifers	-Finding an alternative approach to ensure drinking water security is essential

Sl	Observation	Source	Management issue	Comment
	shallow tube wells, 35 deep tube wells with six handpumps, and 50 tube wells with submersible pumps (target was 130)			
4.	Over-extraction issues were identified in places with available groundwater, like Jaliapara, raising concerns about sustainable resource sharing and management.	- KIIs - FGDs -Field observation	-Extractions are irrational in the absence of a centralized water supply system	- Water management committee for installation and management of centralized water supply
5.	Degradation of forest cover and creation of barren patches	- FGDs - KIIs - Field observation	-Reduced infiltration and water holding by forests -Erosion and sedimentation affecting streams and water quality	-Restoration, afforestation, and reforestation activities
6.	Expansion of agriculture and horticulture inside the forests and use of agrochemicals and pesticides	- Field observation - Water quality data	-Degradation of forests and wildlife -Water quality affect -Runoff containing Nitrate and Phosphate increases the risk of eutrophication	- Development of good practice guidelines for relevant stakeholders to safeguard water resources
7.	Declining groundwater table, not getting water at shallow depths, going deeper, scarcity is notable in areas like Hnila, Whykong, and Baharchara, with significant difficulties in accessing water even at depths of 1200 feet.	- FGDs - KIIs - Water quality test - Social survey	- Shallow tubewell gets abandoned, -Even with all the deep tubewells, not enough water is available now, -The water quality of many deep tubewells is not potable.	- Use of deep tube wells should be banned. Shallow tube wells can be used.
8.	People are adapting by using artificial aquifers, ring wells, and dug wells.	- FGDs - KIIs - Field observations	-Low-cost technique, -Sustainable use of water for household use and irrigation, etc., -Not suitable for drinking	-Sylhet sand may be used inside the ring well/dug well to improve water quality. -After filtration, this water

Sl	Observation	Source	Management issue	Comment
				should be drinkable.
9.	Solid wastes dumped into streams	- FGDs - Water quality assessment - Field observations	-Channel Blockage -Surface Water quality deterioration, -Groundwater contamination by leachate -Drinking water scarcity for birds and animals	- Improvement of waste management and implementation of good practice guidelines
10.	Pond and ring/dug well water levels are at the same level as sanitary toilets, creating risks of groundwater contamination by coliforms.	-Water quality data -Field observation	Contaminants, such as toxic metals, hydrocarbons, trace organic contaminants, nanoparticles, and other emerging contaminants, are a threat to human health, ecological services,	-The recommended minimum distance between a sanitary toilet and a well will be 50 to 100 feet
11.	Ponds and dighis became shallow and could not hold water in the dry season.	-Field observation -Social survey	-Water crisis becomes serious havoc during the dry season,	-Re-excavation of existing water reservoirs.
12.	Elevated water demand due to population growth, refugee influx, and increased tourism, and there will be a hike in demand due to Sabrang Tourism SEZ.	-Field observation -FGDs -KIIs	- Increase in the number of deep tubewells installed -Water supply business increase -Deforestation	-Planning for alternative sources like seawater desalination -Water conservation and recycling
13.	Salinity intrusion due to the flow of tidal water, use of the same land for Boro, rice and salt farming	-KII -Field observation -Water quality data	-Harm the bioavailability of plant nutrients such as N, P, K, Ca, or Mg -Reduce crop yield -Decreasing food security -Salinization of groundwater	-Irrigation water should be stored in ponds/reservoirs, -In the dry season, vegetable cultivation should be emphasized over Salt and shrimp farming.
14.	The construction of marine drives cuts the watershed, and	-Field observation	- Damage freshwater and estuarine ecosystems,	The waterway should always be open;

Sl	Observation	Source	Management issue	Comment
	people block and kill the streams. Even in some places, the culverts have been blocked.		-excessive sediment deposition, -Fish migration interrupted -Illegally encroached on the water body	Regulators should be constructed in lieu of culverts.
15.	A central water supply system has been established by DPHE WB finance in Whykong, but not all the people are getting equal access.	-FGDs -Field observation	-Limited number of taps -Managerial issues and political influence	-Updated guidelines -Study the issues to find solutions -Clear guidance and transparency in execution
16.	RWH system are being distributed by DPHE but the selection system crates discrepancies and the people are charged extra money to get selected.	-KII -Field observation	-Political beneficiaries or their relatives are enjoying this benefit, -Lack of accountability and transparency during delivery;	-Strict monitoring by the UNO office -Clear and transparent guidelines and implementation
17.	RWH system users reported the need to use chemicals to treat preserved rainwater to avoid insect infestation. Also, a 3000 L tank is not adequate for them to cover the entire rainy season.	-FGDs	-If not appropriately installed, RWH tanks may attract mosquitoes and coliforms, -There are different opinions about the water quality of RWH.	-Installation and maintenance should be done correctly. -Periodic water quality checkup
18.	In the majority of the streams, the riparian vegetation seemed inadequate	-Field observation -GIS analysis	-Highland runoff and erosion increases, -Reduced rate of infiltration and groundwater recharge,	-Create a 10 m riparian buffer using native species along both stream banks
19.	Construction of embankments on streams stagnates water and leads to water contamination in the absence of the riparian buffer zone.	-Field observation -Water quality data	-Deterioration of surface water quality	-Create a 10 m riparian buffer using native species along both stream banks

Sl	Observation	Source	Management issue	Comment
20.	Embankment locations, if upstream, create issues for water access to downstream people, and the stream downstream gets dried up, leading to the risk of the stream being dead.	-Field observation -FGDs -Discharge data	-Reduced downstream water flow -Drying up and death of streams -Encroachment promotion -Salinity intrusion	-Embankments are to be adequately planned, installed, and managed after proper study through watershed modeling
21.	'Kudum Guha' is a habitat for bats, and bats are to be managed properly to avoid public health risks	-KII -Field observation	-Dead bats rotten in streams -Water from the cave flows to streams with embankments	-Studying bat population and regulating flow from the Kudum Guha stream
22.	Water sources for wildlife inside the forests of TWS are dwindling, and human-wildlife conflicts have been reported as they reach localities.	-KII -FGDs - Field observation	-Decreased wildlife population -Human-wildlife conflicts	-Studying wildlife population and their distribution to plan water sources for them inside forests
23.	The absence of any water management group or committee or any other formal structure leads to inequality in access to water and the right to water resources.	-KII -FGDs -Field observation	-Water access-related conflicts and grievances -Unsustainable and wasteful use of water from the watershed -Social inequality in water access	-Formation of stream-centric water management groups with CMCs -Capacity building with management guidelines
24.	BFD seems not to have any mandate or activities related to watershed while all the streams are coming out of the forests under BFD management	-KIIs -FGDs -Field observation	-Encouraging worse practices related to watershed -BFD is missing the chance to make it a source of revenue	-Increasing BFD's roles in watershed issues -Exploring options to improve management through a revenue model
25.	The co-management initiative also lacks a clear concern or structure for addressing the water issues that are critical in	-FGDs -KIIs	-Efforts are already in place for forest conservation; needn't do a separate water management committee	-Making water management committee a part of CMC

Sl	Observation	Source	Management issue	Comment
	places like Teknaf.			
26.	Shallow tubewell in large number has been abandoned due to lowering of groundwater table. This is creating risks of groundwater contamination.	-KIIs -FGDs -Field observation	-Abandoned tubewells poses risks of groundwater contamination in flooding events -They also offer and opportunity for artificial aquifer recharge	-Mark all abandoned tubewells -Use them for artificial aquifer recharge or dismantle them
27.	No activities from the Bangladesh Agricultural Development Corporation (BADC) in Teknaf for irrigation infrastructure. The BADC operates from Cox's Bazar and constructed the Whykong sluice gate	-KIIs -FGDs	-Farmers are suffering from irrigation needs -Specifically, the amount of land under winter crops is meager	-BADC needs local presence
28.	Other sluice gates constructed by various government departments are poorly planned, allowing seawater intrusion, damaging crops.	-FGDs -Field observation	-Poorly planned sluice gates create waterlogging or salinity intrusion issues	-Study to evaluate all existing sluice gates using watershed modeling -Removal of defective ones -Establishing any new based on model outcome
29.	Farmers sometimes build makeshift dams to control saline water intrusion.	-Field observation	-These unplanned structures sometimes help and sometimes create waterlogging	-Should be based on watershed model to avoid problems
30.	Farmers rely on streams and groundwater wells for dry season irrigation, facing issues due to groundwater levels.	-FGDs -Field observation	-The unplanned use of stream water and groundwater wells are unsustainable	-Integrated planning through modeling and watershed management committee and GoB entities
31.	The impacts of climate change, such as reduced rainfall and increasing salinity	-KII -Field Observation -FGDs	-Climate change will further complicate watershed health and output	-Climate aspects should be taken into building watershed model for better planning for

Sl	Observation	Source	Management issue	Comment
	intrusion, exacerbates water scarcity and affects agriculture and biodiversity. - DPHE and World Bank initiatives, like the central water supply in Unchiprang, illustrate complex and costly efforts to improve water access, demonstrating the need for substantial investment and community engagement in water management solutions.		- Central water supply initiatives should be taken as a source of lessons to address current limitations for a more robust system under the water management committee	the future - Public consultation and social/ environmental impacts through feasibility studies are essential for central water supply system
32.	LGED has not stake in surface water management in Teknaf. LGED's SSWRDP (Small Scale Water Resource Development Project) handle irrigation projects in catchments < 10,000 hectares, which do not exist in Teknaf. LGED aims to establish water management committees through cooperatives under SSWRDP, where the government covers 70% of expenses, and cooperatives contribute 30% and manage water issues, mainly for irrigation.	- KII	- People are stressed with water crisis due to deteriorating watershed health while government initiatives are not equally addressing problems in this area	- Integration of all central GoB efforts or projects related to water and watershed should be deployed to solve TWS water issues - LGED has already mandate to form water management cooperatives which can be replicated through CMCs in Teknaf
33.	SCRIDP (South Chittagong Rural Infrastructure Development Project) funded	- KII	- Due to the absence of proper planning for Teknaf	- Need detailed study to make the project effective to address most of the issues

Sl	Observation	Source	Management issue	Comment
	by JAICA, which involves infrastructure development, including water management efforts like canal and pond excavation and afforestation.			identified for TWS watershed in this study
34.	Perennial streams are reducing in number, with many drying up in winter due to upstream water harvesting. This impacts water availability downstream.	-KIIs -Field observation -GIS analysis	-Watershed is deteriorating structurally. -Flash flood vulnerability is increasing -Climate change vulnerability is increasing	-Detailed mapping of streams and communicate maps to all to conserve them -Vigilance from BFD and CMC to safeguard streams -Excavation when needed -Restoring riparian zone
35.	Groundwater pH is high, reducing its suitability for drinking and household use. Arsenic levels are within safe limits, but salinity and contamination risks are concerns.	- Water quality testing - FGDs - KIIs - Field observation	-Consumption of contaminated water is creating public health concern	-Rather than discrete water supply better to go for central water supply with proper treatment under water management committee
36.	Water projects are taken discretely by different organizations in different places without a systems approach and coordinated effort for which the return on investment are poor and managing the resources created are proven to be problematic. Long term maintenance and sustainability of such projects are become a big issue.	- KIIs - FGDs	-Uncoordinated projects create more problems than they solve -Lot of investment is going into creating infrastructure which becomes obsolete and a burden for local people	-Coordination among entities in undertaking projects and avoiding duplication of efforts and expenses is essential for efficient watershed management at TWS

Sl	Observation	Source	Management issue	Comment
37.	Water supply for refugees, project by DPHE at camp 26 on BFD land and desalination by NGO	- KIIs	-Supply for refugees only create local grievance and enhance refugee-host conflicts	-Rational distribution of water to local community is need
38.	Family expenditure of marginal income families are increasing as they pay for purchasing water	- KIIs - FGDs - Survey	-Inequality in accessing water related ecosystem services from the TWS watershed	-Formation of water management committee with participation of all people to ensure equitable access to water
39.	Severe degradation of forest covers due to deforestation	- Literature review - Field observations - LULC analysis	-Reduced water holding capacity of forests -Decreased percolating and infiltration -Fast removal of rainwater from the basin -Increased soil erosion and landslide leading to sedimentation	-Conservation of the remnant forests -Restoration of forest cover starting with riparian buffer using native species -Awareness and enforcements
40.	Lack of coordinated and integrated approach among GoB institutions, NGOs and local leaderships in addressing the issues	- Field observations - KIIs - FGDs	-Discrete projects exacerbating problems -Permission related issues as different entities have different power structure and roles/responsibilities, priorities -No dedicated committee at upazila level to discuss and solve issues -Many project are centrally taken without necessary local consultations	-Coordination through a upazila level committee including local institutions, local leaders, NGOs, and local community representation through CMCs -A dashboard showing water related projects and programs with performance indicators

5.0 Watershed Management Plan

Based on the information gathered from the field and literature, as well as insights from the LULC, we have identified the major issues related to the TWS watershed and water security of communities in the area. All these has been accumulated into a proposed watershed management plan for the TWS (Table 17).

Table 17: Watershed Management plan for TWS

Sl	Action item	Involved stakeholders	Modality	Area focus	Comment
1.	Expanding the innovative adaptive mechanism – the artificial aquifer - developed by the local community	CODEC can pilot one and show it as a demonstration to the stakeholders so that the GoB. In the long run, DPHE, LGED, PIO office, WDB can mainstream this as a component of their activities. NGOs and local initiative can also be adopted.	- Currently, they dig 20-30 feet deep, 10-15 feet wide and 20-30 feet long deep trenches, under the trench they put gravel and Sylhet sand to bury horizontally laid shallow tubewell filter and fill the whole trench with Sylhet sand and on top they cover with the usual sand at the site. An estimation indicates the potential of storing 1 million liters of water in a 20 ft deep sand trench. - Local large-scale open spaces like school playgrounds, Eidgahs can be converted into artificial aquifers that can hold substantial amounts of rainwater during the rainy season, which the community can tap during the dry period to secure the water supply in dry months. - Standardizing an engineering design specification and material standard to be used as well as water quality and withdrawal guideline, monitoring plan will be needed and can be done by GoB agencies - After formation of WMCs, they will be responsible for managing these facilities -	- Entire Teknaf peninsula where large open space is available near the community for Artificial aquifer recharge and storage	- Research through piloting is suggested before large scale deployment. Meanwhile, promotion of small-scale household level installations can be encouraged.

2.	Creating riparian buffers around he streams, starting with the priority ones	CODEC is already piloting which can be further expanded, and it should be part of routine plantation/ restoration activities of BFD. Besides, LGED, WDB, DPHE or PIO offices, while implementing any project involving a stream should enhance riparian vegetation. In future, it will be a regular activity for WMCs, once formed.	- BFD can prepare a riparian species guidebook and riparian conservation and restoration modality and share with all stakeholders. - It is known that a 50m buffer area with rich riparian vegetation on both sides of a stream offset any impact on water yield and water quality in the stream. Hence, in developed country, the good practice guideline indicates keeping a 50 m area on both banks of a stream conserved and undisturbed for	-	- The map provided in the document on riparian buffer can be a guideline
3.	Stream mapping, basin mapping and monthly or daily discharge measurements for several years	- BFD, CEGIS, IWM, WDB and other institutions with capability. The CPG members can	- This document provides two different stream maps (i) based on DEM analysis in HEC-HMS and (ii) secondary stream data from different sources accumulated by Open Street Map. - GPS tracking is the only option for	- TWS watershed area including forests and settlement	- The digital maps can be used as a guide - Security is a concern in such mapping - Involving local people with deeper knowledge about the

		be used for mapping. Academic institutions can also assist.	accurate stream maps and repeated measurements in wet and dry season can help identification of seasonal and perennial streams. Need to mark each stream or sections thereof with the local stream names - Also, this will help identifying the installations of pipes and the number of dams along the streams for better management planning		local streams can be helpful
4.	Restoration of spring shed areas and forest cover in general, CODEC or other development partners can assist BFD in setting pilot restoration	- BFD and development partners need to do it and provide the data to other stakeholders	- Based on riparian zone buffer produced and the stream map coupled with the LULC maps identifies the spring shed areas and headwater region of the stream. These needs to be prioritized in restoration and afforestation initiative. These areas are to be demarcated for CPGs to guard them and in the future WMC, upon formation, will work with BFD for conservation and restoration initiatives. - Basin level conservation for the headwater regions will be needed	- Upper watershed areas in the TWS watershed	- It will be a long-term initiative. - Through watershed modeling based on recent data from the watershed will help in planning and implementing as well as predicting outcomes to prioritize - For quick piloting, output from this work can be used
5.	Aquifer mapping	- IWM, WARPO, WDB and DPHE with BFD	- There are many techniques on aquifer mapping, and there are specialized government and academic research entities to conduct such study - Adopting a suitable method, in light of the past JAICA study, a detailed aquifer and aquifer recharge location maps need to be prepared and maps are to be generated and widely distributed	- Entire TWS watershed areas including the forest and settlement areas	- It'll be time consuming and fund intensive. However, essential for the better outcomes through focused watershed planning for water security for the communities in

					the area.
6.	Development of Good practice guidelines (GPGs) for stakeholders related to land use to make sure none of their activities impact the watershed health negatively, instead increase positive impacts	- BFD, Academia, Development sector, Sectoral experts from agriculture, horticulture, pisciculture, tourism operators, wildlife, CMCs, local community leaders	- Through intensive field visits and consultation, preparing a detailed report on the current land use practices in the watershed areas and how those are affecting watershed. Examples of current land uses are: – agricultural plots, horticulture plots, jhum, fishery projects, BFD's plantation activities, harvesting operators, Toilet establishment, Water selling from aquifers on private land, etc. - Taking lessons from GPGs developed in similar and other geographical settings - Analysis of alternatives to be singled out as good practices for each specific land use - Creating a monitoring and evaluation plan to adapt the GPGs with changing situations	- Entire watershed areas of TWS both upstream and downstream	- Implementing the guidelines will be challenging, yet through awareness building, training and sensitizing the youths, the relevant organizations can foster adoption of GPGs by the local community and the sector actors. - Fund can be sourced from GoB or development partners
7.	Water quality and public health monitoring	- DPHE and other health related GoB entities like local hospitals, as well as NGOs working on WaSan like ICDDR,B	- Current study indicates issues with water quality for all sources of water used for drinking and bathing and other uses. Hence, DPHE needs to conduct a systematic survey in collaboration with academic or research institutions to develop water quality indices map to guide local people in suing safer water for their daily needs	- Settlement areas in TWS with focus on streams from which water is consumed	- This can be done as part of the routine monitoring initiatives of DPHE with their own funding by making the scale a bit larger
8.	Formulation of water user groups or water management	- Can be done under co-management	- Piloting cooperative watershed management for community-level water supply based on the available	- WMCs can be organized by stream basins	- In the beginning, CMCs can be used with support from

	committees as part of CMCs in each area organized around major streams and water sources	window but with involvement of more relevant stakeholder. Participation of local administration for coordination	streams through the Water Management Committee (WMC) or water user group (WUG) or Water district (as known in the USA) or any other suitable name. - WMC will coordinate with the GoB institutions' projects and programs to ensure equitable and sustainable sharing of public funding for water security - In the long run, there will be physical facilities under WMC management, and they will have their basin level watershed management plan to conserve the watershed, maintain water yield and quality, and sustainably treat and use water equitably by charging people for water to cover costs	involving adjoining villages getting water from respective basins. Each WMC will have maps with option to exchange water, if needed	BFD and CODEC to pilot few of these by taking advantages of DPHEs projects on centralized water supply system. In the future, the WMCs can become standalone entities under UNOs leadership for better coordination.
9.	Ring well and dug well monitoring	- DPHE and NGOs working with WatSan	- There is no formal standard for installation, material use and management of ring well and dug wells. - In consultation with Academia and research institutions, based on an assessment of the current ring wells and dug wells in the area, detailed engineering design, specification and material criteria as well as management guideline to safeguard and sustainably use them are to be prepared - The community awareness on such standards and specification and training to people involved with	- Settlement areas in TWS with focus on streams from which water is consumed	- It is relatively easy to do. - Many of such installations are close to sanitary toilets increasing chances of contaminations by coliform. - It can be done by DPHEs budget or funding from development partner as it is their jurisdiction

			material supply and installation of such units are to be created through training and campaigns - To avoid contamination from biological debris, ring well and dug well can also be filled with the gravel and Sylhet sand and water can be conserved in sand and harvested using a shallow tubewell as in artificial aquifers innovated as an adaptation measure by local people - A standard for maintaining distance between toilet and ring or dug well will be necessary. - Unused ring and dug wells are to be either used for aquifer storage and recovery (ASR) or filled up through WMCs to reduce the risks of contamination.		
10.	Identify all dry wells, use for aquifer storage and recovery (ASR) or fill up with sand	- DPHE, Union parishad, CMCs	- Mapping all functional and non-functional wells in the TWS watershed with data on their depth, year of installation, materials used, and active status are to be collected and a map is to be prepared - Based on the map, DPHE can collaborate with the local leadership and WMC (when formed) to remove the unused wells or convert them into ASR - Training of local skilled persons involved in tubewell installation will be needed to deploy this initiative	- Settlement areas in TWS with focus on streams from which water is consumed	- DPHE has data since they have been installing majority of the shallow and deep tubewells

			successfully		
11.	Cut all piped connection gradually and before that arrange alternative and ensure sharing of piped water through ASR initiatives	- BFD, CMC, Local leadership and DPHE	- Marking all piped connections and the amount of water harvested and wasted are to be estimated for using in community consultation to make sure that cutting such pipes do not create any issue. - Using the pipes, central water supply network can be established and CMCs and initially use one pipe under its management to store water and distribute it for a nominal charge to ensure equitable water access. - In the long rung with the formation of WMC, all such activities will be taken care of by WMC based on their basin level watershed management plan and water supply network.	- Entire TWS watershed areas including the forest and settlement areas	- It will be challenging but through adequate social consultation based on factual data on equity and wastefulness of current method, all will agree
12.	Monitoring of culverts throughout the area to ensure that they are not blocked by anyone	- LGED, Roads and Highways Department, and WDB	- Keeping a location map of all culverts on all streams on the stream network map and on a specific time interval, monitoring all culverts to ensure they remain functional and not blocked to make sure no stream or part of them get killed by blockade of streams. - On Marine drive, some of the culverts are already blocked which needs to be cleared to restore the streams	- Settlement areas in TWS with focus on streams from which water is consumed	- Relatively easy and can be part of routine activities for departments with Culverts - This aspect can be part of agenda in upazila coordination meeting
13.	Development of better solution to block saline water without hindering fish migration, and better	- LGED, Roads and Highways Department, and WDB	- Makeshift embankments erected by communities with any study is harmful for the ecosystem - A detailed standard and guideline and a modality to regulate makeshift erection	- Coastal areas where the streams fall to the Bay of Bengal	- It will take time but the departments, with their engineering prowess can develop such standards as

	management, Bringing the existing locally erected dams under standard and monitoring.		of embankments is to be put in place, - The departments has their own		GPGs in consultation with academic and researchers
14	Development of water retention areas inside the forests and hills to ensure rainwater storage and aquifer recharge as well as to support wildlife	- BFD, WDB, CMCs, and LGED	- Identification of areas in the upper watershed that can be used for water retention at minimal budget and can crate positive impacts on wildlife needs to be marked from DEM model - Then BFD can join hand with DPHE and WDB to establish a network of such water retention areas which may have positive synergy on tourism as well besides their ecological watershed roles.	- Hilly terrain of TWS	- It will be a long-term project but CODEC can work with BFD wo pilot a few.
15	Re-excavation of larger pond and water retention structures already available	- WDB and DPHE	- GIS based analysis can produce a map of existing waterbodies are their total areas in the vicinity of TWS. Increasing their water holding capacity by reactivation, enlargement and water loss prevention measures will improve the local resilience and reduce the dependency of some of the local communities on surface water streams - Also, water retention areas can be created on streams where area is available and these can be used in the future by WMCs to treat water from and supply. It will also help in upping the water table.	- Settlement areas in TWS where there are existing ponds and regions available to expand them	- There are already initiatives like this under implementation in different areas of Bangladesh by WDB and DPHE which can be mainstreamed in Teknaf.
16	Watershed modeling using HEC-HMS	- Academia and development	- HEC-HMS model can simulate the water discharge from a watershed or its	- Entire TWS watershed areas	- We tried to build the model but there are

		partners with support from WDB and other entities related to water like BFIDC and BFD	basins and sub-basins if there is available high quality temporal data on discharge from the streams, the weather data, the land use and land cover data and the climate change scenarios for the area. - Such model helps also to model the possibility of flash floods and their damage zones in the case of excessive rainfall. - It can also be used to model the water yield under different future land use scenarios, and the fluctuations in the availability in water in streams for the management of water structures - It can assist in planning and managing culverts and embankments by evaluating their roles of water logging	including the forest and settlement areas	no data o discharges from the streams - From now onwards, an organized data collection system for discharge is needed
17	Improving waste management to enhance water quality	- Local elected leadership, NGOs, Tour operators, Community	- Waste management plan and waste management facilities with waste processing initiatives are to be put in place to make sure no wastes flows to the streams, specifically no plastic wastes.	- Settlement areas in TWS and tourism facilities within the scope of the watershed	- It needs to create awareness, create waste collection and processing facilities from circularity concept
18	Regulating water business and installation of many tubewells on the same site to avoid over extraction and deaths of aquifers	- UNO office, DPHE and BFD	- Strict regulation of water harvesting from the aquifers on private land are to be implanted to make sure people in the community has right on the groundwater for social equity and cohesion. - Business cases can be developed upon formation of WMCs to share benefits with such private landowners.	- Settlement areas in TWS	- It will require involvement of local leaders and community activists to regulate this business which is creating inequality in the society and burden on the poor

19	Banning agrochemicals in upper watershed horti and agriculture and fisheries projects where downstream community use the water for drinking	- BFD, DAE, Local administration, CPGs, CMC	- GIS based mapping of the current land under agricultural and horticultural use as well as fisheries projects. - Identification of farmers and train them on integrated pest management (IPM) and modern paste management techniques like use of beneficial organisms like paste eaters (frog and other small animals) - Monitoring the use of agrochemicals by water quality testing	- Entire TWS watershed areas including the forest	- DAE should take lead with support from BFD and CMCs
20	**Promotion of alternative water sources like rainwater harvesting, sea water desalination and atmospheric vapor condensation or fog catching**	**- DPHE, WDB, BFD, NGOs, CMCs,**	**- Enhancement of RWH system distribution by addressing current equitability issues created by biased beneficiary selection and the need for chemicals to maintain water quality,** **- Expansion of the sea or Naf River water desalination project of Nobolok through innovation to blend salt farming with water harvesting** **- Promotion of atmospheric vapor deposition devices among the wealthy people to take out their demand for water from the watershed** **- BFD can try installation of fog harvesting to make the soil wet for promotion of natural regeneration, to increase base flow in streams**	**- Entire TWS watershed areas including the forest and settlements**	**- It will require concurrent efforts from different agencies to try the recent innovations and promote the emerging technologies for water resilience.**

during winter dry season beside enhancing groundwater infiltration.

6.0 Conclusion

Having undertaken an extensive analysis, stakeholder engagement, and field observations within the Teknaf Wildlife Sanctuary (TWS) watershed, the management plan was systematically developed to address the multifaceted water resource challenges. The plan integrates community wisdom, scientific research, and governance frameworks to outline actionable steps toward sustainable watershed management. Actions include leveraging local innovations like artificial aquifers, enhancing riparian buffers, detailed stream and aquifer mapping, spring shed restoration, and the establishment of good practice guidelines for land use and waste management. Crucial to the plan's success is the formation of Water Management Committees (WMCs) to steward communal water resources equitably. These committees will work in conjunction with governmental bodies, local communities, NGOs, and academic institutions to implement, monitor, and adapt the proposed interventions.

The commitment to long-term ecological sustainability is evidenced by the emphasis on afforestation efforts, stringent control of agrochemicals, and the restoration of water retention structures within the forested areas of TWS. Alongside these ecological considerations, the plan advocates for advancements in hydrological modeling, rigorous water quality monitoring, and the thoughtful regulation of water businesses to ensure that extraction practices do not deplete aquifers. As the watershed faces increasing pressure from population growth, refugee influx, tourism, and the Sabrang Tourism SEZ, this comprehensive plan positions TWS to navigate these challenges with resilience. It calls for proactive measures like the exploration of alternative water sources, such as seawater desalination, and innovative solutions to prevent saline intrusion while preserving fish migration routes.

The report's conclusion underscores the necessity for an integrated approach, highlighting the intricate balance between human needs, environmental stewardship, and the vital ecosystem services provided by the TWS watershed. Through the active participation of all stakeholders and adherence to the guidelines and action items outlined, this plan aspires to safeguard the watershed's health and ensure water security for all dependent communities and wildlife, thus fostering harmony between development and conservation for the Teknaf region's sustainable future.

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Annex 1: List of Flora of TWS (Uddin et al., 2013)

Local name (Bangla)	Scientific name	Family	Habit
Mushak dana	*Abelmoschus moschatus* Medic.	Malvaceae	Herb
Ratti	*Abrus precatorius* L.	Fabaceae	Climber
Akashmoni	*Acacia auriculiformis* A. Cunn. *ex* Benth. & Hook.	Mimosaceae	Tree
Banrita	*A. concinna* (Willd.) DC.	Mimosaceae	Climber
Belgium	*A. mangium* Willd.	Mimosaceae	Tree
Hergoza	*Acanthus ilicifolius* L.	Acanthaceae	Shrub
Apang	*Achyranthes aspera* L.	Amaranthaceae	Herb
-	*Actephila excelsa* (Dalz.) Muell.-Arg.	Euphorbiaceae	Shrub
Akandphul	*Adenia trilobata* (Roxb.) Engl.	Passifloraceae	Climber
Dakrum	*Adina cordifolia* Hook. f. *ex* Brandis	Rubiaceae	Tree
Nuinna	*Aegialitis rotundifolia* Roxb.	Plumbaginaceae	Shrub
Khoilsha	*Aegiceras corniculata* (L.) Blanco	Primulaceae	Shrub
Bel	*Aegle marmelos* (L.) Corr.	Rutaceae	Tree
-	*Aerides multiflora* Roxb.	Orchidaceae	Epiphyte
-	*A. odorata* Lour.	Orchidaceae	Epiphyte
-	*Aerua monsonia* Mart.	Amaranthaceae	Herb
-	*A. sanguinolenta* (L.) Blume	Amaranthaceae	Herb
Fulkuri	*Ageratum conyzoides* L.	Asteraceae	Herb
-	*Aglaonema hookerianum* Schott	Araceae	Herb
Sil-koroi	*Albizia lucidior* (Steud.) Nielsen	Mimosaceae	Tree
Silkoroi	*A. procera* (Roxb.) Benth.	Mimosaceae	Tree
Chita	*Allophylus cobbe* (L.) Raeuschel	Sapindaceae	Shrub
-	*Alocasia acuminata* Schott	Araceae	Herb
Mankachu	*A. macrorrhizos* (L.) G. Don	Araceae	Herb

Deotara	*Alpinia malaccensis* (Burm. f.) Rosc.	Zingiberaceae	Shrub
Chatim	*Alstonia scholaris* L.	Apocynaceae	Tree
Helencha	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Herb
Upathlenga	*A. sessilis* (L.) R. Br. *ex* Roem & Schult.	Amaranthaceae	Herb
Shadamayishk	*Amaranthus gangeticus* L.	Amaranthaceae	Herb
Kanta-nutia	*A. spinosus* L.	Amaranthaceae	Herb
Notey Sak	*A. viridis* L.	Amaranthaceae	Herb
-	*Ammannia multiflora* Roxb.	Lythraceae	Herb
Tara	*Amomum aromaticum* Roxb.	Zingiberaceae	Shrub
Oll	*Amorphophallus bulbifer* (Roxb.) Blume	Araceae	Herb
Kaju badam	*Anacardium occidentale* L.	Anacardiaceae	Tree
-	*Anisomeles heyneana* Wall. *ex* Benth.	Lamiaceae	Herb
Gobura	*A. indica* (L.) O. Kuntze	Lamiaceae	Herb
Boilum	*Anisoptera scaphula* (Roxb.) Pierre	Dipterocarpaceae	Tree
Ata	*Annona reticulata* L.	Annonaceae	Tree
-	*Anodendron paniculatum* (Roxb.) A. DC.	Apocynaceae	Climber
Chakua	*Anogeissus acuminata* (Roxb. *ex* DC.) Guill. & Perr.	Combretaceae	Tree
Chukka	*Antidesma acuminatum* Wall.	Euphorbiaceae	Shrub
Khudijam	*A. ghaesembilla* Gaertn.	Euphorbiaceae	Shrub
-	*A. roxburghii* Wall. *ex* Tulasne	Euphorbiaceae	Shrub
Pitraj	*Aphanamixis polystachya* (Wall.) R. N. Parker	Meliaceae	Tree
Patakharolla	*Aporosa dioica* (Roxb.) Muell.-Arg.	Euphorbiaceae	Tree
Agar	*Aquilaria agallocha* Roxb.	Thymeliaceae	Tree
-	*Ardisia elliptica* Thunb.	Myrsinaceae	Shrub
-	*A. paniculata* Roxb.	Myrsinaceae	Shrub
-	*A. solanacea* (Poir.) Roxb.	Myrsinaceae	Shrub
Supari	*Areca catechu* L.	Arecaceae	Tree
-	*Argyreia capitiformis* (Poir.) van Cheek Oostr.	Convolvulaceae	Climber

-	*A. roxburghii* Choisy	Convolvulaceae	Climber
Ishwarmul	*Aristolochia tagala* Cham.	Aristolochiaceae	Climber
Chapalish	*Artocarpus chaplasha* Roxb.	Moraceae	Tree
Kanthal	*A. heterophyllus* Lamk.	Moraceae	Tree
Nal	*Arundo donax* L.	Poaceae	Herb
Bilimbi	*Averrhoa bilimbi* L.	Oxalidaceae	Tree
Kamranga	*A. carambola* L.	Oxalidaceae	Tree
Sada baen	*Avicennia alba* Blume	Verbenaceae	Tree
Moricha baen	*A. marima* (Forssk.) Vierh.	Verbenaceae	Tree
Kala baen	*A. officinalis* L.	Verbenaceae	Tree
Dhakagash	*Axonopus compressus* (Sw.) P. Beauv.	Poaceae	Herb
Neem	*Azadirachta indica* A. Juss.	Meliaceae	Tree
Brammi	*Bacopa monieri* (L.) Pennell	Scrophulariaceae	Herb
barak bash	*Bambusa balcooa* Roxb.	Poaceae	Tree
Parua bash	*B. polymorpha* Munro	Poaceae	Tree
Mitinga bash	*B. tulda* Roxb.	Poaceae	Tree
Hizol	*Barringtonia acutangula* (L.) Gaertn.	Lecythidaceae	Tree
Kanson	*Bauhinia acuminata* L.	Caesalpiniaceae	Shrub
-	*Begonia roxburghii* (Miq.) DC.	Begoniaceae	Herb
Kukurmuta	*Blumea lacera* (Burm. f.) DC.	Asteraceae	Herb
Shialmutra	*B. membranacea* Wall. *ex* DC.	Asteraceae	Herb
-	*B. virens* Wall. *ex* DC.	Asteraceae	Herb
Shimul	*Bombax ceiba* L.	Bombacaceae	Tree
Bonshimul	*B. insigne* Wall.	Bombacaceae	Tree
Tal	*Borassus flabellifer* L.	Arecaceae	Tree
Antharogia	*Borreria articularis* (L. f.) Williams	Rubiaceae	Herb
Ghuiojhill sak	*B. latifolia* (Aublet) K. Schum.	Rubiaceae	Herb
Silpati	*Breynia retusa* (Dennst.) Alston	Euphorbiaceae	Shrub
-	*B. vitis-idaea* (Burm. f.) C. E. C. Fischer	Euphorbiaceae	Shrub
Kata koi	*Bridelia retusa* (L.) A. Juss.	Euphorbiaceae	Shrub
Pat khowi	*B. stipularis* (L.) Blume	Euphorbiaceae	Climber
Massjot	*Brownlowia elata* Roxb.	Tiliaceae	Tree
Goran	*Bruguiera gymnorrhiza* (L.) Lamk.	Rhizophoraceae	Tree
Parchallow	*Bulbophyllum lilacinum* Ridl.	Orchidaceae	Epiphyte
Polash	*Butea monosperma* (Lamk.) Taub.	Fabaceae	Tree
Harbanga lata	*Byttneria pilosa* Roxb.	Sterculiaceae	Climber
Nata	*Caesalpinia bonduc* (L.) Roxb.	Caesalpiniaceae	Climber
Letkanta	*C. crista* L.	Caesalpiniaceae	Climber
Radhachura	*C. pulcherrima* (L.) Swartz	Caesalpiniaceae	Tree
Orhor	*Cajanus cajan* (L.) Millsp.	Fabaceae	Shrub
Kadam bet	*Calamus erectus* Roxb.	Arecaceae	Shrub
Udombet	*C. longisetus* Griff.	Arecaceae	Climber
Chotto betmar	*Calliandra umbrosa* (Wall.) Benth.	Mimosaceae	Shrub
Bormala	*Callicarpa arborea* Roxb.	Verbenaceae	Tree

Bormala	*C. macrophylla* Vahl	Verbenaceae	Tree
Keroli	*Calophyllum polyanthum* Wall. *ex* Choisy	Clusiaceae	Tree
Akand	*Calotropis procera* (Ait.) R. Br.	Asclepiadaceae	Shrub
Guicha lata	*Calycopteris floribunda* (Roxb.) Lamk.	Combretaceae	Climber
-	*Campanumoea lancifolia* (Roxb.) Merr.	Campanulaceae	Herb
-	*Carex indica* L.	Cyperaceae	Herb
Pepe	*Carica papaya* L.	Caricaceae	Tree
Sonalu	*Cassia fistula* L.	Caesalpiniaceae	Tree
Hingra	*Castanopsis tribuloides* (Smith) A. DC.	Fagaceae	Tree
Jau	*Casuarina equisetifolia* Forst.	Casuarinaceae	Tree
-	*Cayratia japonica* (Thunb.) Gagnep.	Vitaceae	Climber
Tula	*Ceiba pentandra* (L.) Gaertn.	Bombacaceae	Tree
Datarchua	*Celtis timorensis* Span.	Ulmaceae	Shrub
Thaimonshak	*Centella asiatica* (L.) Urban	Apiaceae	Herb
Khemo	*Ceriops decandra* (Griff.) Ding Hou	Rhizophoraceae	Tree
Assamlata	*Chromolaena odorata* (L.) King Robinson	Asteraceae	Shrub
Premkanta	*Chrysopogon aciculatus* (Retz.) Trin.	Poaceae	Herb
Chikrasi	*Chukrasia tabularis* A. Juss.	Meliaceae	Tree
Tejmul	*Cinnamomum iners* Reinw. *ex* Blume	Lauraceae	Tree
Tubaki-lata	*Cissampelos pareira* L.	Menispermaceae	Climber
Aliangalata	*Cissus adnata* Roxb.	Vitaceae	Climber
Komala	*Citrus aurantium* L.	Rutaceae	Shrub
Jambura	*C. grandis* (L.) Osbeck	Rutaceae	Tree
Ponkarpur	*Clausena heptaphylla* (Roxb.) Wight Arn. *ex* Steud.	Rutaceae	Shrub
Panbilash	*C. suffruticosa* (Roxb.) Wight & Arn.	Rutaceae	Shrub
-	*Cleome rutidosperma* DC.	Capparaceae	Herb
Hurhuria	*C. viscosa* L.	Capparaceae	Herb
Bamjui	*Clerodendrum inerme* (L.) Gaertn.	Verbenaceae	Shrub
Bhant	*C. viscosum* Vent.	Verbenaceae	Shrub
Aparjita	*Clitoria ternatea* L.	Fabaceae	Climber
Chutra	*Cnesmone javanica* Blume	Euphorbiaceae	Climber
Narikel	*Cocos nucifera* L.	Arecaceae	Tree
Kachu	*Colocasia esculenta* (L.) Schott	Araceae	Herb
-	*C. heterochroma* H. Li *et* Z.X. Wei	Araceae	Herb
-	*C. oresbia* A. Hay	Araceae	Herb
Sada guicha	*Combretum decandrum* Roxb.	Combretaceae	Climber
Kanchira	*Commelina benghalensis* L.	Commelinaceae	Herb
Jata kanchira	*C. erecta* L.	Commelinaceae	Herb
Pani kanchira	*C. longifolia* Lamk.	Commelinaceae	Herb
Keumul	*Costus speciosus* (Koenig *ex* Retz.) Smith	Costaceae	Herb

Borun	*Crateva magna* (Lour.) DC.	Capparaceae	Tree
Bopiaz	*Crinum amoenum* Roxb.	Liliaceae	Herb
Gor-rosun	*C. asiaticum* L.	Liliaceae	Herb
Junjuni	*Crotalaria juncea* L.	Fabaceae	Herb
Jhunjhni	*C. pallida* Ait.	Fabaceae	Herb
Talmuli	*Curculigo orchioides* Gaertn.	Liliaceae	Herb
Satipata	*C. recurvata* Dryand.	Liliaceae	Herb
Shadi	*Curcuma amada* Roxb.	Zingiberaceae	Herb
Amada	*C. latifolia* Rosc.	Zingiberaceae	Herb
Shoti	*C. zedoaria* (Christm.) Rosc.	Zingiberaceae	Herb
Shornalata	*Cuscuta reflexa* Roxb.	Cuscutaceae	Climber
Patalpur	*Cyclea barbata* Miers	Menispermaceae	Climber
Churi	*Cymbidium aloifolium* (L.) Sw.	Orchidaceae	Epiphyte
Durba	*Cynodon dactylon* (L.) Pers.	Poaceae	Herb
-	*Cyperus cyperoides* (L.) O. Ktze.	Cyperaceae	Herb
-	*C. iria* L.	Cyperaceae	Herb
-	*C. kyllingia* Endl.	Cyperaceae	Herb
-	*C. laxus* Lamk. var. *laxus*	Cyperaceae	Herb
-	*C. pilosus* Vahl	Cyperaceae	Herb
-	*C. rotundus* L.	Cyperaceae	Herb
-	*Dalbergia rimosa* Roxb.	Fabaceae	Shrub
-	*D. sissoo* Roxb.	Fabaceae	Tree
-	*D. spinosa* Roxb.	Fabaceae	Shrub
Dadbari	*D. stipulacea* Roxb.	Fabaceae	Climber
-	*D. tamarindifolia* Roxb.	Fabaceae	Shrub
Ankilata	*D. volubilis* Roxb.	Fabaceae	Shrub
Dhatura	*Datura metel* L.	Solanaceae	Shrub
Modonmosta	*Dehaasia kurzii* King *ex* Hook. f.	Lauraceae	Tree
krishnachura	*Delonix regia* Rafin.	Caesalpiniaceae	Tree
-	*Dendrobium aphyllum* (Roxb.) Fischer	Orchidaceae	Epiphyte
Kalilata	*Derris scandens* (Roxb.) Benth.	Fabaceae	Climber
Melata	*D. trifoliata* Lour.	Fabaceae	-
-	*Desmodium heterocarpon* (L.) DC.	Fabaceae	Herb
-	*D. heterophyllum* (Willd.) DC.	Fabaceae	Herb
Juta salpani	*D. pulchellum* (L.) Benth.	Fabaceae	Shrub
-	*D. styracifolium* (Osb.) Merr.	Fabaceae	Herb
Kulalia	*D. triflorum* (L.) DC.	Fabaceae	Herb
-	*D. triquetrum* (L.) DC.	Fabaceae	Herb
-	*D. triquetrum* (L.) DC. subsp. *alatum* (DC.) Prain	Fabaceae	Herb
Tali	*Dichopsis polyantha* Benth.	Sapotaceae	Tree
Makunjill	*Digitaria sanguinalis* (L.) Scop.	Poaceae	Herb
-	*D. violascens* Link	Poaceae	Herb
Chalta	*Dillenia indica* L.	Dilleniaceae	Tree
Hargenza	*D. pentagyna* Roxb.	Dilleniaceae	Tree

Ekuish	*D. scabrella* Roxb. *ex* Wall.	Dilleniaceae	Tree
Suprialu	*Dioscorea alata* L.	Dioscoreaceae	Climber
-	*D. belophylla* (Prain) Voigt *ex* Haines	Dioscoreaceae	Climber
Ratal, Bon alu	*D. bulbifera* L. var. *bulbifera* L.	Dioscoreaceae	Climber
-	*D. kamoonensis* Kunth	Dioscoreaceae	Climber
-	*D. melanophyma* Prain & Burkill	Dioscoreaceae	Climber
Randrealeku	*D. oppositifolia* L.	Dioscoreaceae	Climber
-	*D. pentaphylla* L.	Dioscoreaceae	Climber
-	*Di. trinerva* Roxb.	Dioscoreaceae	Climber
Dholi garjan	*Dipterocarpus alatus* Roxb. *ex* G. Don	Dipterocarpaceae	Tree
Sil garjan	*D. costatus* Gaertn.	Dipterocarpaceae	Tree
-	*D. gracilis* Blume	Dipterocarpaceae	Tree
Kaligarjan	*D. turbinatus* Gaertn.	Dipterocarpaceae	Tree
Dracaena	*Dracaena spicata* Roxb.	Agavaceae	Shrub
Katamehedi	*Duranta repens* L.	Verbenaceae	Shrub
-	*Dysolobium dolichoides* (Roxb.) Prain	Fabaceae	Climber
Shama grass	*Echinochloa colonum* (L.) Link	Poaceae	Herb
Keshoraj	*Eclipta alba* (L.) Hassk.	Asteraceae	Herb
Kachuripana	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae	Herb
Belphoi	*Elaeocarpus floribundus* Blume	Elaeocarpaceae	Tree
Jalpai	*E. robustus* Roxb.	Elaeocarpaceae	Tree
-	*Elatostema sesquifolium* (Blume) Hassk.	Urticaceae	Herb
-	*Eleocharis palustris* (L.) R. Br.	Cyperaceae	Herb
-	*Elephantopus scaber* L.	Asteraceae	Herb
Malan kuri	*Eleusine indica* (L.) Gaertn.	Poaceae	Herb
-	*Endospermum chinense* Benth.	Euphorbiaceae	Tree
Zalna	*Engelhardtia spicata* Lesch. *ex* Blume	Guglandaceae	Tree
Helencha	*Enhydra fluctuans* Lour.	Asteraceae	Herb
Gila	*Entada scandens* auct. non Benth.	Mimosaceae	Climber
Koni grass	*Eragrostis tenella* (L.) P. Beauv. *ex* Roem. & Schult.	Poaceae	Herb
-	*Eranthemum strictum* Coleb. *ex* Roxb.	Acanthaceae	Herb
Katkatriabaho	*Eryngium foetidum* L.	Apiaceae	Herb
Mandar	*Erythrina fusca* Lour.	Fabaceae	Tree
Mandar	*E. indica* Lamk.	Fabaceae	Tree
Mandar	*E. ovalifolia* Roxb.	Fabaceae	Tree
-	*Etlingera linguiformis* (Roxb.) R. M. Smith	Zingiberaceae	Shrub
Dudhia	*Euphorbia hirta* L.	Euphorbiaceae	Herb
Dudhiya	*E. thymifolia* L.	Euphorbiaceae	Herb
-	*Evolvulus nummularius* (L.) L.	Convolvulaceae	Herb
Gewa	*Excoecaria agallocha* L.	Euphorbiaceae	Tree
Bot	*Ficus altissima* Blume	Moraceae	Tree
Bot	*F. benghalensis* L.	Moraceae	Tree

Jir	*F. benjamina* L.	Moraceae	Tree
-	*F. fistulosa* Reinw. *ex* Blume	Moraceae	Shrub
Dumur	*F. hispida* L. f.	Moraceae	Herb
Dewall dumar	*F. pumila* L.	Moraceae	Climber
Jagya dumar	*F. rcemosa* L.	Moraceae	Tree
-	*F. rumphii* Blume	Moraceae	Tree
-	*F. scandens* Buch.-Ham.	Moraceae	Climber
Chotochorkigu	*F. semicordata* Buch.-Ham. *ex* Smith	Moraceae	Tree
Pakur	*F. virens* Ait.	Moraceae	Tree
-	*Fimbristylis dichotoma* (L.) Vahl subsp. *dichotoma*	Cyperaceae	Herb
-	*F. miliacea* (L.) Vahl	Cyperaceae	Herb
-	*Fissistigma polyanthum* (Hook. f. & Thom.) Merr.	Annonaceae	Climber
Paniala	*Flacourtia indica* (Burm. f.) Merr.	Flacourtiaceae	Shrub
-	*F. inermis* Roxb.	Flacourtiaceae	Shrub
-	*Flagellaria indica* L.	Flagellariacea	Climber
Bara shaphan	*Flemingia macrophylla* (Willd.) O. Kuntze *ex* Merr.	Fabaceae	Shrub
-	*F. strobilifera* (L.) R. Br.	Fabaceae	Shrub
-	*Floscopa scandens* Lour.	Commelinaceae	Herb
Kau phal	*Garcinia cowa* Roxb. *ex* DC.	Clusiaceae	Tree
Dayphal	*G. xanthochymus* Hook. f. *ex* T. Anders.	Clusiaceae	Tree
Jongli jiga	*Garuga floribunda* Decne. var. *gamblei* (King *ex* Smith) Kalkman	Burseraceae	Tree
Jeolbhadi	*G. pinnata* Roxb.	Burseraceae	Tree
-	*Geissapsis cristata* Wight & Arn.	Fabaceae	Herb
-	*Geodorum densiflorum* (Lamk.) Schltr.	Orchidaceae	Herb
-	*Globba multiflora* Wall. *ex* Baker	Zingiberaceae	Herb
Ulatchandal	*Gloriosa superba* L.	Liliaceae	Climber
-	*Glycosmis mauritiana* (Lamk.) Tanaka	Rutaceae	Shrub
Datmajan	*G. pentaphylla* (Retz.) A. DC.	Rutaceae	Shrub
Gamari	*Gmelina arborea* Roxb.	Verbenaceae	Tree
-	*Gnetum oblongum* L.	Gnetaceae	Climber
-	*Goniothalamus sesquipedalis* (Wall.) Hook. F. & Thom.	Annonaceae	Shrub
-	*Gouania tiliaefolia* Lamk.	Rhamnaceae	Climber
Assar	*Grewia microcos* L.	Tiliaceae	Shrub
-	*Gymnopetalum cochinchinense* (Lour.) Kurz	Cucurbitaceae	Climber
-	*Gynostemma pentaphylla* (Thumb.) Makino.	Vitaceae	Climber
Bish lata	*Hedyotis scandens* Roxb.	Rubiaceae	Herb
Hatisun	*Heliotropium indicum* L.	Boraginaceae	Herb

Chalia	*Hemarthria protensa* Steud.	Poaceae	Herb
Anantamul	*Hemidesmus indicus* (L.) R. Br.	Asclepiadaceae	Climber
-	*Hemigraphis hirta* (Vahl) T. Anders.	Acanthaceae	Herb
Sundari	*Heritiera fomes* Buch.-Ham.	Sterculiaceae	Tree
Dakrum	*Heterophragma adenophylla* (Wall. *ex* G. Don) Benth.	Bignoniaceae	Tree
Joba	*Hibiscus rosa-sinensis* L.	Malvaceae	Shrub
Bolla	*H. tiliaceus* L.	Malvaceae	Shrub
Kurchi	*Holarrhena antidysenterica* (L.) Wall. *ex* Decne.	Apocynaceae	Shrub
Barala	*Holigarna longifolia* Roxb.	Anacardiaceae	Tree
-	*Homalomena aromatica* (Roxb. *ex* Sim) Schott	Araceae	Herb
Telsur	*Hopea odorata* Roxb.	Dipterocarpaceae	Tree
Pargacha	*Hoya parasitica* (Roxb.) Wall. *ex* Wight	Asclepiadaceae	Climber
-	*Hydrolea zeylanica* (L.) Vahl	Hydrophyllaceae	Herb
-	*Hygrophila polysperma* (Roxb.) T. Anders.	Acanthaceae	Herb
Bhuikadam	*Hymenodictyon excelsum* (Roxb.) Wall.	Rubiaceae	Tree
-	*Hyptis brevipes* Poit.	Lamiaceae	Herb
Tokma	*H. suaveolens* (L.) Poit.	Lamiaceae	Herb
Shamalata	*Ichnocarpus frutescens* (L.) R. Br.	Apocynaceae	Climber
Ulu	*Imperata cylindrica* (L.) P. Beauv. var. *latifolia* (Hook. f.) C. E. Hubb.	Poaceae	Herb
Kalmi sak	*Ipomoea aquatica* Forssk.	Convolvulaceae	Climber
Dholkalmi	*I. fistulosa* Mart. *ex* Choisy	Convolvulaceae	Shrub
Huffta alu	*I. mauritiana* Jacq.	Convolvulaceae	Climber
Chagalkhuri	*I. pes-caprae* (L.) R. Br.	Convolvulaceae	Climber
Gate phul	*I. quamoclit* L.	Convolvulaceae	Climber
Toto grass	*Ischaemum indicum* (Houtt.) Merr.	Poaceae	Herb
-	*Ixora acuminata* Roxb.	Rubiaceae	Shrub
Rangan	*I. javanica* DC.	Rubiaceae	Shrub
Swet rangan	*I. pavetta* Andr.	Rubiaceae	Shrub
Jui	*Jasminum auriculatum* Vahl	Oleaceae	Climber
Wild jasmin	*J. grandiflorum* L.	Oleaceae	Climber
-	*J. scandens* Vahl	Oleaceae	Shrub
Sadajeol	*Jatropha curcas* L.	Euphorbiaceae	Tree
Nilnishinda	*Justicia gendarussa* Burm. f.	Acanthaceae	Shrub
Jogathmardan	*J. simplex* D. Don.	Acanthaceae	Shrub
Tiutara	*Kaempferia galanga* L.	Zingiberaceae	Herb
Lau	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae	Herb
Jarul	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	Tree
Jiga	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	Tree

Lantana	*Lantana camara* L.	Verbenaceae	Shrub
Lal Bichuti	*Laportea interrupta* (L.) Chew	Urticaceae	Herb
Kantakachu	*Lasia spinosa* (L.) Thw.	Araceae	Herb
Mehedi	*Lawsonia inermis* L.	Lythraceae	Shrub
Phupharia	*Leea acuminata* Wall.	Leeaceae	Shrub
-	*L. aequata* L.	Leeaceae	Shrub
Banchilata	*L . crispa* L.	Leeaceae	Shrub
-	*L. indica* Merr.	Leeaceae	Shrub
-	*Lepidagathis incurva* Buch.-Ham. *ex* D. Don	Acanthaceae	Herb
Baraharina	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sapindaceae	Shrub
Ipli-ipil	*Leucaena leucocephala* (Lamk.) de Wit.	Mimosaceae	Tree
Dandakalash	*Leucas aspera* (Willd.) Link	Lamiaceae	Herb
Gaochia	*L. lavandulaefolia* Smith	Lamiaceae	Herb
Pani karpur	*Limnophila indica* (L.) Druce	Scrophulariaceae	Herb
Koethbel	*Limonia acidissima* L.	Rutaceae	Tree
Barabatna	*Lithocarpus elegans var. elegans* (Blume) Hatus. *ex* Soepad.	Fagaceae	Tree
Menda	*Litsea glutinosa* (Lour.) Robinson	Lauraceae	Tree
Kukuchita	*L. monopetala* (Roxb.) Pers.	Lauraceae	Tree
Rokton	*Lophopetalum wightianum* Arn.	Celastraceae	Tree
Mulsi	*Ludwigia adscendens* (L.) Hara	Onagraceae	Herb
-	*L. hyssopifolia* (G. Don) Exell apud A. & R. Fernandes	Onagraceae	Herb
Pahari dhundul	*Luffa graveolens* Roxb.	Cucurbitaceae	Climber
-	*Luisia zeylanica* Lindl.	Orchidaceae	Epiphyte
Bura	*Macaranga peltata* (Roxb.) Muell.-Arg.	Euphorbiaceae	Shrub
Porgasa	*Macrosolen cochinchinensis* (Lour.) Van Tiegh.	Loranthaceae	Parasite
Ramjoni	*Maesa indica* (Roxb.) A. DC.	Myrsinaceae	Shrub
Maricha	*M. ramentacea* (Roxb.) A. DC.	Myrsinaceae	Shrub
Kamela	*Mallotus philippensis* (Lamk.) Muell. Arg.	Euphorbiaceae	Shrub
Aam	*Mangifera indica* L.	Anacardiaceae	Tree
Uriam	*M. sylvatica* Roxb.	Anacardiaceae	Tree
Kasava	*Manihot esculenta* Crantz	Euphorbiaceae	Shrub
Khirni	*Manilkara hexandra* (Roxb.) Dubard	Sapotaceae	Shrub
-	*Mantisia radicalis* (Roxb.) D. P. Dam & N. Dam	Zingiberaceae	Herb
-	*M. spathulata* Schult.	Zingiberaceae	Herb
Ararot	*Maranta arundinacea* L.	Marantaceae	Herb
Futki	*Melastoma malabathricum* L.	Melastomaceae	Shrub
Ghura neem	*Melia azedarach* L.	Meliaceae	Tree

Moli bash	*Melocanna baccifera* (Roxb.) Kurz	Poaceae	Tree
Tiki okra	*Melochia corchorifolia* L.	Sterculiaceae	Herb
Sadakalmi	*M. umbellata* (L.) Hallier f.	Convolvulaceae	Climber
Champa	*Michelia champaca* L.	Magnoliaceae	Tree
Koroiphula	*Micromelum minutum* (G. Forster) Wight & Arn.	Rutaceae	Shrub
Assamlata	*Mikania cordata* (Burm. f.) Robinson	Asteraceae	Climber
Tasbi	*Miliusa globosa* (DC.) G. Panigr. & Mishra	Annonaceae	Climber
-	*Millettia cinerea* Benth.	Fabaceae	Herb
Bara lajjabati	*Mimosa invisa* Mart. *ex* Colla.	Mimosaceae	Herb
Lajjabati	*M. pudica* L.	Mimosaceae	Herb
Rang kat	*Mitragyna rotundifolia* (Roxb.) O. Kuntze	Rubiaceae	Tree
-	*Molineria recurvata* (Dryand.) Herbert.	Liliaceae	Herb
Khetpapra	*Mollugo pentaphylla* L.	Moraceae	Herb
Bonkorolla	*Momordica dioica* Roxb. *ex* Willd.	Cucurbitaceae	Climber
Nukha	*Monochoria vaginalis* (Burm. f.) Presl	Pontederiaceae	Herb
Alkushi	*Mucuna pruriens* (L.) DC.	Fabaceae	Climber
Kamini	*Murraya koenigii* (L.) Spreng.	Rutaceae	Tree
-	*Musa acuminata* Colla	Musaceae	Herb
Kalasonia	*Mussaenda frondosa* L.	Rubiaceae	Shrub
Silchuri	*M. roxburghii* Hook. f.	Rubiaceae	Shrub
Parmul	*Nelsonia canescens* (Lamk.) Spreng.	Acanthaceae	Herb
Kadam	*Neolamarckia cadamba* (Roxb.) Bosser	Rubiaceae	Tree
Lal Shaphla	*Nymphaea rubra* Roxb. *ex* Andr.	Nympheaceae	Herb
Golpata	*Nypa fruticans* Wurmb.	Arecaceae	Shrub
Tulsi	*Ocimum americanum* L.	Lamiaceae	Herb
Ramtulsi	*O. gratissimum* L.	Lamiaceae	Herb
-	*Oplismenus burmanii* (Retz.) P. Beauv.	Poaceae	Herb
Phanimansa	*Opuntia dillenii* Haw.	Cactaceae	Herb
Horhuta	*Oreocnide integrifolia* (Gaud.) Miq.	Urticaceae	Shrub
-	*Ormosia robusta* (Roxb.) Baker	Fabaceae	Tree
Thona	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	Tree
-	*Osbeckia aspericaulis* Hook. f. *ex* Triana	Melastomaceae	Shrub
Moishkanta	*Oxyceros kunstleri* (King & Gamble) Tirveng.	Rubiaceae	Climber
Keyakanta	*Pandanus foetidus* Roxb.	Pandanaceae	Shrub
Keyakanta	*P. odorus* Ridl.	Pandanaceae	Shrub
-	*Panicum brevifolium* L.	Poaceae	Herb
-	*P. notatum* Retz.	Poaceae	Herb
Vanda	*Papilionanthe teres* (Roxb.) Schltr.	Orchidaceae	Epiphyte
Kodoa phan	*Paspalum scrobiculatum* L.	Poaceae	Herb
Jhumku lata	*Passiflora foetida* L.	Passifloraceae	Climber

Napi gach	*Peliosanthes teta* Andr.	Haemodoraceae	Herb
-	*Pentatropis capensis* (L. f.) Bullock	Asclepiadaceae	Climber
Lal-bishkatali	*Persicaria flaccida* (Meissn.) H. Gross *ex* Loesen.	Polygonaceae	Herb
Lal-kukri	*P. hydropiper* (L.) Spach	Polygonaceae	Herb
Bara panimorich	*P. orientalis* (L.) Spach	Polygonaceae	Herb
-	*Phaulopsis imbricata* (Forssk.) Sweet	Acanthaceae	Herb
-	*Phoebe lanceolata* (Nees) Nees	Lauraceae	Shrub
Khejur	*Phoenix sylvestris* Roxb.	Arecaceae	Tree
-	*Pholidota imbricata* Hook. f.	Orchidaceae	Epiphyte
Pituli pata	*Phrynium imbricatum* Roxb.	Marantaceae	Shrub
Bakkumgula	*Phyla nodiflora* (L.) Greene	Verbenaceae	Herb
Amlaki	*Phyllanthus emblica* L.	Euphorbiaceae	Tree
Bhuiamla	*P. niruri* L.	Euphorbiaceae	Tree
Chitki	*P. reticulatus* Poir.	Euphorbiaceae	Shrub
Fotka	*Physalis minima* L.	Solanaceae	Herb
-	*Pilea melastomoides* (Poir.) Wedd.	Urticaceae	Shrub
Pan	*Piper betle* L.	Piperaceae	Climber
Ban pan	*P. sylvaticum* Roxb.	Piperaceae	Climber
Kurmar	*Pithecellobium angulatum* Benth.	Mimosaceae	Tree
-	*Pogonatherum crinitum* (Thunb.) Kunth	Poaceae	Herb
Choto bush	*P. paniceum* (Lamk.) Hack.	Poaceae	Herb
Mechu sak	*Polygonum plebeium* R. Br.	Polygonaceae	Herb
-	*Pongamia pinnata* (L.) Pierre	Fabaceae	Tree
Batilata	*Pothos scandens* L.	Araceae	Climber
Kulla kuri	*Pouzolzia zeylanica* (L.) *Benn.*	Urticaceae	Herb
Lallong	*Premna esculenta* Roxb.	Verbenaceae	Shrub
Gutgutia	*Protium serratum* (Wall. *ex* Coelbr.) EngL.	Burseraceae	Tree
Piara	*Psidium guajava* L.	Myrtaceae	Shrub
Ban-assar	*Pterospermum semisagittatum* Buch.-Ham. *ex* Roxb.	Sterculiaceae	Tree
Batna	*Quercus gomeziana* A. Camus	Fagaceae	Tree
Mankanta	*Randia dumetorum* Lamk.	Rubiaceae	Shrub
-	*Rhaphidophora grandis* Schott	Araceae	Climber
-	*Rhizophora mucronata* Poir.	Rhizophoraceae	Tree
Foxtail	*Rhynchostylis retusa* (L.) Blume	Orchidaceae	Epiphyte
-	*Rhynchotechum ellipticum* (Diet.) DC.	Gesneriaceae	Shrub
Reri	*Ricinus communis* L.	Euphorbiaceae	Herb
-	*Rotala indica* (Willd.) Koehne	Lythraceae	Herb
-	*R. rotundifolia* (Buch.-Ham. *ex* Roxb.) Koehne	Lythraceae	Herb
Pindi	*Rungia pectinata* (L.) Nees. in Wall.	Acanthaceae	Herb
Teng	*Saccharum arundinaceum* Retz.	Poaceae	Herb

Kash	*S. spontaneum* L.	Poaceae	Herb
Pandi korai	*Samanea saman* (Jacq.) Merr.	Mimosaceae	Tree
Hoklati	*Sambucus canadensis* L.	Caprifoliaceae	Tree
Ritha	*Sapindus saponaria* L.	Sapindaceae	Tree
Ashok	*Saraca thaipingensis* Cantley *ex* Prain	Caesalpiniaceae	Shrub
Achila	*Sarcochlamys pulcherrima* Gaudich.	Urticaceae	Shrub
Baoli lata	*Sarcolobus carinatus* Wall.	Asclepiadaceae	Climber
-	*Schefflera bengalensis* Gamble	Araliaceae	Climber
Bandhani	*Scoparia dulcis* L.	Scrophulariaceae	Herb
Bhela	*Semicarpus anacardium* L.f.	Anacardiaceae	Tree
Dadmordon	*Senna alata* (L.) Roxb.	Caesalpiniaceae	Shrub
Chakunda	*S. obtusifolia* (L.) Irwin & Barneby	Caesalpiniaceae	Herb
Eski	*S. occidentalis* Roxb.	Caesalpiniaceae	Shrub
Kalkesunde	*S. sophera* (L.) Roxb.	Caesalpiniaceae	Herb
Chakunda	*S. tora* (L.) Roxb.	Caesalpiniaceae	Herb
Bokful	*Sesbania grandiflora* (L.) Poir.	Fabaceae	Shrub
Bajra	*Setaria glauca* (L.) P. Beauv.	Poaceae	Herb
Sal	*Shorea robusta* Roxb. *ex* Gaertn. f.	Dipterocarpaceae	Tree
Nakphul	*Sida acuta Burm.* f.	Malvaceae	Herb
Junka	*S. cordata* (Burm. f.) Borss.	Malvaceae	Herb
Berela	*S. cordifolia* L.	Malvaceae	Herb
Lal-berela	*S. rhombifolia* L.	Malvaceae	Herb
Kumari lata	*Smilax ferox* Wall. *ex* Kunth	Smilacaceae	Climber
Kumari lata	*S. laurifolia* L.	Smilacaceae	Climber
Kumari lata	*S. ovalifoila* Roxb.	Smilacaceae	Climber
Kumari lata	*S. perfoliata* Lour.	Smilacaceae	Climber
-	*Solanum barbisetum* Nees	Solanaceae	Shrub
Betbegun	*S. capsicoides* All.	Solanaceae	Shrub
Beregul	*S. lasiocarpum* Dunal	Solanaceae	Shrub
Puti begun	*S. nigrum* L.	Solanaceae	Herb
-	*S. sisymbrifolium* Lamk.	Solanaceae	Shrub
Gota begun	*S. torvum* Swartz	Solanaceae	Shrub
Byakur	*S. violaceum* Ortega	Solanaceae	Shrub
Kanta kari	*S. virginianum* L.	Solanaceae	Shrub
-	*Sonneratia alba* J. Smith	Sonnertiaceae	Tree
Keora	*S. apetala* Buch.-Ham.	Sonnertiaceae	Tree
Keora	*S. caseolaris* (L.) Engl.	Solanaceae	Tree
Bean	*Spatholobus acuminatus* Benth.	Fabaceae	Climber
-	*S. roxburghii* Benth.	Fabaceae	Climber
Chagalnadi	*Sphaeranthus indicus* L.	Asteraceae	Herb
Mathamoriaguinshak	*Spilanthes acmella auct.* non L. Thw.	Asteraceae	Herb
Amra	*Spondias pinnata* (L.f.) Kurz.	Anacardiaceae	Tree

Bina joni	*Sporobolus diander* (Retz.) P. Beauv.	Poaceae	Herb
-	*S. indicus* R. Br.	Poaceae	Herb
Bina joni	*Stachytarpheta jamaicensis* (L.) Vahl	Verbenaceae	Herb
-	*Staurogyne argentea* Wall.	Acanthaceae	Herb
Lalgurania alu	*Stemona tuberosa* Lour.	Stemonaceae	Climber
Thanda manik	*Stephania glabra* (Roxb.) Miers	Menispermaceae	Climber
Muichanlata	*S. japonica* (Thunb.) Miers	Menispermaceae	Climber
Phulkadam	*Stephegyne parvifolia* Korth. auct. Non Roxb.	Rubiaceae	Tree
Jongli badam	*Sterculia foetida* L.	Sterculiaceae	Tree
Bsaket badam	*S. villosa* Roxb. *ex* Smith	Sterculiaceae	Tree
-	*Stereospermum personatum* (Hassk.) Chatterjee	Bignoniaceae	Tree
Bishkachu	*Steudnera colocasioides* Hook. f.	Araceae	Herb
Sheora	*Streblus asper* Lour.	Moraceae	Shrub
-	*Strobilanthes polystachia* Nees.in Wall	Acanthaceae	Herb
-	*Strophanthus wallichii* Decne.	Apocynaceae	Shrub
Silver bell	*Styrax serrulatus* Roxb.	Styraceae	Shrub
Maricha	*Suregada multiflora* (A. Juss.) Baill.	Euphorbiaceae	Tree
Mehogoni	*Swietenia mahagoni* Jacq.	Meliaceae	Tree
Civit	*S. floribunda* Griff.	Anacardiaceae	Tree
-	*Symplocos racemosa* Roxb.	Symplocaceae	Climber
-	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	Herb
Bhutijam	*Syzygium balsameum* (Wight) Walp.	Myrtaceae	Tree
Nalijam	*S. claviflorum* (Roxb.) A.M. Cowan & J.M. Cowan	Myrtaceae	Tree
Kalojam	*S. cumini* (L.) Skeels	Myrtaceae	Tree
Dhakijam	*S. firmum* Thw.	Myrtaceae	Tree
Panijam	*S. formosum* (Wall.) Masamune	Myrtaceae	Tree
Bhutijam	*S. fruticosum* DC.	Myrtaceae	Tree
Khaijam	*S. syzygioides* (Miq.) Merr. & L. M. Perry	Myrtaceae	Tree
Tagar	*Tabernaemontana corymbosa* Roxb. *ex* Wall.	Apocynaceae	Shrub
Tagar	*T. recurvata* Roxb.	Apocynaceae	Shrub
Mati munda	*Tacca integrifolia* Ker-Gawl.	Taccaceae	Herb
Tentul	*Tamarindus indica* L.	Campanulaceae	Tree
-	*Tapiria hirsuta* Hook. f	Anacardiaceae	Herb
Segun	*Tectona grandis* L. f.	Verbenaceae	Tree
Bon-neel	*Tephrosia purpurea* (L.) Pers.	Fabaceae	Herb
Arjun	*Terminalia arjuna* (Roxb. *ex* DC.) Wight & Arn.	Combretaceae	Tree

Bohera	*T. bellirica* (Gaertn.) Roxb.	Combretaceae	Tree
Katbadam	*T. catappa* L.	Combretaceae	Tree
Haritoki	*T. chebula* Retz.	Combretaceae	Tree
Challalata	*Tetracera sarmentosa* (L.) Vahl subsp. *andamanica* (Hoogl.) Hoogl.	Dilleniaceae	Climber
Chundul	*Tetrameles nudiflora* R. Br.	Datiscaceae	Tree
Nekung riubi	*Tetrastigma angustifolium* (Roxb.) Planch.	Vitaceae	Climber
-	*Thunbergia fragrans* Roxb.	Acanthaceae	Climber
Nekung riubi	*T. grandiflora* (Roxb. *ex* Rottler) Roxb.	Acanthaceae	Climber
Phuljharu	*Thysanolaena maxima* (Roxb.) O. Kuntze	Poaceae	Herb
Ghora gulancha	*Tinospora cordifolia* (Willd.) Hook. f. & Thoms.	Menispermaceae	Climber
Gulancha	*T. crispa* (L.) Hook. f. & Thoms.	Menispermaceae	Climber
Toon	*Toona ciliata* M. Roem.	Meliaceae	Tree
-	*Torenia vegans* Roxb.	Scrophulariaceae	Herb
Gobar jiga	*Trema orientalis* (L.) Blume	Ulmaceae	Tree
-	*Trevesia palmata* (Roxb.) Vis.	Araliaceae	Shrub
Pitali	*Trewia nudiflora* L.	Euphorbiaceae	Tree
Banokra	*Triumfetta rhomboidea* Jacq.	Tiliaceae	Herb
-	*Tylophora tenuissima* (Roxb.) Wight & Arn.	Asclepiadaceae	Climber
-	*Uraria lagopoides* DC.	Fabaceae	Herb
-	*U. rufesens* (DC.) Schind.	Fabaceae	Shrub
Banokra	*Urena lobata* L.	Malvaceae	Herb
-	*U. sinuata* L.	Malvaceae	Herb
Sumudra pyaj	*Urginea indica* (Roxb.) Kunth	Liliaceae	Herb
Latkan	*Uvaria hamiltonii* Hook. f. & Thom.	Annonaceae	Climber
Shial lata	*Vernonia patula* (Dry) Merr.	Asteraceae	Herb
Monwal	*Vitex altissima* L. f.	Verbenaceae	Tree
Chotonishinda	*V. trifolia* L. f.	Verbenaceae	Shrub
Ashal	*V. glabrata* R. Br.	Verbenaceae	Tree
Horina	*V. peduncularis* Wall. *ex* Schauer	Verbenaceae	Tree
Marmaria puta	*Vitis repens* (Lamk.) Wight & Arn.	Vitaceae	Climber
Bonlichu	*Walsura robusta* Roxb.	Meliaceae	Tree
Dhatri-phul	*Woodfordia fruticosa* (L.) Kurz	Lythraceae	Shrub
Ghagra	*Xanthium indicum* Koen. *ex* Roxb.	Asteraceae	Herb
Gandi	*Xanthophyllum flavescens* Roxb.	Xanthophylaceae	Tree
Dud kachu	*Xanthosoma violaceum* Schott	Araceae	Herb
Bazna	*Zanthoxylum rhesta* (Roxb.) DC.	Rutaceae	Tree
-	*Zea mays* L.	Poaceae	Herb

Paletara	*Zingiber montanum* (Koen.) Dietr.	Zingiberaceae	Herb
Laltara	*Z. roseum* (Roxb.) Rosc.	Zingiberaceae	Herb
-	*Ziziphus funiculosa* Buch.-Ham. *ex* Lawson	Rhamnaceae	Shrub
Jangli kul	*Z. glabrata* Heyne *ex* Roth	Rhamnaceae	Climber
Boroi	*Z. mauritiana* Lamk.	Rhamnaceae	Tree
Kankra	*Z. oenoplia* (L.) Mill.	Rhamnaceae	Shrub

Annex 2 : List of Fauna of Teknaf (IFESCU, 2023)

Class	**Family**	**Local name**	**Scientific name**
Mammal	Canidae	Golden Jackal	*Canis aureus*
	Felidae	Fishing Cat	*Prionailurus viverrinus*
	Mustelidae	Hog Badger	*Arctonyx collaris*
	Viverridae	Large Indian Civet	*Viverra zibetha*
		Small Indian Civet	*Viverricula indica*
	Elephantidae	Asian Elephant	*Elephas maximus*
	Suidae	Wild Boar	*Sus scrofa*
	Cervidae	Indian Muntjac	*Muntiacus muntjac*
	Muridae	Lesser Bandicoot Rat	*Bandicota indica*
Aves	Phasianidae	Kalij Pheasant	*Lophura leucomelanos*
	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*
	Anastomidae	Asian Openbill	*Anastomus oscitans*
	Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus*
	Ardeidae	Yellow Bittern	*Ixobrychus sinensis*
		Cinnamon Bittern	*Ixobrychus cinnamomeus*
		Black-crowned Night Heron	*Nycticorax nycticorax*
		Striated Heron	*Butorides striata*
		Indian Pond Heron	*Ardeola grayii*
		Western Cattle Egret	*Bubulcus ibis*
		Grey Heron	*Ardea cinerea*
		Great Egret	*Ardea alba*
		Intermediate Egret	*Egretta intermedia*
		Little Egret	*Egretta garzetta*
	Phalacrocoracidae	Little Cormorant	*Microcarbo niger*
	Accipitridae	Black-winged Kite	*Elanus caeruleus*
Reptiles	Testudinidae	Elongated Tortoise, Yellow-headed Tortoise	*Indotestudo elongata*
		Asian Giant Tortoise, Burmese Brown Tortoise	*Manouria emys*
	Geoemydidae	Batagur, Common	*Batagur baska*

Class	**Family**	**Local name**	**Scientific name**
		Batagur	
		Three-striped Roofed Turtle, Threestriped Roof Turtle	*Batagur dhongoka*
		Bengal Roof Turtle	*Batagur kachuga*
		Keeled Box Turtle	*Cuora mouhotii*
		Arakan Forest Turtle	*Heosemys depressa*
		Sylhet Roofed Turtle	*Pangshura sylhetensis*
	Trionychidae	Asiatic Softshell Turtle, Southeast Asian Softshell Turtle	*Amyda cartilaginea*
Amphibian	Bufonidae	Kuno Bang	*Duttaphrynus melanostictus*
	Dicroglossidae	Ashmater jhi jhi bang	*Zakerana asmati*
		Jhi jhi bang	*Zakerana pierrei*
		Nepali jhi jhi bang	*Zakerana nepalensis*
		Torai jhi jhi bang	*Zakerana teraiensis*
		Kakrabhuk bang	*Fejervarya cancivora*
		Kotkoti bang	*Euphlyctis hexadactylus*

1(i)

1(ii)

1(iii)

1(iv)

1(v)

Plate 1(i, ii, iii, iv, v): Surveying local people of TWS

Plate 2: Water sample collection

Plate 3: Flow discharge measurement

Plate 4: Water quality parameters measurement

Plate 5: Stream depth measurement

Plate 6: Water sample handing for analysis

Plate 7: Stream tracking using GPS

8(i)

8 (ii)

Plate 8 (i & ii): KIIs in TWS

9(i)

9(ii)

9(iii)

9(iv)

Plate 9(i, ii, iii & iv): FGDs in TWS