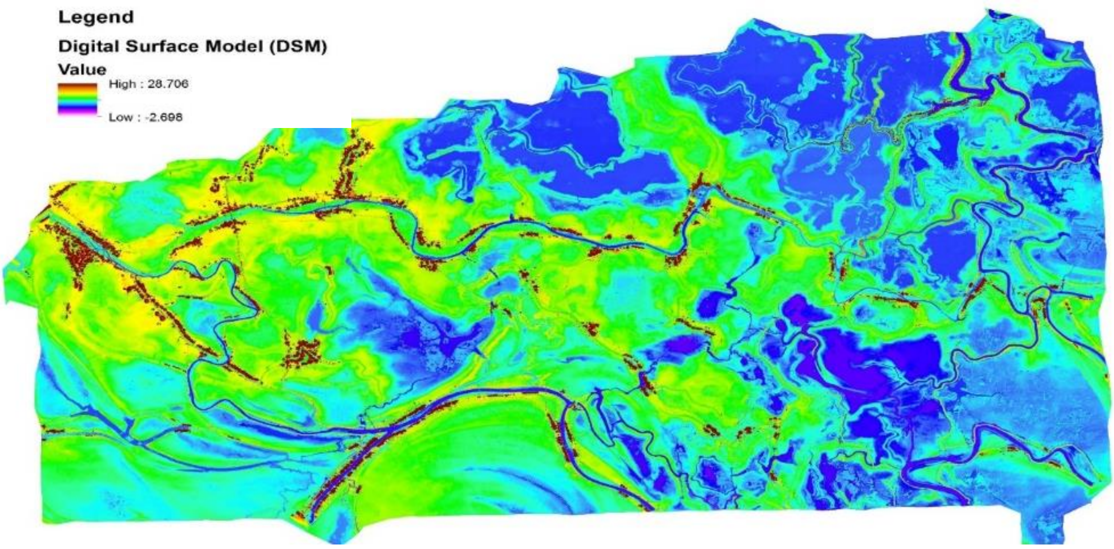
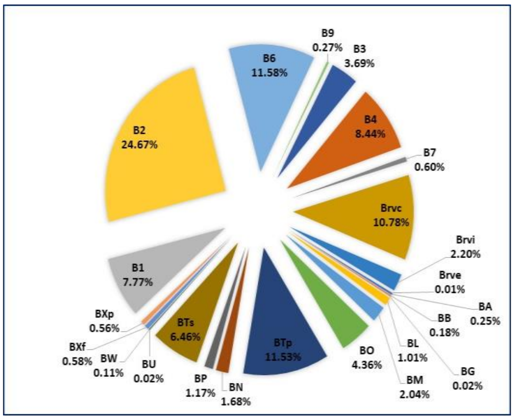
Government of the People's Republic of Bangladesh

Ministry of Water Resources

Department of Bangladesh Haor & Wetlands Development





STUDY ON INTERACTION BETWEEN HAOR AND RIVER ECOSYSTEM INCLUDING DEVELOPMENT OF WETLAND INVENTORY AND SUSTAINABLE WETLAND MANAGEMENT FRAMEWORK

DRAFT FINAL REPORT

May 2020

Volume-I: Main Report

MEGATECH

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The Draft Final Report consists of the following volumes:

Volume	Title of the Report
Volume-I	Main Report Annex-A: Terms of References
Volume-II	Appendix-A: Details of the Ground Truthing Survey Methodology and Survey Findings Appendix-B: Details of LiDAR Survey Appendix-C: Plots of Cross-Section at Tanguar Haor and Hakaluki Haor Appendix-D: Wetland Delineation Appendix-E: Biodiversity Study Appendix-F: Fisheries Resources Study Appendix-G: Vegetation Survey Study Appendix-H: Agricultural Study Appendix-J: Socio-Economic Study
Volume-III	Inventory of Wetlands

EXECUTIVE SUMMARY

Department of Bangladesh Haor and Wetland Development (DBHWD) is mandated by the government for overall coordination and monitoring for integrated development in the haor and wetland areas in the country to holistically address the problems related to water resources, agriculture, socio-economic and environmental concerns in the haor and wetlands of the country. DBHWD has already developed Haor Master Plan with a view to protect, preserve and conserve the haor wetlands from degradation as well as for sustainable management of wetlands. There still exists number of unidentified haors, beels, jheels as well as wetlands in this country which also contribute greatly to environment, ecosystem and biodiversity.

The project has been formulated with a view to prepare an inventory of the wetlands through classification of satellite images, delineations of wetlands, study of interaction between haor and river ecosystems and LiDAR survey of Tanguar haor for an area of approximately 120 sq. km. for empirical data collection. The study also aims to identify the different types of wetlands in the different hydrological regions of Bangladesh and preparation of detail map.

For fulfilment of the study objectives, the major activities those have been carried out includes:

- Collection of currently available remotely sensed images of recent years, georeferenced the images and ground truthing by field survey and classification of the satellite images to identify the exact locations and boundaries of wetlands.
- LiDAR survey of Tanguar haor for an area of approximately 152 sq. km. for empirical data collection.
- Classification of wetlands of Bangladesh according to their hydrological functions, important ecosystem, ecosystem services, physiographic characteristics and demography.
- Identification of connectivity of haors and wetlands with adjacent river system.
- Development of an inventory of wetlands along with different categorical contour maps.
- Comprehensive stakeholder consultations to find out gap(s), and incorporating their suggestions for successful completion of the wetland inventory;
- Monitoring and evaluation of piloting sites to find out gap in selected best management practices.
- Finalization of wetland management framework based on their (wetlands) cluster-wise best management practices and piloting results.

The primary data that has been collected under this study is mentioned below:

- A total of 339 Nos. of high-resolution satellite imagery has been procured from DigitalGlobe covering the whole country. 215 GCPs among pre-selected 250 has been captured for ground truthing and accuracy assessment.
- A total 10 nos. of cross – section survey for Tanguar haor and 7 nos. of cross – section survey for Hakaluki haor have been conducted. The maximum length of cross-section survey is 12 Km and the spacing between transect lines is 1200m for Tanguar haor and for Hakaluki Haor, the maximum length of cross-section survey is 14 km and the spacing between transect lines is 2000m. Discharge measurements were conducted at 4 locations on each of Tanguar & Hakaluki Haor and a total of 16 nos. of measurements were conducted during August to September 2019 @ of 2 spells on each location.
- LiDAR survey has been conducted on 20^{th} March 2019 for Tanguar haor for a total area covered by photos is 157 sq. km in mono coverage and 136 sq. km in stereo coverage.
- A total of 20 sets of surface water samples have been collected from Tanguar haor and Hakaluki haor area. The in – situ field measurement parameters are pH, dissolved oxygen (DO) and temperature. The water samples have been tested in the laboratory for the parameters of Total hardness as $CaCO_3$, Free carbon dioxide, Chemical Oxygen Demand, Biochemical Oxygen Demand (BOD_5; 20°C), Turbidity, Phosphate, Ammonia as Nitrogen, Total Suspended Solids (TSS), Nitrate-Nitrogen (NO_3-N) and Color.
- Also, the in – situ field measurement parameters (such as pH, dissolved oxygen (DO) and temperature, Total Dissolve Solid (TDS), Turbidity, Salinity and Conductivity) of water quality data for Baikka beel (10 nos.) from North East wetland cluster, Borobila beel (10 nos.) from North Central wetland cluster, Beel Halti (12 nos.) from North Western wetland cluster and Baluhor Baor (16 nos.) and Borni Baor (16 nos.) from south western wetland cluster has been collected.
- Data Collection on Biodiversity, Fisheries Resources, Forest, Agricultural Development and Socio – economic data for Tanguar and Hakaluki Haor has been collected under this study for dry and wet season. Similarly, the data for clustered wetlands such as Baikka beel, Borobila beel, Beel Halti, Baluhor Baor, Borni Baor and Kaptai lake has been collected for dry season only.

The approach and methodology that has been followed to fulfill the study objectives can be summarized as follows:

- ✓ For wetland delineation, average year (1:2.33 year) water levels in the major rivers have been considered. About 20 years' time series water level data has been processed for several BWDB gauges in each region to find the closest date of average year flood. The images of that date or closest to that date has been used for wetland delineation. The extent of wetlands has been produced for the driest and wettest periods using collected high resolution images. The Sentinel-1 and Sentinel-2 image have been used in wetland delineation for both wet and dry seasons. These images were duly pre-processed and later were classified in Erdas Imagine environment by using unsupervised classification technique. Finally, the classes resembled water were recoded and vectorized to get the wetland boundary for the dry and wet period.

- ✓ The inventory has been prepared based on hydrological region of Bangladesh and the map-based outputs is in 1:10000 scale. A total 4443 nos. of maps have been produced to cover the whole country. The inventory is in tabular format including the location (districts, upazila, union and mouza), area and other physical features such as agro-ecological zone and bio-ecological zone.
- ✓ The extent of wetlands has been produced for the driest and wettest periods using collected high resolution images. The Sentinel-1 and Sentinel-2 image have been used in wetland delineation for both wet and dry seasons. These images were duly pre-processed and later were classified in Erdas Imagine environment by using unsupervised classification technique. Finally, connectivity of identified wetlands with their adjacent rivers has been identified to find out the interaction between haor and river ecosystem.
- ✓ Data Collection on Biodiversity, Fisheries Resources, Forest, Agricultural Development and Socio – economic data has been conducted through Focus Group Discussion (FGD), Personal Interview (PI), Key Informant Interviews (KII) and Household Survey (HS) for different wetlands.
- ✓ The vulnerability assessment has been done based on four major issues and descriptions of those issues are given below:

    a. Value Assessment: A total of four types of values have been considered to assess the vulnerability; these are (i) Ecological value, (ii) Economical value, (iii) Hydrological value and (iv) Social value.

    b. Threats Assessment: As with the values, a list of pre-defined threats is given. Two scores, one for severity of threat and one for likelihood of threat, are given to each threat and a simple matrix is used to give a single score.

    c. Links between Values & Threats: The matrix table determines how the threats are likely to impact on the values.

    d. Vulnerability Assessment: Once all of the input's values are entered in the matrix table, then the vulnerability assessment has been completed.

Each value and threat have been given scores such as High (H), Medium (M), Low (L), and None (N). The final stage combines all values in a matrix to give a single value for each value and threat intersect, which have shown in below:

Value Score X *Link* X *Threat Score* = *Final Assessment Value*

where the scores H, M, L and N have numerical values of 3, 2, 1 and 0, respectively. So, the final assessment score is a number between 0 and 27.

The major findings from the study can be summarized as follows:

Findings from Delineation and Inventory of Wetland

- The total number of wetlands during wet season is about 61,150 with an area of about 1,687,312 ha whereas in dry season the number of wetlands is about 30,942 with an area of about 284,835 ha.
- The inventory has been prepared based on hydrological region of Bangladesh and the map-based output is in 1:10000 scale. A total 4443 nos. of maps have been produced to cover the whole country. The inventory is developed tabular format including the location (districts, upazila, union and mouza), area and other physical features such as geology, agro- ecological zone and bio-ecological zone and others.
- The study reveals that in average year hydrological condition, the North West (NW) region loses about 64% area of the rivers and canals in dry season with respect to the wet season water area. In terms of length the reduction of the extent of the rivers and canals in dry season is 46.69% (5,721 km) with respect to the wet season extent. In wet season the rivers and canals are connected to the closed water bodies in 725 locations whereas in dry season the connecting points reduced to 30 locations.
- The North Central (NC) region loses about 65% area of the rivers and canals in dry season with respect to the wet season water area for average year hydrological condition. In terms of length, the reduction of the extent of the rivers and canals in dry season is 49.5% (3,003 km) with respect to the wet season extent. In wet season the rivers and canals are connected to the closed water bodies in 485 locations whereas in dry season the connecting points reduced to 47 locations.
- The statistic on dry and wet season extents of the rivers and canals reveals that the North East (NE) region loses about 47% area of the rivers and canals in dry season with respect to the wet season water area and in terms of length the reduction of the extent of the rivers and canals in dry season is 55% (5,916 km) with respect to the wet season extent. The rivers and canals are connected to the closed water bodies in 1315 and 56 points in wet and dry season respectively.
- The South East (SE), South Central (SC) and South West (SW) regions loses about 52.71%, 11.36% and 7.44% area of the rivers and canals in dry season with respect

to the wet season water area respectively. In terms of length, the reduction of the extent of the rivers and canals in dry season is 62% (2,880 km), 18.47% (1,356 km) and 20.65% (3,720 km) with respect to the wet season extent for SE, SC and SW region respectively.

- The Eastern Hill (EH) region loses about 17.33% area of the rivers and canals in dry season with respect to the wet season water area for average year hydrological condition. In terms of length, the reduction of the extent of the rivers and canals in dry season is 36.21% (2,882 km) with respect to the wet season extent. In wet season the rivers and canals are connected to the closed water bodies in 778 locations whereas in dry season the connecting points reduced to 79 locations.
- The number of ponds having an area greater than 0.17 ha has been digitized for capturing the complete picture of the closed water body in the country. The number of ponds found to be 1,84,346 for North – western hydrological region whereas 1,02,196 nos. of ponds belongs to North – central region. The North – eastern region has 72,657 nos. of ponds whereas South – eastern, Eastern hill, South – central and South – western has 6,886; 38,087; 61,412 and 89,197 nos. of ponds respectively.
- Most of the area of wetlands in Bangladesh falls under the category of Ganges tidal floodplain (41.37%) which is followed by high Ganges river floodplain (12.87%) and then Northern and Eastern hills (10.86%). The minimum area of wetland covers Akhaura terrace (0.01% of the total wetland area). It can also be concluded that about 65.45% area of wetlands is under three dominant agro-ecologiical zones namely Ganges tidal floodplain, Ganges river floodplain and Northern and Eastern hills.
- The study reveals that Saline Tidal Floodplain covers about 38% of the total wetland area in Bangladesh. The Chittagong Hills and CHTs is the 2nd highest bio-ecological zone which covers about 37,322 ha (13%) of total wetland area which is followed by Ganges Floodplain (10%). The study also indicates that Chakaria Sundarban zone contains the minimum wetland area (only 17 ha).

Findings from the Study of Interaction between Haor and River Ecosystem

Three major river systems govern in the haor area inside Bangladesh: the Surma-Baulai, the Kalni- Kushiyara and the Kangsa-Dhanu. The Surma is the main river of this system which fed by Barak River. The Baulai is another important river of this system which flows entirely within Bangladesh. Major tributaries of Surma-Baulai river system are Sarigowain, Piyan, Dhalagang, Chela, Jalukhali, Jadukata and Someswari rivres. This river system meets the Kalni-Kushiyara system at Bajitpur upazila of Kishoreganj district. The main left tributaries of Kushiyara river are Sonai-Bardal river, Juri river and Manu river. The combined flow of the Dhanu River and Baulai River forms the Ghora-Utra River.

The faunal biodiversity prefers to utilize some components of haor ecosystem, rather than river ecosystem, because resources collection from haor is quite easy, especially in winter season. It has been observed that native faunal species prefer to use the connecting areas of haor and river ecosystem in compare to migratory faunal species; this happened due to tolerance behavior of native fauna on presence of anthropogenic activities.

Backwater from the Surma- Jadukata-Baulai River system intrudes the haor in pre-monsoon. Simultaneously, rainwater from the Meghalayan hilly areas flows into the haor through a good number of small streams. Its morphological shape, topography, inter-connectivity among the water bodies, shallow and deep levees/ridges, emergent vegetation, reed lands and swamp forest serve as the most prolific ground for breeding, nursing, grazing and sheltering place for fish species. Its low sediment, less turbid and transparent water facilitates photosynthesis process that promotes huge phytoplankton growth. The rich nutrient content with good water quality of this wetland promotes the growth of zooplankton, bentho-zooplankton and periphyton. The reeds, grass, and emergent vegetation, rivers and streams facilitate breeding and hatching process of the fish species.

Tanguar and Hakaluki Haor falls under freshwater wetland and have a unique freshwater ecosystem where biotic [living (e.g. flora, fauna. microbes, etc.)] and abiotic [e.g. non-living (physical & chemical components)] community interact with each other at various trophic level. The interactions within communities of organisms at population and community level play a key role in determining the stability and resilience of the ecosystem. Communities are structured by multiple biotic processes, and external conditions may strongly influence the outcome.

Tanguar Haor has lentic (still) water and its associated rivers have lotic (flowing) water. Three rivers such as Jadukata River, Boulai River and Patnai River have been identified that have direct connection with Tanguar Haor. It has known from stakeholder consultations that upstream water, from more than 30 streams of Meghalaya Hills of India, also enters the Tanguar Haor in the rainy season and enriches its ecosystem.

Like Tanguar Haor, Hakaluki Haor has also lentic (still) water and its associated rivers have lotic (flowing) water. A total of five rivers namely (i) Juri / Kantinala River, (ii) Sonai / Bordol River, (iii) Damai River, (iv) Fanai River and (v) Kuiachara River, have direct connection with the Hakaluki Haor.

The fish population dynamics of Tanguar Haor is intensively influenced with the hydrological regime of this wetland. Fish movement occurs beel to beel and migration occurs beel to river or vice-versa. In Tanguar Haor, migration takes place beel to beel through a river, Tanguar Haor to the Surma River, Tanguar Haor to the Jadukata River or vice-versa.

In Tanguar haor, in the pre-monsoon, major carps like Rui, Catla and Mrigel go long distances to find suitable place and environment for breeding. The fertilized eggs roll down with river current and within 4 days' time they enter the floodplain adjacent to the river

(Ahmed, 2015). Minor carps, catfishes and barbed fish species move to the flowing rivers/streams/ canals and breed in the shrubs/grasses of the adjacent levees/ridges in the early monsoon.

From the river Kushiyara, there are frequent upstream movement of fish towards the beels and tributaries of Hakaluki haor. The beels in Hakaluki haor provide winter shelter for the mother fisheries. In early monsoon these mother fisheries produce millions of fries for the entire downstream fishing communities.

Findings from Piloting Study

As a part of the study, a pilot site has been selected based on four criterions such as, Physical and Hydrological Criteria, Social Criteria, Biological Criteria, Management/ General Criteria. To select a new site for piloting, it needs a longer period of monitoring as well as investments in the field for maintaining the bio-ecological ecosystem. Considering the limitation of time and financial support, Baikka beel has been selected as a pilot site as because it has been operated by Management of Aquatic Resources through Community Husbandry (MACH) program since 2003. Under this study, the impact of MACH project has been conducted in comparison between the baseline data and data collected under this study. Also, the gaps and limitations of the management approach have been evaluated in this study.

Findings from the Field Survey of Pilot Site

- ✓ Since the commissioning of the BRMO, which was developed under MACH and CNRS in 2004, a number of bio – ecological, social, economic and cultural conditions have changed, impacting the lives of the people living at Baikka Beel.
- ✓ Unfortunately, presently co-management organizations in the Baikka Beel of Hail haor area face several problems and challenges in wetland management. Presently, the government does not provide any financial support to the RMOs, so it is difficult to manage the haor efficiently and monitor it properly,
- ✓ During 1999 – 2004, the number of fish species recorded in Baikka beel varies from minimum 71 nos. of species and maximum 85 nos. of species (MACH, 2003; Haque, 2013). Present study also reveals these facts that as a sanctuary, which has been well managed by a local beel management committee, but in practical the scenario of fisheries resources and biological diversity conditions of Baikka Beel was little bit different. A total of 46 nos. of fish species is available. Among the available 46 nos. of indigenous fish species, 22 nos. of less available species (48%), 07 nos. of rarely available species (15%), i.e. total 63% species are categorised as vulnerable species, which could be threatened and endangered within a few years of time if better wetland management practices as well as conservation effort of biodiversity of these species are ascertained at Baikka Beel and other adjacent beel and action taken accordingly.

- ✓ The main reasons of such vulnerability of good number of fish species in this water body are:
  - i) Heavy growth of aquatic weeds like water hyacinth, water lily, lotus etc. inside the beel area;
  - ii) Siltation and sedimentation reduced drastically the water level during dry season;
  - iii) Insufficient number of brush shelters inside the beel; although the water body is under sanctuary but occurring of undesirable poaching of fish during that season etc., all those are severely hindering fish breeding and spawning habitat to recruit enough number of indigenous fish species in Baikka beel and other adjacent wetland of Hail Haor area.
- ✓ The fishermen group reported that drastic environmental changes such as incidences of flash floods, which had a negative impact on the fish and prevented these participants from working as fishermen throughout the years. Some of the small-scale commercial and subsistence fishermen in the area observed that despite an increase in the quantity of fish in the beel (due to the conservation regulation), they were not able to catch fish freely because they couldn't gain fishing rights under the regulation. On the other hand, the BRMO allowed business people coming from outside the area to lease a portion of the sanctuary and harvest fish in a regulated way. Such a dual practice fueled animosity among the direct stakeholders, although BRMO stakeholders tried to negotiate between business people and fishermen.
- ✓ The tree vegetation diversity of Baikka beel were analyzed using the quantitative indexing approaches, the Shannon- Wiener index indicate the diversity status of the site where as Magalef index is showing the richness and Simpson is showing the dominance. The study found the tree vegetation diversity is quite good as the Shannon index is around 0.68 in range of (0 to 1).
- ✓ Though a management approach exists there, the study reveals that about 8 nos. of tree species are becoming rare, whereas 2 nos. of tree species totally lost from the ecosystem of Baikka beel.
- ✓ Baikka Beel biodiversity seems to be reducing due to various reasons; most faunal biodiversity exists within and periphery of beel and peripheral villages. In past, Baikka Beel was rich with faunal diversity, especially for the migratory avian species. Short stay duration of migratory bird inside the beel occurs now, due to various reasons such as disturbance of migratory bird habitats, illegal wildlife / bird hunting & fish collection - especially at night, etc. Suggested to ensure active monitoring program on the issues by strengthen the local resource management organization (RMO) via GoB.
- ✓ Peripheral villagers have some knowledge on local biodiversity that exists within and outside of their villages. Some peripheral village fauna uses the peripheral beel land and water-bodies as their habitat (seasonal and/ or permanent). Faunal population is

decreasing continuously due to over exploitation of natural resource (legal & illegal), habitat disturbance, illegal hunting, etc. It is recommended to ensure regular awareness program to the peripheral villagers on faunal diversity conservation and its importance to nature and human society.

- ✓ Precise boundary of Baikka Beel is not yet well defined; peripheral villagers and other powerful people sometime use the Beel land as per their need and also for their economic benefit by ignoring Baikka Beel's contribution to the natural environment and the nearby human society. Outer boundary of Baikka Beel area needs to be ensured exactly, and people interference and resource collection needs to be restricted by the GoB.
- ✓ Current management on Baikka Beel is weak in comparison to that of past by local RMO. Some illegal fish collection and fishery related activities occur inside the beel, occasionally, and the RMO can't handle those issues timely due to lack of resources.
- ✓ Faunal diversity is decreasing due to weak management on Baikka Beel by local RMO. Few avian diversities are noticeable mainly in winter season including few migratory birds, but many other types of biodiversity always exist there, and play vital roles in the existing natural environment. Suggested to ensure strengthen of local RMO via GoB.
- ✓ Pesticides use for agriculture and herbicide use in tea garden also pollutes the beel land and its water-bodies, both in dry and rainy season. Suggested to ensure banning of pesticide use for agricultural activities and herbicide in the tea garden.
- ✓ The number & type of migratory birds as well as other wild life species are decreasing due to the multifarious disturbances, habitat destruction, hunting, food scarcity, pesticide use, etc. Suggested to expand more restricted areas for wild life and fish species, create more public awareness for non-use of agro-pesticide or tea garden herbicide, etc.
- ✓ All sorts of fish, fish fry, fish egg and other natural resources are harvesting from the beel, indiscriminately at all nights, and some of these are use as food by specific wetland dependent wild life species; weak monitoring exists on it by RMO. Suggested to ensure effective monitoring program on it throughout the year from GoB as well as ensure punishment for violation of management rules.
- ✓ Tourism activities are increasing at Baikka Beel that also disturbs the faunal habitat, their movement, breeding places, etc. Suggested to restrict the tourism aspects via direct GoB supervision, not through RMOs.

Findings of Ecosystem Boundary Delineation

The probable faunal ecosystem boundary at different wetlands has been delineated in general-way, based on macro-scale assessment via field observation and literature review.

The major eco-components of faunal biodiversity are (i) Amphibia, (ii) Reptile, (iii) Aves and (iv) Mammal.

Amphibia: The amphibian species require both water and land for their survival. The travel distance varies among the amphibian species, and in general, maximum travel distances of some amphibian species (terrestrial & aquatic) are in between 300 to 500 meter from the wetlands. So, this distance could be the probable home range / ecosystem boundary for the amphibian species.

Reptile: Reptilian species vary among themselves, and most species require both water and land for their survival. The travel distance varies among the reptilian species, and in general, maximum travel distance of few reptilian species could be in between 0.5 to 1.0 km from the wetland. So, this distance could be the probable ecosystem boundary for the reptilian species.

Aves: Avian species are diversified, and some species require both water and land for their survival. The travel distance varies among the avian species, and in general, maximum travel distance of few avian species could be in between 2.0 to 4.0 km from the wetlands. So, this distance could be the probable home range / ecosystem boundary for the avian species.

Mammal: Mammalian species vary among themselves, and few species require both water and land for their survival. The travel distance varies among the mammalian species, and in general, maximum travel distance of few mammalian species could be in between 2.0 to 5.0 km from the wetland. So, this distance could be the probable home range / ecosystem boundary for the mammalian species.

Wetland Management Framework and Best Management Practice

The study proposes a participatory collaborative management regime for the wetlands of Bangladesh. A bottom up approach has been proposed in the decision-making process regarding wetland management. The study proposes a five-tier organizational structure from local level to national level for wetland management such as i) Village/Local Wetland Conservation Groups (VWCG), ii) Union Wetland Conservation Forum (UWCF), iii) Upazila Wetland Management Committee (UWMC), iv) District Wetland Management Committee (DWMC) and v) National Wetland Co-ordination Authority (NWCA). Relevant stakeholders i.e. governmental agencies (Department of Bangladesh Haor and Wetlands Development, Department of fisheries, Forest department, Department of agriculture, civil administration), elected representatives (local government), users of the wetland, local elites (religious leader, teachers etc.), relevant entrepreneur, civil society representative, journalist and NGO representative has been proposed as the participating actors in different tiers of the Co-management/ collaborative management organizations.

Proposed Interventions for Wetland Management Framework:

- Establishment of effective sanctuaries for fish and birds in entire haor area
- Implement dredging of rivers, canals and beel areas for increasing water flow and depth
- Construction of eco-friendly water control structure
- Tree plantation in haor dyke areas like hijol and koros trees
- Lease collection after fish harvesting
- Alternative income generation for the fishermen during breeding season

Findings from the Field Survey

- The surveyed LiDAR data used to delineate the boundaries of the wetlands very accurately in the project area which have been found highly validated by the wetlands separated from the high-resolution satellite image analysis.
- The bathymetric survey results reveal that the minimum elevation of the Tanguar and Hakaluki haor is -3.164 mMSL and -0.914 mMSL respectively.
- The discharge varies from 3.02 to 33.91 m^3/s for Tanguar haor and 4.12 to 261.22 m^3/s for Hakaluki haor whereas the velocity ranges from 0.005 to 0.057 m/s for Tanguar haor and 0.028 to 0.67 m/s for Hakaluki haor.
- pH value of collected surface water samples varies from 6.4 to 8.62 in the Tanguar haor area where as for Hakaluki haor area it ranges from 6.63 to 7.4. In most of the cases the values are within the range of Bangladesh drinking water standard.
- The Dissolved Oxygen (DO) content value of the collected samples ranges from 7.68 to 8.8 mg/l for Tanguar haor whereas it varies from 5.27 to 8.28 mg/l for Hakaluki haor areas. In context of Bangladesh drinking water standard, the DO value of Tanguar haor and Hakaluki haor exceed the limit except in 1 location of Hakaluki haor area.
- The laboratory analysis of collected water sample reveals that Total Hardness as CaCO3 varies from 27 to 48 mg/l for Tanguar haor and 14.9 to 19 mg/l for Hakaluki haor and all the values are below Bangladesh drinking water standard.
- Biochemical Oxygen Demand (BOD5) ranges between 2.8 to 6 mg/l for Tanguar haor and 3 to 4.2 mg/l for Hakaluki haor whereas Chemical Oxygen Demand (COD) varies from 6 to 20 mg/l for Tanguar haor and 5 to 8 mg/l for Hakaluki Haor. The turbidity values range from 1.43 to 5.25 NTU for Tanguar haor and 1.54 to 59.4 NTU for Hakaluki haor area.

Findings from Data Collection on Biodiversity, Fisheries Resources, Vegetation Survey, Agricultural Development and Socio – economic Study

Biodiversity: The identified faunal species at different wetland have been divided into four biological classes namely amphibia, reptilia, aves and mammalia. All identified faunal species play a vital role for balancing the existing ecosystem via intra-ecological and inter-ecological niches. Some species use the areas as their permanent habitat, while others use as temporary habitat. Finding of inventory on faunal biodiversity is presented below:

Wetland	Species Present Study			
	Amphibia	Reptilia	Aves	Mammalia
Tanguar haor	8	16	76	12
Hakaluki haor	8	23	131	16
Kaptai Lake	12	32	104	39
Baluhor Baor	7	12	59	12
Borni Baor	7	18	65	11
Borobila Beel	9	15	52	12
Baikka Beel	6	11	69	9
Beel Halti	5	12	54	9

Fisheries:

- In case of Tanguar haor, commonly numbers of available, moderately available, less available, rarely available and not available species are respectively 14, 16, 17, 16 and 8. Similarly at Hakaluki haor, the numbers of species of commonly available, moderately available, less available, rarely available and not available respectively are 17, 17, 21, 12 and 11. In both haors, the less available and rarely available species can be considered as vulnerable species, will be threatened and endangered within a couple years. IUCN Bangladesh (2003) found 32 nationally threatened freshwater fish species in the Hakaluki haor, which was a positive indicator of declining fish biodiversity in that aquatic ecosystem.

- About 8 nos. of fish species are not available during dry season in Tanguar Haor such as Nanid (*Labeo nandina*), Mohashaol (*Tor tor*), Gangmagur (*Plotosus caniu*), Chittal (*Notopterus chitala*), Shilon (*Silonia silondia*), Deshi Pangus (*Pangasius pangasius*), Baghair (*Bagarius yarrellii*) and Rita (*Rita rita*). During wet season, 8 nos. of fish species are not available in Tanguar Haor such as Nanid (*Labeo nandina*), Mohashaoal (*Tor tor*), Deahi Pangus (*Pangasius pangasius*), Gangmagur (*Plotosus caniu*), Shilon (*Silonia silondia*), Along (*Megarasbora elanga*), Ilish (*Tenualosa ilisha*) and Baghair (*Bagarius yarrellii*).

- In Hakaluki haor, 14 nos. of fish species are not available in dry season such as Nanid (*Labeo nandina*), Mohashal (*Tor tor*), Gangmagur (*Plotosus caniu*), Chittal (*Notopterus chitala*), Shilon (*Silonia silondia*), Deahi Pangus (*Pangasius pangasius*), Baghair (*Bagarius yarrellii*), Rita (*Rita rita*), Ilish (*Tenualosa ilisha*), Borali (*Barilius barila*), Fasha, Along (*Megarasbora elanga*), Posuti Punti (*Oreichthys cosuatis*), Baspata (*Paramugil parmatus*). In wet season, 14 nos. of fish species are not available in Hakaluki haor such as Nanid (*Labeo nandina*), Mohashoal (*Tor tor*), Deshi Pangus (*Pangasius pangasius*), Gangmagur (*Plotosus caniu*), Shilon (*Silonia silondia*), Along (*Megarasbora elanga*), Borali (*Barilius barila*), Kosuti punti (*Oreichthys cosuatis*).

- In Kaptai Lake, numbers of commonly available, moderately available, less available, rarely available and not available species respectively are 10, 14, 21, 9 and 4. Both less available and rarely available species can be categorized as vulnerable species, which is sharing 56% of species (both 39% less available + 17% rarely available species) are in alarming stage; those are on the way to be endangered within few years of time.
- Category wise availability of fishes at both Baluhar Baor and Borni Baor shows that, in both cases there are major proportions of these fish species become vulnerable, which are in the line of critically threatened or endangered soon or later.
- The trend of availability of vulnerable species (both less available + rarely species) and declining species biological diversity are very close between Baikka Beel and Beel Halti. Although at Borobila Beel number of vulnerable species having lower trend but huge vegetative growth at shallow water depth of the beel ecosystem during dry/winter season occurred huge mortality of the existing fish stocks due to deterioration of water quality parameters viz. dissolved oxygen, pH, alkalinity and hardness etc.
- No visible haor management practice exists either from any side of GoB or NGOs except Baikka beel. Local people do not get easy access to collect haor resources. Powerful people take advantage and take its resources unprofessionally, and thus, destroy its resources. Peripheral villagers and outside peoples are collecting natural resources from haor indiscriminately that ultimately damage the haor entity and its fisheries resources.
- At least 4 nos. of breeding spots have been identified in Tanguar haor such as Nazarkhali Khalerbak/ Bhanga, Bagmara Kanda, near the right bank where bend and deeper part is there- Alamer Duar, Shoshan Kanda, Chhara beel- Koraibari stream.
- A total of five fish sanctuaries is identified in Tanguar haor such as Rupaboi beel Fish Sanctuary, Rowa beel Fish Sanctuary, Tekunna beel Fish Sanctuary, Ballardubi beel Fish Sanctuary and Alamer Duar River Fish Sanctuary.
- Hakaluki haor are identified as important for fish sanctuaries such as Takuni beel, Moishar Dhak beel, Ronchi beel, Bhuterkona beel, Lampang beel and the confluence of Juri River.

Vegetation Survey:

- A total of 52 species under 30 families were found in the Tanguar haor sites from 61 plots and of total 24400 m^2 area during the first survey period (dry season) and 54 species were found from 51 plots of wet season. Amid of them, Moraceae switched 4 species, Fabaceae clicked 10 species and Meliaceae family carried out 3 species respectively, rest of the species had gone to several families.
- A total of 28 species were found in the Hakaluki haor sites from 50 plots and of total 20000 m^2 area during dry season and 34 species were found in wet season from 53 plots. Amid of them, Moraceae switched 4 species, Fabaceae clicked 5 species and Meliaceae family carried out 2 species respectively, rest of the species had gone to several families.
- The study found the tree vegetation diversity is in the mid-range as the Shannon index is around 0.54 in range of (0 to 1) for both the Tanguar haor and Hakaluki haor.
- The Mean above-ground, below-ground and Total Biomass Carbon (TBC) of the Tanguar haor areas were 21.37913 Ton per ha, 4.55077 Ton per ha and 25.92991 Ton per ha respectively and 28.01954 Ton per ha, 5.56763 Ton per ha and 33.58718 Ton per ha respectively for Hakaluki haor area.
- The study found 6 trees species and 4 shrub species in the sample plots of the Ratargul swamp forest. The forest is mostly dominated by *Barringtonia acutangula* (Hijol), *Millettia pinnata* (Koroch) and *Crataeva magna* (Barun). Among the shrub Murta is the most common plant found in the forest, which also have great importance for cottage industry in the region.
- The study found the tree vegetation diversity is not rich as the Shannon index is around 0.27 in range of (0 to 1) and Mean above-ground, below-ground and Total Biomass Carbon (TBC) were 26.20 Ton per ha, 5.34 Ton per ha and 31.54 Ton per ha respectively for Ratargul swamp forest.
- The vegetation study of Baikka beel reveals that 16 trees species and 3 shrub species were present in the sample plots of the area. The forest is mostly dominated by *Barringtonia acutangula* (Hijol), *Millettia pinnata* (Koroch), *Terminalia arjuna* (Arjun), *Ficus bengalensis* (Bot), *Trewia polycarpa* (Pitali), *Albizia lebbeck* (Koroi) and *Lagerstroemia speciosa* (Jarul). Among the herbs and shrubs *Typha elephantiana* (Hogal) and *Arundo donax* (Nal Khagra) are the most common plant found in the wetland. However, it is recorded that Murta was present there but now no longer exist.
- The tree vegetation diversity is quite good as the Shannon index is around 0.68 in range of (0 to 1) and Mean above-ground, below-ground and Total Biomass Carbon (TBC) were 23.83 Ton per ha, 4.94 Ton per ha and 28.77 Ton per ha respectively for Baikka beel.

- The study found 23 trees species and 2 shrub species in the sample plots of Borobila beel area. The forest is mostly dominated by *Psidium guajava* (Peyara), *Samanea saman* (Raintree), *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot) *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Albizia lebbeck* (Koroi) and *Lagerstroemia speciosa* (Jarul). Among the herbs and shrubs *Typha elephantiana* (Hogal) and *Saccharum spontaneum* (kash ful) are the most common plant found in the Borobila beel.
- The study found 23 trees species and 2 shrub species in the in the sample plots of the Beel Halti area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot), *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), and *Borassus flabellifer* (Tal). Among the herbs and shrubs Motmote, Chitki and *Ipomoea carnea* (Dhol kolmi) are the most common plant found in the Beel Halti area.
- The tree vegetation diversity is quite good as the Shannon index is around 0.53 in range of (0 to 1) for Beel Halti area. The study also shows that the mean above-ground, below-ground and Total Biomass Carbon (TBC) of the Beel Halti area were 42.67 Ton per ha, 8.07 Ton per ha and 50.74 Ton per ha respectively
- The vegetation around the Baluhor Baor is classified under village homestead forest and are mostly privately owned. The study found 32 trees species and 2 shrub species in the sample plots of the area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot) *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Acacia auriculiformis* (Akashmoni) and *Acacia catechu* (Khoi Babla). Among the herbs and shrubs *Typha elephantiana* (hogla), and *Ipomoea carnea* (Dhol kolmi) are the most common plant found in the wetland.
- The study found the tree vegetation diversity very rich as the Shannon index is around 0.90 in range of (0 to 1) for Baluhor baor. Mean above-ground, below-ground, and Total Biomass Carbon (TBC) of the Baluhor baor areas were 44.12 Ton per ha, 7.86 Ton per ha and 51.97 Ton per ha respectively.
- The study found 29 trees species and 2 shrub species in the selected plots of the Borni baor area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Acacia auriculiformis* (Akashmoni) and *Albizia procera*. Among the herbs and shrubs *Saccharum spontaneum* (kash ful), *Typha elephantiana* (hogla), and *Ipomoea carnea* (Dhol kolmi) are the most common plant found in the wetland.
- The study found the tree vegetation diversity rich as the Shannon index is around 0.69 in range of (0 to 1) for Borni baor area. Mean above-ground, below-ground, and Total Biomass Carbon (TBC) of the Borni baor area were 27.43 Ton per ha, 5.13 Ton per ha and 32.56 Ton per ha respectively.

- The study has recorded 52 species and 487 woody individuals along with 4 species of bamboos in the sampling plot of Kaptai lake. The vegetation is mostly dominated by *Gmelina arborea* (Gamar), *Dipterocarpus turbinatus* (Garjan), *Artocarpus chaplasha* (Chapalish), *Albizia lebbeck* (Koroi), *Hopea odorata* (Telsur), and *Syzygium grande (dhaki Jam).* Out of the 4 bamboo species, *Melocanna baccifera (*Muli Bansh) is the most common species. *Byttneria aspera, Sterculia balanghas, Physalis angulate* and *Macaranga peltata* are among the climbers, shrubs found in the sample plots.
- The study found the tree vegetation diversity rich as the Shannon index is around 0.78 in range of (0 to 1) for Kaptai lake. Mean above-ground, below-ground, and Total Biomass Carbon (TBC) of the Kaptai lake areas were 50.72517Ton per ha, 8.48571Ton per ha and 59.21089 Ton per ha respectively.
- The study findings indicate that the vegetation structure and diversity is changing over the time. Though the species diversity in different site is still healthy but the distribution or spread of different tree species is not healthy, i.e. a number of species are found abundantly but many indigenous species are sporadically found.
- Another important finding is that local people are replacing the indigenous multipurpose tree species (like Palash, Shimul) by high yielding timber producing tree species (like, Mahaguni and Akash moni). This replenish of vegetation around the wetlands like Baor and Beels is hampering the balance of the microclimate and habitat of wildlife especially indigenous and migratory birds. Additionally, removal of trees from large wetland like Tanguar and Hakaluki haor is also a major issue for health wetland management.

Agriculture:

Tanguar and Hakaluki Haor

The following issues have been observed at Tanguar and Hakaluki haor during the RRA/FGD exercises with the farmers:

- *Vulnerability to Early Flash Flood:* Boro rice, being the only crop grown in haor basin is vulnerable to early flash floods due to sudden heavy rainfall within and outside haor basin as well in upstream beyond the boarder. In case early onset of monsoon, early flash flood is almost inevitable causing total crop damage.
- *Scarcity of Irrigation Water:* Though haors remains submerged for about a half the year, Boro rice is exposed to water stress in the reproductive and grain growth stages due to lack of adequate irrigable water and infrastructure facilities for water conveyance and distribution. In fact, only 19-20 percent of Boro land is irrigated in Hakaluki and Tanguar haor area. This adds to the uncertainty of the crop and discourages desired investment due to risk of crop failure.

- *Poor Technical Knowhow:* Due to inaccessibility of the area for lack of communication facilities, farmers have minimal access to modern technological massages and extension services making farmers dependent on traditional practices of crop production and management.
- *Low Input Use in Boro Production:* Boro rice is the only crop for livelihood for most of farming community of the area. Accordingly, farmers make efforts to cover all their land with boro rice even beyond their capacity to manage it well in terms resource use to increase yield and productivity.
- *Blast Disease in BRRIdhan 28:* Being the short duration HYV, farmers widely use BRRIdhan 28 to escape early flash flood. However, due to long exposure of the variety in the area, it has become susceptible to Rice Blast disease. For last few years Blast disease has emerged as havoc causing serious yield loss of Boro rice.
- *Labor Crisis at Planting and Harvesting Time:* Due to ecological condition, farmers have to transplant and harvest boro rice within a short time due to absence of mechanization of planting and harvesting. Accordingly, farmers are dependent of hired labor coming from adjacent districts to carry out these vital operations. Labor shortage also a cause of inefficiency of other cultural practices.

Borobila Beel

- Over a long period, gradual siltation has significantly raised the bed resulting reduced water depth at peak time. Re-excavation, at the bottom would increase the depth and duration of water, help maintain water quality, increase fish productivity as well as other aquatic agricultural production practices;
- Use of rice transplanter and reaper in muddy lands (with plastic wheels) would reduce labor cost, ease and shorten the time for both the operations.
- The aquatic weeds seem to be main cause of degradation of water quality due to rotting may otherwise be used for composting and/or preparing beds for floating agriculture;
- Constructing sluice gates at Golaper Embankment and Boro Khal point would help regulate water to control flooding and drainage to minimize crop damage and facilitate timely planting of Boro rice.
- The management of the beel, especially the Khash land at the bottom is traditionally leased out to businessmen who exploit the water body without considering its sustainability and biodiversity. Vesting the management of Khash water body to concerned farmers and fishermen would help improve productivity of aquatic resources, improve water quality and sustainability of biodiversity.

Beel Halti

- The canal connecting the beel with Banar river need to be re-excavated to maintain continued/ long–term flow of water from the beel;

- The river Banar need to be excavated to maintain the stream flow towards larger flowing rivers and thus allowing quicker recession of the monsoon water from beel;
- The beel may be excavated at Government (KHASH) part of its basin and put the soil on croplands and thus elevating the same providing facilities i) for multiple crops, ii) early Boro crop, iii) accommodate early monsoon flood and save the crops, iv) promote more fishery wealth, v) to maintain a deeper part as fish sanctuary to protect and regenerate fish species and breeding, vi) protect the eutrophication and water quality, vii) attract tourists with maintained beauties with different suitable aquatic plants, local and guest birds, plants, fish species, fish catches, boat fairs and so on;
- The beel may be protected from inflow of soil and extra nutrients by constructing embankments and making a walkway with beautiful hedge and locally adopted extinct plants species to attract tourists. This can add to family income from tourists;
- A fish sanctuary may be maintained for enriching aquatic production and farmer's income;
- Construction of sluice gates needed at Golaper Bandh (Embankment) and Boro Khal (canal) point to control water pressure of the beel;
- The management of the beel needs to be with the concerned farmers and fishermen instead of leasing to businessmen who exploit the water body without considering its' sustainability and biodiversity;
- Use of rice transplanter and reaper in muddy lands (with plastic wheels) would reduce labor cost, ease and shorten the time for both the operations;
- Rotting of aquatic weeds, seemingly the main cause of degradation of water quality may otherwise be used for composting and/or preparing beds for floating agriculture.

Social Study:

Tanguar and Hakaluki Haor

- Construction of embankment to protect flash flood;
- Prohibited duck rearing in the open water;
- Stop catching fish throughout the year specially during the breeding season of fishes;
- Ensure financial support for the actual fishermen for certain (nonproductive) period;
- Lease the haor to the actual fishermen in and around the area;
- Building awareness among the people of haor area;
- Develop communication for haor area, for easy movement inside the haor and other urban area;
- Arrange and conduct training on haor resource management;
- Initiative for eco-tourism development in the haor area and
- Develop fish and bird sanctuary in the haor;

Recommendations: The major recommendation that has been made under this study can be summarized as below:

- The vulnerability assessment has been done as per guidelines of Ramsar Convention (1971) & Convention on Biological Diversity (CBD, 2006) as well as Millennium Ecosystem Assessment (MEA, 2005) which has to be replicated for the major and critical wetlands in Bangladesh through detailed data collection.
- All sorts of fish fry, fish egg and other natural resources are harvesting from the wetlands, indiscriminately, and some of these are used as food by specific wetland dependent wild life species; no monitoring exists on it either from any side of GoB or Local Community. It is suggested to ensure effective monitoring program on it throughout the year from GoB as well as to ensure punishment for violation of management rules.
- Faunal diversity is decreasing due to non-visible management of wetlands. Few avian diversities are noticeable mainly in winter season including few migratory birds, but many other types of biodiversity always exist there and play a vital role in the existing natural environment. It is suggested to ensure the best management practice on wetlands & its resources by involving peripheral villagers, i.e. villagers could play a vital role to stop over harvesting of natural resources, illegal hunting of wild life species, over harvesting of fishes and other aquatic resources, etc.
- It is strongly recommended that the co-management systems should be continued, enhanced and re-adopted as the integrated Best Wetland Management Practices (BWMPs) by GoB and concerned departments and ministries in coordinated way to restore threatened natural ecosystem habitat and conserve fish biological diversity at Tanguar and Hakaluki Haor ecosystem.
- Dredging is extremely recommended for depleted rivers, canals and beel areas for increasing water flow and depth for proper migration and better survival of gravid and juvenile stocks throughout the year.
- Banning of wild fish catch need to be restored during June – July months, during that time the fishermen should be provided alternative/supportive income opportunities like Govt. Hilsa Fisheries conservation and management program.
- Manually driven boat rather than engine boat is recommended to keep the ecosystem undisturbed.
- Short duration boro rice varieties (maturing in < 150 days) such as BRRIdhan 81, BRRIdhan 84 and BRRIdhan 86, BRRI Hybrid 5, maturing in 143, 141, and 140 days, respectively with 6.5 t/ha yield may be used by replacing long duration BRRIdhan 29 and other similar varieties.
- Scarcity of Irrigation Water may be managed by (a) developing surface water reservoirs by digging at suitable locations; (b) Developing necessary water pumping,

conveyance and distribution infrastructure; (c) Developing both surface and ground water resources to achieve full irrigation coverage; (d) Growing less water requiring upland crops in the upper position of catena by replacing Boro rice; and (e) Adopting more water efficient irrigation technologies such as Alternate Wetting and Drying (AWD) method of irrigation.

- It is high time to replace BRRIdhan-28 by newly developed Blast resistant short duration (< 150 days or less) like BRRIdhan 81, BRRIdhan 84 and BRRIdhan 86, BRRI Hybrid Dhan 5 and other introduced hybrid varieties introduced by different seed companies. Farmers need to be supported in adopting the new varieties.
- Adequate support is needed to develop suitable mechanical devices for transplanting (transplanter) and harvesting (harvester/reaper) suitable for use in wet (often submerged) haor ecosystem.
- To improve farmers' knowledge and skills; modern packages of crop production and management technologies should be demonstrated with farmer participation and providing technology training to as many farmers as possible within shortest possible time to mitigate knowledge and skill gaps.
- The wetlands may be excavated at its Government part (KHASH) and put the soil on croplands and thus elevating the same providing facilities i) for multiple crops, ii) early Boro crop, iii) accommodate early monsoon flood and save the crops, iv) promote more fish culture, v) to maintain a deeper part as fish sanctuary to protect and regenerate fish species and breeding, vi) protect the eutrophication and water quality, vii) attract tourists with maintained beauties with different suitable aquatic plants, local and guest birds, plants, fish species, fish catches, boat fairs and so on.
- The management of the wetlands needs to be activated with the concerned farmers and fishermen instead of leasing to businessmen who exploit the water body without considering its' sustainability and biodiversity;
- Radio-telemetry technique is a common method which frequently is used to delineate the faunal biodiversity home range / ecosystem boundary. However, the cost as well as time was not sufficient to conduct such type of survey. So, for delineation of site-specific ecosystem boundary, a Radio-telemetry technique is highly recommended.
- From the perspective of Hakaluki and Tanguar Haor, the stakeholder has suggested to plant Hijol, Koroch and Barun. The stakeholders have also suggested to reintroduce Kadam, Shimul, Raintree, Bot, Pitali because these plants were there in the recent past & they can be grown and survived in such environment. The stakeholders have mentioned some causes for which they have selected these species. The causes are;

    a) These are the native plants of haor area, and it is wise to plant native plants under any plantation program. Native plants are crucial in habitat restoration and help to restore plant diversity, stabilization and replenish soil.

b) Fresh water swamp forest consists of flood-tolerant evergreen trees & they are adapted to monsoon flooding for three to four months to depths of 0.5 to 2.5 m

c) The swamp plants provide habitat for fishes & birds & thus increase the number of fishes & birds.

d) The suggested plants can also give protection against wave action, storm action, erosion

e) Hijol is used to make Kathha for fishery purpose.

f) Capable of withstanding the flood, these trees may be conserved and protected as seed trees for future propagation.

- Enrichment of plantation with Hijol, Koroch, Barun and Murta in the ratargul swamp forest is recommended by the stakeholders. During field survey and stakeholder consultations, the strip plantation beside the road from patul- Naldanga is suggested for Beel Halti area. Preferred species are kodom, shimul and hijol.
- Reintroduction of Hijol tree is suggested for Borni baor as it provides habitat for fish and birds. Also, koroi, kadam and shimul may be the second options for tree plantation.
- The study proposes a co-management system of the wetlands. Effectiveness of the management would depend on the strength of the implementing agency. If the real stakeholders are well represented and the decision-making structure is a democratic one, only then the system will function and succeed. During initial years of such management, active support of the project should be there, and financial rules and norms must be clearly worked out and implement in an integrated way.

In the stakeholder's consultations, PIC and PSC meetings and field workshops several study projects have been suggested for the restoration and protection of wetlands and development of associated livelihood. As such, a 2nd phase of the study considering the following issues is highly recommended under this study:

1. Investigation of the status of fish, vegetation, forests, birds, livelihoods, navigation and farming pattern and develop a framework to use the natural resources of the wetlands in an equitable way and support the livelihoods of all stakeholders;
2. Establish the level of function and condition of wetlands to detect changes and stressors and to characterize trends over time.
3. Establish and or restore the connectivity between the rivers and wetlands, migration opportunity of fish, status of biodiversity, environmental health of the eco-system, socio-economic status and water availability.
4. Detailed cross – section survey/topographic survey of major wetlands and collection of hydrological data.

5. Development of water balance model to represent the key hydrological processes in the wetland.
6. Development of hydrodynamic river model to simulate the flow and water level along regional rivers and development of flood inundation map of wetlands for identifications of monthly variation of water level which will helps the decision makers to wise use of wetlands.
7. Development of system linkage model to represent qualitative and quantitative relationships among physical, ecological and socio-economic variables and to identify the potential impacts of climate change on ecology and livelihoods.
8. Identifications of wetlands that need to be dredged/ re-excavated to meet up the future water demand in an equitable manner.
9. Determination of long – term impacts of dredging/ re-excavation of wetlands on groundwater recharge through the development of regional groundwater flow model.
10. Cluster wise piloting of the recommended wetland management framework and monitoring the same and come up with updated recommendations.
11. Development of a comprehensive and user-friendly data and information management system for the identified wetlands.

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GLOSSARY OF TERMS

Aman	:	Monsoon rice crop cultivated during July-August and harvested in mid-December.
Baor	:	Baors are oxbow lakes, formed by dead arms of rivers.
Bathymetric survey	:	Bathymetric survey is the measurement of the depth of water in oceans, rivers, wetlands or lakes. Bathymetric maps look a lot like topographic maps, which use lines to show the shape and elevation of land features.
Beel	:	Beels are shallow lakes, which form in the lowest parts of the haor; sometimes these are perennial but more often seasonal. The water surfaces are contiguous with the ground water table and that beels are sustained from ground water to a large extent. Surface water does also collect in the beels during wet season, often spilling out of them into the main river system
Biodiversity	:	Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.
Boro	:	Rice grown during the dry winter season, transplanted during January-mid February and harvested during mid-May.
Digital Elevation Model (DEM)	:	Topography configuration of a land surface including its relief and contours, the distribution of mountains and valleys, the patterns of rivers, and all other features, natural and artificial, that produce the landscape.
Discharge	:	Discharge is the volumetric flow rate of water that is transported through a given cross-sectional area
District	:	An administrative unit comprising several upazila
Division	:	An administrative unit comprising several administrative districts
Ecosystem	:	An ecosystem could simply be defined as a collection of communities of organisms (biotic) and the environment (abiotic) in which they live and interact with each other.
Ecosystem services	:	The benefits that people receive from ecosystems, including provisioning, regulating, and cultural services

Estuary	:	An estuary is a partly enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open
Focus Group Discussions (FGD)	:	A focus group discussion involves gathering people from similar backgrounds or experiences together to discuss a specific topic of interest. It is a form of qualitative research where questions are asked about their perceptions attitudes, beliefs, opinion or ideas.
Geo-referencing	:	Geo-referencing is a technique used for aligning the images to highly accurate spatial locations on ground surface.
Ground Truthing	:	The ground truthing is used to validate the horizontal accuracy of the final, ortho-rectified imagery in terms of the relative (internal) position between two points.
Haor	:	Haors are bowl-shaped depressions of considerable aerial extent lying between natural levees of the rivers or high lands of the northeast region of Bangladesh. In most cases, haors have been formed as a result of peripheral faulting leading to the depression of the haor area. In the wet seasons, the haors are full of water, but during the dry seasons, these are dried up except for the beels.
Hijal	:	A type of water tolerant tree normally seen in the Haor areas.
Jheel	:	Jheel a local term representing a reach of an old river channel bed. Usually it appears as an oxbow lake.
Khal	:	Local name for a drainage channel connecting beels/rivers
Lake	:	A lake is an area filled with water, localized in a basin, surrounded by land, apart from any river or other outlet that serves to feed or drain the lake
LiDAR	:	LiDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the earth and its surface characteristics.
Ornithological study		Ornithological study is the scientific field dedicated to the study of birds. Any bird - whether it is a tiny hummingbird or an extra-large emu - falls under the realm of ornithology.
Ramsar	:	City in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands was agreed on 2 February 1971; thus the

		Convention's informal nickname, "Ramsar Convention on Wetlands"
Ramsar Sites	:	Wetlands designated by the Contracting Parties for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar Criteria
Sentinel-1 Satellite Image	:	The Sentinel-1 Satellite Image comes from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument.
Sentinel-2 Satellite Image	:	Sentinel-2 is a wide-swath, high-resolution, multi-spectral imaging mission supporting Copernicus Land Monitoring studies, including the monitoring of vegetation, soil and water cover, as well as observation of inland waterways and coastal areas.
Swamp	:	A swamp is a wetland that is dominated by woody plants (shrubs and trees). Swamps are often near rivers or streams.
Tide	:	Tides are the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the Moon and the Sun and the rotation of the
Tree Biomass	:	Tree biomass may be that of a single individual or all individuals occupying a unit of area.
Wetland	:	The Bangladesh Water Act, 2013 defines wetland as "Wetland means any land where water remains at the level of surface or close to it and which inundates with shallow water from time to time, and where grows such plants that may usually grow and survive in marsh land." The RAMSAR Convention (1971) has defined wetlands as 'areas of marsh, fen, peat land, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters'.
Wetland Inventory	:	The RAMSAR Convention (1971) has defined wetlands Inventory as 'the collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities.'
Wetland Vulnerability	:	Wetland vulnerability refers to the relationship between exposure to a particular risk event, the impact of that event on a wetland, and the ability of the wetland to cope with the impacts or the efforts needed to minimize the impacts.

ACCRONYMS AND ABBREVIATION

AIGA	American Institute of Graphic Arts
AoI	Area of Interest
AoS	Areas of Significance
AEZ	Agro-Ecological Zone
AWD	Alternate Wetting and Drying
BADC	Bangladesh Agricultural Development Corporation
BFRI	Bangladesh Fisheries Research Institute
BMD	Bangladesh Metereological Department
BMP	Best Management Practices
BNH	Bangladesh National Herbarium
BOBLME	Bay of Bengal Large Marine Ecosystem
BOB	Bay of Bengal
BOD	Biochemical Oxygen Demand
BRMO	Borogangina Resource Management Organization
BTM	Bangladesh Transverse Mercator
BWDB	Bangladesh Water Development Board
BWMPs	Best Wetland Management Practices
CBAECA	Community Based Adaptation in the Ecologically Critical Area
CBD	Convention on Biological Diversity
CBO	Congressional Budget Office
CHT	Chittagong Hill Tracts
CNRS	The National Center for Scientific Research
CoC	Code of Conduct
COD	Chemical Oxygen Demand
CREL	Climate Resilient Ecosystem and Livelihoods
CZP	Coastal Zone Policy
DAE	Department of Agricultural Extension
DBHWD	Department of Bangladesh Haor and Wetlands Development
DC	District Commissioner
DFID	Department for International Development
DFR	Draft Final Report
DEM	Digital Elevation Model
DG	Director General
DGPS	Differential Global Positioning System
DO	Dissolved Oxygen
DoE	Department of Environment
DSM	Digital Surface Model
DTM	Digital Terrain Model
DPHE	Department of Public Health Engineering
DWMC	District Wetland Management Committee
ECA	Ecologically Critical Area

ECR	Environmental Conservation Rules
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization
FCD	Flood Control and Drainage
FCDI	Flood Control Drainage and Irrigation
FD	Forest Department
FGD	Focus Group Discussion
FGDC	Federal Geographic Data Committee
FR	Final Report
IEE	Initial Environmental Examination
IUCN	International Union for Conservation of Nature
JPEG	Joint Photographic Expert Group
LGED	Local Government Engineering Department
GCP	Ground Control Point
GEF	Global Environment Facility
GIS	Geographical Information System
GoB	Government of Bangladesh
GNSS	Global Navigational Satellite System
GPS	Global Position System
GRD	Ground Range Detected
GRoWI	Global Review of Wetland Resources and Priorities for Wetland Inventory
HEP	Hydro Electric Power
HORAS	Hybrid Off-river Augmentation System
HS	Household Survey
IDW	Inverse Distance Weighted
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IPAC	Integrated Protected Area Comanagement
IR	Inception Report
IWRM	Integrated Water Resource Management
KII	Key Informant Interviews
LiDAR	Light Detection and Ranging
ToR	Terms of Reference
PRA	Participatory Rural Appraisal
PRSP	Poverty Reduction Strategy Paper
MACH	Management of Aquatic Resources through Community Husbandry
MEA	Millennium Ecosystem Assessment
MoA	Ministry of Agriculture
MoWR	Ministry of Water Resources

MoFL	Ministry of Fisheries and Livestock
MoEF	Ministry of Environment and Forests
MoL	Ministry of Land
MPAs	Marine Protected Areas
NAP	National Adaptation Plan
NBSAP	National Biodiversity Strategy and Action Plan for Bangladesh
NCS	National Conservation Strategy
NEC	National Environmental Committee
NEMAP	National Environment Management Action Plan
NEMIP	North East Minor Irrigation Project
NGO	Non-governmental organization
NOC	No Objection Certificate
NWCA	National Wetland Co-ordination Authority
NWDI	Normalized Difference Water Body
NWP	National Water Policy
PAPD	Port Authority Police Department
PDF	Portable Document Format
PI	Personal Interview
PIC	Project Implementation Committee
PR	Progress Report
PRA	Participatory Rural Appraisal
PRM	Participatory Resource Mapping
PSC	Project Steering Committee
PSF	Pond Sand Filter
QPR	Quarterly Progress Report
RFM	Rational Function Model
RGB	Red Green Blue
RL	Reduced Level
RMC	Re-excavation Management Committee
RMO	Resource Management Organization
RMS	Root Mean Square
RPC	Rational Polynomial Coefficients RPC
RS	Remote Sensing
RSS	Reconnaissance Soil Survey
RTK	Real-Time Kinematics
SDC	Standards Development Committee
SEMP	Systems Environment Management Plan
SOB	Survey of Bangladesh
SPARRSO	Space Research and Remote Sensing Organization
SRDI	Soil Resources Development Institute
SRTM	Shuttle Radar Topographic Mission

SWD	Social Welfare Development
UNDP	United Nations Development Programme
UNESCO	United Nations Educational Scientific Cultural Organization
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WARPO	Water Resources Planning Organization
WWTP	Waste Water Treatment Plant
MoAg	Ministry of Agriculture
TBC	Total Biomass Carbon
IMED	Implementation Monitoring and Evaluation Division
TEV	Total Economic Value
TC	Technical Committee
ToR	Terms of Reference
UTM	Universal Transverse Mercator
UWCF	Union Wetland Conservation Forum
UWMC	Upazila Wetland Management Committee
VC	Village Committee
VWCG	Village/ Local Wetland Conservation Groups

1 INTRODUCTION

1.1 Background

Bangladesh is the largest delta in the world predominantly comprising a large network of rivers and wetlands. They are very important both from environmental and economic considerations. The importance of protection and safeguard of the wetlands have been mentioned in the Article 18.A of the Constitution of Bangladesh.

"The state shall endeavor to protect and improve the environment and to preserve and safeguard the natural resources, biodiversity, wetlands, forests and wild life for the present and future citizens." (Constitution of Bangladesh, Act 18.A)

Considering the importance of the wetlands and its conservation, Government of Bangladesh enacted several acts including Bangladesh Water Act, 2013, Bangladesh Environmental Protection Act, 1995, Bangladesh Environmental Protection Act (Revised), 2010, Water Reservoir Conservation Act, 2000, National River Protection Commission Act, 2013 etc. Moreover, policies regarding wetlands have been declared such as National Policies on Water, Environment, and Fisheries etc.

Bangladesh is a signatory to several international conventions and protocols such as the Ramsar Convention, MDG, and SDG and is committed to the development and conservation of the wetlands. *The **Bangladesh Water Act, 2013** defines wetland as "Wetland means any land where water remains at the level of surface or close to it and which inundates with shallow water from time to time, and where grows such plants that may usually grow and survive in marsh land." The **RAMSAR Convention (1971)** has defined wetlands as 'areas of marsh, fen, peat land, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters*'

Wetlands in Bangladesh are represented by inland freshwater, estuarine brackish water and tidal salt-water coastal areas. Bangladesh has eight different hydrologic regions which comprise enormous areas of different types. of wetlands including rivers and streams, freshwater lakes and marshes, haors (deep depressions), baors (oxbow lakes), beels (low-lying depressions in the floodplain), water storage reservoirs, fish ponds, flooded cultivated fields and estuarine systems with extensive mangrove swamps. The characteristics of these wetlands are different depending on their functionality, connectivity with rivers, habitats characteristics etc. The past, present, and future of Bangladesh, and its people's livelihoods are intimately connected with water and wetlands. More than 90% of the country's total area consists of alluvial plains, crisscrossed by a complex network of rivers and their tributaries. Floodplains, beels, haors and baors represent the inland freshwater wetlands. Over two-third of Bangladesh could be termed as wetlands, considering rivers, estuaries, mangroves, floodplains, bee Is, baors and haors. The country's wetland ecosystems also offer as very important and critical habitats for globally significant biological diversity. The haor and reverie wetland is a habitat of thousands of waterfowl and migratory birds during the winter season and also the shelter habitat of resident waterfowl. 175 species of waterfowl have been recorded from haor area (IUCN, Bangladesh); every winter the haor is the home to about 200 species of migratory waterfowl including perhaps as many as 100,000 to 150,000 ducks and other species.

The wetland resources are treated as very important assets of Bangladesh considering their enormous social and economic importance and ecosystem services. Agriculture, fishing, forest products and navigation are the major functions of wetlands. The livelihoods of around five million (fifty lac) peoples are dependent on fishing in the wetlands of Bangladesh. Most of the wetlands are used as water transport routes which is contributing a lot in communication system of the· country. During the dry season, large numbers of domestic livestock, mainly cattle and buffalo, are allowed to graze in the marshes, and the aquatic vegetation is harvested to provide fodder during monsoon. In recent years, the wetlands have also been used for rearing domestic ducks in commercial basis as value chain and aquatic plants have also been collected for use as fertilizer and fodder. Some of the wetlands have high potential for eco-tourism, and scope for scientific research and conservation education. Wetlands also play a key role in the carbon cycle management through sinking CO_2 and hence in climate change mitigation, as well in helping people to adapt to climate change. Consequently, a large group of people are intricately linked to the productivity and sustainability of wetlands which provide immediate benefits to local people and the economy of the country.

However, rapid degradation of wetlands resources in Bangladesh demands a new approach to wetland sustainable management. A major portion of the wetland area has been converted from its natural state to support alternative land uses for agriculture, fisheries, village road construction, urbanization, industry, and other development pursuits. Wetlands have also been degraded by unsustainable land use practices; vegetation destruction; nutrient and toxin loading, sedimentation, turbidity, and altered flow regimes. Intensive use of agrochemicals and water transport has also affected the natural balance of wetlands. Therefore, there is a dire need to manage the wetlands in an integrated approach so that the renewability of the natural resources could be maintained while sustaining social and economic benefits from the wetlands and biodiversity.

Department of Bangladesh Haor and Wetland Development (DBHWD) is mandated by the government to overall coordination and monitoring for the integrated development in the haor and wetland area that will holistically address the problems related to water resources, agriculture, socio-economic and environmental concerns. DBHWD has already developed Haor Master Plan with a view to protect, preserve and conserve the haor wetlands from degradation as well as for sustainable management of wetlands. But there still exists number of unidentified haors, beels, jheels as well as wetlands in this country which also contribute greatly to environment, ecosystem and biodiversity. Therefore, the study project has been formulated with a view to establish a national wetland inventory and wetland management framework emphasizing interaction between haor and river ecosystem to identify wetlands all over the country, for identifying wetland suitable for restoration, to reserve and conserve biodiversity of wetland areas, to assess its status and trends considering climate variability, impact as well as for sustainable wetland management. As a result, a study for the whole country as shown in Figure 1-1 is proposed to delineate and classify the wetlands for establishment of inventory and identifications of interaction between haor and river ecosystem.

1.2 Objectives of the Study

The overall objective of the project is to prepare an inventory of the wetlands and assess the best wetland management practices for developing a cluster-wise national wetland management framework. The specific objectives of the project are:

- Study on interaction between haor and river ecosystem
- Prepare a structured framework for planning and designing a wetland inventory following the Ramsar guidelines.
- Identify the different types of wetlands in the different hydrological regions of Bangladesh on detail map.
- Cluster wetlands based on their hydrological functions, vegetation, ecosystem services, physiographic characteristics and demography on detail map.
- Make a comprehensive inventory, baseline with ecological characteristics of wetlands including bio-diversity and historical background information on wetlands.
- Assess of the existing management practices to find out the cluster-wise best practices of wetland management for a specific region/cluster.
- Develop region/cluster-wise wetland management framework for Bangladesh emphasizing interaction between haor and river ecosystem.

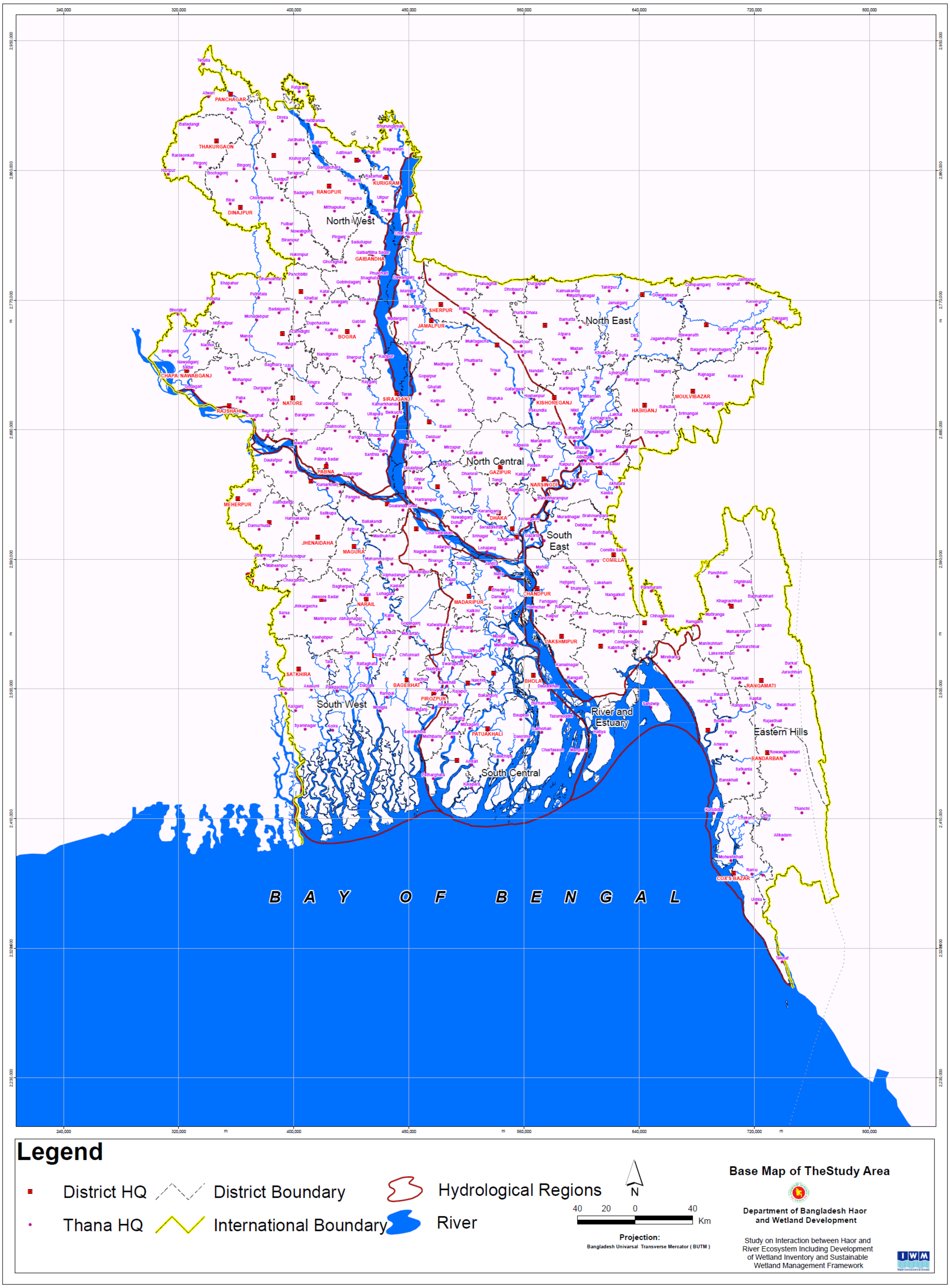


Figure 1-1: Base Map of the Study Area

1.3 Scope of the Works

The following activities are envisaged in achieving the study objectives:

1. A review of the available published literature & documents to determine the extent of knowledge and information available for wetland inventory and wetland management.
2. A comprehensive review of existing policies, strategies and plans related with wetland management.
3. Finalization of the proposed inventory methods to fulfill the specific objectives and following the Ramsar Convention along with other international standards.
4. Procurement of currently available remotely sensed images of recent years to identify the exact locations and boundaries of wetland, calculate their area and also determine their types, status and characteristics.
5. Geo-referencing of the satellite images using GIS software and ground truthing by field survey to validate the different features of wetlands (absolute and relative locations, area etc.) from the satellite images compared with the real world.
6. Classification of the satellite images using Remote Sensing software and characterizing connectivity status with other channels.
7. Delineation of wetlands from classified images to categorize wetlands according to their habitat characteristics that suits the purpose of wetland management framework.
8. Re-delineation of wetlands using historical maps, Digital Elevation Model (DEM) and available existing boundaries of wetlands and overlapping the outcomes with the findings of the satellite images to determine the accuracy and reliability of the data.
9. LiDAR survey of Tanguar haor for an area of approximately 120 sq. km. for empirical data collection.
10. Classification of wetlands of Bangladesh according to their hydrological functions, important ecosystem, ecosystem services, physiographic characteristics and demography through reviewing existing literature, international guidelines (e.g. Ramsar guidelines) and other relevant documents.
11. Prioritize of the most appropriate wetland classification criteria for Bangladesh and clustering them.
12. Identification of connectivity of haor and wetlands with adjacent river system to find out the interaction between haor and river ecosystem.
13. Development of an inventory of wetland along with different categorical contour map through collection of data on their functions, geo-morphological data, physiographic features, flora and fauna species and conducting hydrological assessment of different wetlands through physical surveys.

14. Evaluation of the region wise clustered wetland’s value through field survey.
15. Identification of the most possible causes of wetland degradation and sources of pollution.
16. Assessment of the vulnerability of wetland considering their importance in ecosystem and resource conservation.
17. Delineation of ecosystem boundary of clustered wetlands based on their classification using GIS and RS technology.
18. Intensive consultation with local people and different officials of different government organizations to find out gaps, and incorporating their suggestions for successful completion of the wetland inventory;
19. Finalization of the inventory of wetland in Bangladesh;
20. Selection of cluster-wise best practice of wetland management through assessing the existing management practices, reviewing the international wetland management guidelines and stakeholder consultation.
21. Selection of pilot sites and implementation, monitoring and evaluation of piloting will help to find out gap in selected best management practices.
22. Finalization of wetland management framework based on their cluster-wise best management practices and piloting results.
23. Dissemination of the concept of wetland inventory and cluster-wise wetland management framework through workshops and documentation.

1.4 Output of the Study

The main outputs of the study are as follows:

- Delineated water bodies from satellite images.
- Map showing different types of wetlands having an area greater than 5 hactors according to hydrological region in Bangladesh.
- A comprehensive wetland inventory based on geo-morphological data, physiographic features, flora and fauna species and hydrological features for the selected wetland.
- Connectivity and interactions between wetland and river ecosystems.
- Valuation of region wise clustered wetlands.
- Vulnerability of wetland considering their importance in ecosystem and resources conservation for the selected wetlands.
- Causes of wetland degradation and sources of pollution for the selected wetland.
- Wetland management framework for best practice of wetland management for pilot areas.

1.5 Study Team

The study team has been provided with computing facilities and other necessary logistic support. A List of professionals of the study team is given in Table 1-1.

Table 1-1: List of Professionals

Sl. No.	Name of The Professionals	Position
1.	Md. Salim Bhuiyan	Team Leader/Institution Specialist
2.	Goutam Chandra Mridha	Water Resources Expert
3.	Dr. Faruq Ahmed Mohiuddin, PEng	River Morphologist
4.	Md. Yousuf Mamun	Hydrologist
5.	M. Mustaque Ahmed	Agriculturist/Agronomist
6.	Dr. Md. Gulam Hussain	Fisheries Expert
7.	Dr. Mohammad Mohsinuzzaman Chowdhury	Ecologist/Biodiversity Expert
8.	Mohammad Salah Uddin	Soil/Landuse Expert
9.	Dr. Md. Nazmus Sadath	Forest Expert
10.	Md. Akbar Hossain	Sociologist
11.	Ghulam Jilanee Nazree Murshed	Economist
12.	Md. Zahid Hasan Siddiquee	RS Expert
13.	Dr. Mollah. Md. Awlad Hossain	GIS Expert
14.	Md. Rafiqul Islam	Community Mobilization Expert
15.	Mohammad Saiful Alam Khan	Workshop Facilitator
16.	Fouzia Khanam	GIS Analyst
17.	Md. Golam Mortoja	RS Analyst
18.	Md. Atiqur Rahman	Data analyst
19.	Md. Saidur Rahman	Field Co-Ordinator / Supervisor
20.	S. M. Sahabuddin	Data Entry Operator
21.	Md. Ashraful Islam	Field Level Surveyor

1.6 Structure of the Report

This report is the Draft Final Report of “Study on Interaction between Haor and River Ecosystem including Development of Wetland Inventory and Sustainable Wetland Management Framework”. The report is organized in **Three Volumes** for sake of clarity and ease of comprehending the issues address during the study. The volumes are as follows:

Volume	Report Title
Volume-I	Main Report Annex-A: Terms of References
Volume-II	Appendix-A: Details of the Ground Truthing Survey Methodology and Survey Findings Appendix-B: Details of LiDAR Survey Appendix-C: Plots of Cross-Section at Tanguar haor and Hakaluki haor Appendix-D: Wetland Delineation Appendix-E: Biodiversity Study Appendix-F: Fisheries Resources Study Appendix-G: Vegetation Survey Study Appendix-H: Agricultural Study Appendix-J: Socio-Economic Study
Volume-III	Inventory of Wetlands

This is the **Volume-I** that comprise 9 chapters including a list of references mentioned in the report. A list of acronyms and abbreviations used in the report has been presented following the table of contents.

Chapter 1 focuses on the project background, study objectives, scope of works, expected outputs.

Chapter 2 provides the physical setting of the project that includes the project area description, its topography, physiographical setting, river system and surface water, physiography and soil condition, land use.

Collection and review of reports of the previous studies and findings related to this study are briefly described in **Chapter 3.**

Chapter 4 provides an overview of laws, policies and guidelines.

Chapter 5 describes approaches and methodologies has been carried out different scope of services.

Chapter 6 focuses on the major data collection issues. It deals with the data collection program from both the primary and secondary sources.

Chapter 7 presents the study findings of the project.

Conclusions and recommendations of the study presents in **Chapter 8.**

Chapter 9 cited the References of the reports and manuals consulted for the preparation of report.

Annex of the report include the following:

Annex-A: Terms of Reference (ToR) of the Study.

2 STUDY AREA PROFILE

This chapter conceived with a view to snatch the general overview of the study area. The study mainly aims to classify the wetlands of whole Bangladesh covering an area of about 147,570 km^2 through image analysis along with the preparation of an inventory for pilot wetlands. It extends from 20'34N to 26'38N latitude and from 88'01E to 92'41E longitude. Maximum extension is about 440 km in the E-W direction and 760 km in the NNW-SSE direction. The Indian States of West Bengal, Assam, Meghalaya and Tripura border Bangladesh in the west, north and east respectively. Myanmar forms the southern part of the eastern frontier. The total length of the land border is about 4,246 km, of which 93.9% is shared with India and about 6.1% with Myanmar. The country is bounded in the south by the Bay of Bengal. Although Bangladesh is a small country, the length of the coastline is more than 580 km. The territorial waters of Bangladesh extend 12 nautical miles (22.22 km) and the area of the high seas extending to 200 nautical miles (370.40 km) measured from the base lines constitutes the economic zone of the country.

2.1 Geographical Setting

The physical geography of Bangladesh is varied and has an area characterized by two distinctive features, a broad deltaic plain subject to frequent flooding and a small hilly region crossed by swiftly flowing rivers. Roughly 80% of the landmass is made up of fertile alluvial lowland called the Bangladesh Plain. The plain is part of the larger Plain of Bengal, which is sometimes called the Lower Gangetic Plain. Although altitudes up to 105 meters above sea level occur in the northern part of the plain, most elevations are less than 10 meters above sea level; elevations decrease in the coastal south, where the terrain is generally at sea level. With such low elevations and numerous rivers, water and concomitant flooding is a predominant physical feature. About 10,000 square kilometers of the total area of Bangladesh is covered with water, and larger areas are routinely flooded during the monsoon season. The geographic profile along with allied features of Bangladesh is illustrated in Table 2-1.

Table 2-1: Bangladesh Country Profile

Location	Southern Asia, bordering the Bay of Bengal between Burma and India
Geographic coordinates	24.00 N, 90.00 E
Area	Total 148,460 sq. km.
	Land 130,170 sq. km.
	Water 18,290 sq. km.
Land boundaries	Total 4,413 km
	Border countries (2) Burma 271 km, India 4,142 km
Coastline	580 km
Maritime claims	Territorial sea 12 nm
	Contiguous zone 18 nm
	Exclusive economic zone 200 nm
	Continental shelf to the outer limits of the continental margin
Climate	Tropical; mild winter (October to March); hot, humid summer (March to June); humid, warm rainy monsoon (June to October)
Terrain	Mostly flat alluvial plain; hilly in southeast
Elevation extremes	Mean elevation 85 m
	Elevation extremes lowest point Indian Ocean 0 m
	Highest point Keokradong 1,230 m
Natural resources	Natural gas, arable land, timber, coal
Land use	Agricultural land 70.1%
	Arable land 59%; permanent crops 6.5%; permanent pasture 4.6%
	Forest 11.1%
	Other 18.8% (2011 est.)
Irrigated land	53,000 sq km (2012)
Total renewable water resources	1,227 cu km (2011)
Freshwater withdrawal (domestic/ industrial/ agricultural)	Total 35.87 cu km/yr
	Per capita 238.3 cu m/yr (2008)
Geography - note	Most of the country is situated on deltas of large rivers flowing from the Himalayas the Ganges unites with the Jamuna (main channel of the Brahmaputra) and later joins the Meghna to eventually empty into the Bay of Bengal

(Source: CIA World Fact book)

2.2 Physiography of Bangladesh

Bangladesh is situated in the Bay of Bengal in close proximity to India, Bhutan, Burma and Nepal. The majority of the country consists of large alluvial river plains formed by the Brahmaputra, Ganges and Meghna rivers. Bangladesh covers an area of 143,998 km^2 and can be generally categorized as having a humid tropical climate with the south eastern corner having a tropical rainforest climate. The Brahmaputra River is the largest sand-bedded braided river in the world in terms of catchment area, discharge and sediment load. Its catchment area covers 666 000 km^2, incorporating areas of Tibet, Bhutan, China, India and Bangladesh. The catchment area receives intense rainfall during the summer monsoon which together with snowmelt in the Himalayas contributes to a mean peak annual discharge of 65,500 m^3/s.

Two of the world's largest rivers, the Brahmaputra and the Ganges confluence in Bangladesh, these together with numerous other rivers interlace Bangladesh with over 24000 km of river channels. During the annual monsoon the catchment areas for the Brahmaputra and Ganges, 90% of which lie outside of Bangladesh, receive very intense rainfall. Despite the extensive river system, consisting of approximately 230 significant rivers, the rainfall is not effectively drained through Bangladesh and severe overland flooding usually occurs.

Rashid (1991) refined the previous definitions based on topographic features, drainage patterns, soil associations, morphologies and land use. Rashid (1991) identified 24 physiographic regions in Bangladesh as shown in Figure 2-1.

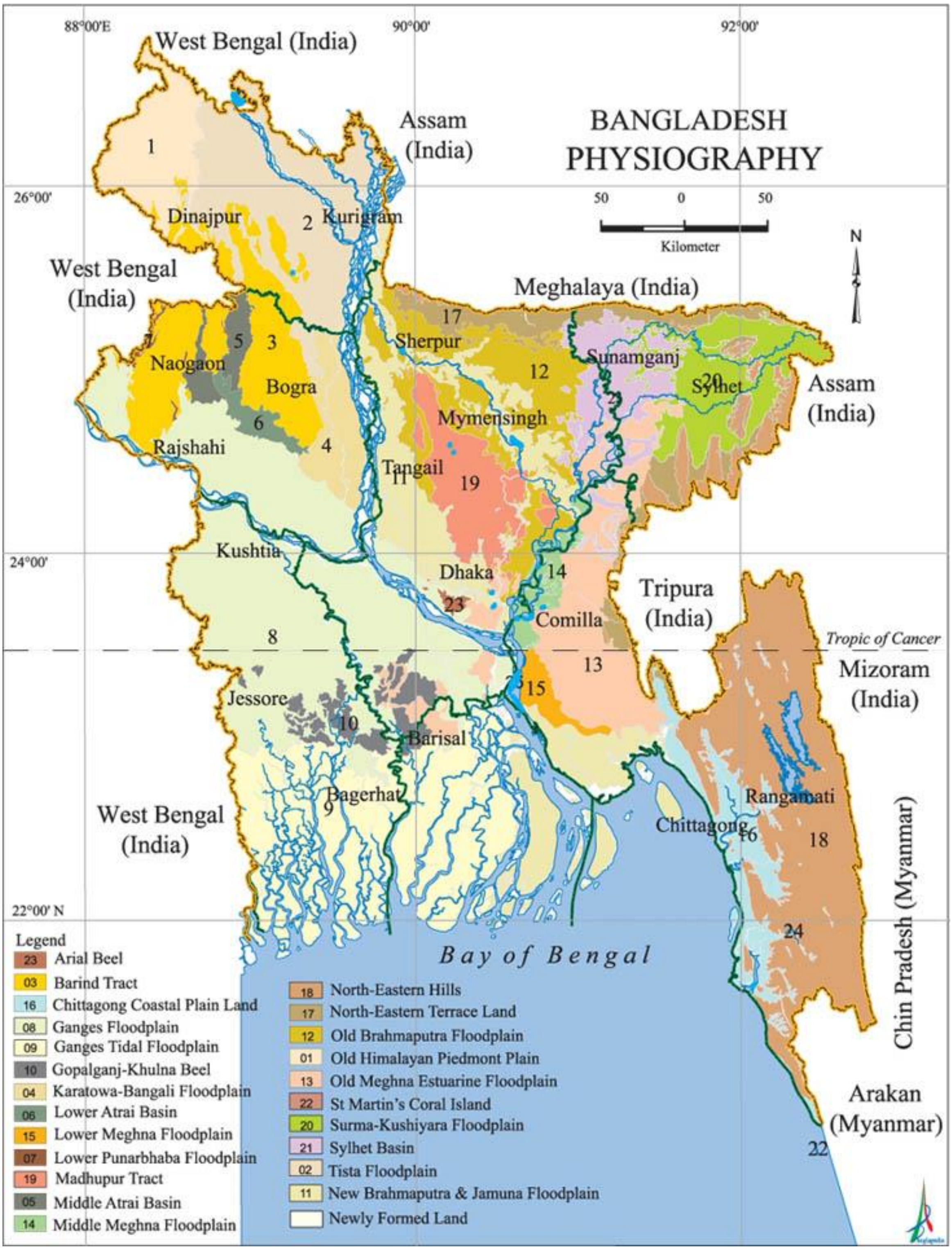


Figure 2-1: Physiographical Zones of Bangladesh (Source: Banglapedia)

(1) Himalayan Piedmont Plains

The Himalayan Piedmont Plains are the alluvial cones of the rivers originating in the Terai region of the Himalayan foothills. The region is bounded by the Mahananda River in the west and the Dinajpur-Karatoa River in the east. The rivers in this region are entrenched in recent alluvial deposits of fine sand and silts with gradients of approximately 0.00091. The alluvial deposits in the south of the Himalayan Peidmont Plains overlay Pleistocene clays of the Barind Tract.

(2) Teesta Floodplain

The Teesta Floodplain covers a large area from the high sandy levees of the Dinajpur-Karatoa River to the right bank of the Brahmaputra River. To the South, the Teesta floodplain reaches down to Bogra along the course of the ancient Teesta River. The floodplain is cut across by the Teesta, Dharla and Dudkumar rivers.

(3) Barind Tract

The Barind Tract forms one of the many terraces within the Bengal Basin of Pleistocence age. Three rivers have cut valleys into the Barind Tract and separate it into four parts. The Barind Tract is characterized by its relatively high elevation, entrenched dedritic stream pattern and scarcity of vegetation.

(4) Little Jamuna Floodplain

The little Jamuna is a former path of the Tista River. Its valley is very narrow in the region of Dinajpur but widens south of Hili. The recent alluvial deposits of sandy-silt contrast with the clay deposits of the Barind Tract. The valley terminates in south Naogaon Upazila.

(5) Middle Atrai Floodplain

The Middle Atrai floodplain is a 81 km long valley with the Barind tract rising on both sides. It stretches from Chirirbandar to Mahadebpur. The lower areas of the Middle Atrai floodplain are subject to flash flooding. The Atrai River is entrenched into the clay deposits of the Barind tract, whilst its floodplain consists of sandy material.

(6) Lower Punarbhaba Valley

The Lower Punarbhaba valley is 81 km in length, beginning south of Dinajpur town in India and finishing where the Punarbhaba and the Mahananda rivers confluence. The valley is on average 3 to 8 km in width with the higher Barind tract on either side giving the valley an entrenched appearance. The valley has very poor drainage and is known locally as duba (swampy).

(7) Lower Atrai Basin

The Lower Atrai Basin has an approximate area of 3120 km^2. The entire basin is inundated during the rainy season with a depth of water of between 0.6 to 3.7 m. The western part of the basin is aggrading with silt from the Barind tract.

(8) Lower Mahananda Floodplain

The Lower Mahananda Floodplain has an area of 402 km^2 and lies between the Barind and the Ganges floodplain. The Mahananda River, which is slightly entrenched, forms the western boundary of Bangladesh along the Piedmont plain in Dinajpur district. It crosses the border of Bangladesh in Gomastapur Upazila before confluencing with the Ganges south of Chapai-Nawabganj town.

(9) Ganges Floodplain

Parts of the Ganges floodplain to the south of the Ganges River are considered by Rashid (1991) to be part of the delta. The north Ganges floodplain is an elevated area that stretches from Premtali in Godagari Upazila to Shujanagar Upazila. The southernmost portion of the north Ganges floodplain forms a levee that in places follows the course of the Ganges River, the land is characterised by saucer-shaped basins, old river levees and point bars. As the levee has built up this area has become progressively more arid.

(10) Brahmaputra-Jamuna Floodplain

The right bank floodplain of the Jamuna River was once a part of the Tista floodplain (region 2). On average the right bank floodplain is flooded for 3-4 months of each year, during the peak of the annual monsoon. The most notable distributary of the Jamuna on the right bank is the Bengali River. The Jamuna-Dhaleswari floodplain forms the left bank of the Jamuna. Several distributaries of the Jamuna flow through this region, of which the Dhaleswari is the most significant. The southern part of this region was once part of the Ganges floodplain.

(11) Old Brahmaputra Floodplain

The Brahmaputra River underwent an avulsion around 1790 and adopted a southern course along the Jamuna River. The old course between Bahadurabad and Bhairab is now known as the Old Brahmaputra and is significantly smaller. The Brahmaputra had built up large levees along the floodplain, which the new river rarely tops. In the north of the Old Brahmaputra floodplain there is a long depression running parallel to the Meghalaya Plateau, to the south the floodplain is level.

(12) Susang Hills and Piedmont

The Susang hills extend for 161 km from Jamalpur district to Sunamganj district, they include the foothills of the Meghalaya Plateau. Entrenched mountain streams cut through this region depositing sand. The rocks in this region are mostly sandstones and shales of Eocene age, with nummulitic limestone and white clay also prominent. The Piedmont plains further south cover the majority of Nalitabari, Haluaghat and Kalmakanda Upazila. The plains have a low gradient and are generally only mildly flooded during the monsoon season, but are prone to flash flooding.

(13) Madhupur Tract

The Madhupur Tract is a large Pleistocene inlier, with an area of approximately 2558 km^2. This elevated region is tilted towards the south east. The northern area of this region is dominated by its plateau like hills between which run narrow meandering valleys. The central tract area is again characterized by plateau like hills, but with slender tops and deep circular valleys. The southern part of the Madhupur Tract is very flat, with noticeable gradients due to entrenched streams. The flatness of the southern area has been reinforced by artificial levelling in rice fields and around Dhaka.

(14) Haor Basin

The Haor basin region is characterized by its large number of lakes. It stretches from the Mahadeo and Mogra rivers to the plain of central Sylhet. The Haor basin covers an area of approximately 4505 km^2. The region appears to be sinking at a rate of approximately 2cm per year (Rashid, 1991), and has sunk 9 - 12 m over the last several hundred years (Morgan and McIntire, 1959).

(15) Sylhet High Plains

The Sylhet high plains are an elevated region that separates parts of the Haor Basin. This region is characterized by entrenched streams, lakes and water filled depressions that drain out in the early winter. The average elevation of the region is 9m above mean sea level.

(16) Sylhet Hills

The foothills of the Megahalaya Plateau fall within Bangladesh in the northern part of the Sylhet district. The Megahalaya foothills are composed of sandstones and limestones, sandy shales and pebble beds of the Pliocene. In addition to the Megahalaya foothills there are four groups small hills in northern Sylhet known as the Tila ranges. These Tilas are composed of Pleistocene clays and sands over coarse ferruginous sandstones and Miocene shales.

(17) Meghna Floodplain

Most of the Meghna Floodplain was built up by the Brahmaputra River when it followed its old course. The Meghna River is still filling in most of the depressions left by the Brahmaputra River.

(18) Tippera Surface

The Tippera Surface is a distinctive physiographic area to the southeast of Dhaka. It is comprised of three sub-regions, the eastern Piedmont strip, the low floodplain and the high floodplain. The eastern Piedmont strip consists of Pleistocene sediments overlain by sandy clays from the Tripura Hills in India. The long low floodplain of the Tippera Surface stretches from Nabinagar to Maijdi in the south and like the high floodplain is almost level. Both the low and high floodplains contain extensive man-made raised areas to protect against flooding.

(19) Moribund Delta

The Moribund delta is characterized by heavily sediment laden entrenched rivers with low discharge capacities, an abundance of cut-off meanders and large areas of plains high above normal flood levels. The main distributary of the Ganges in this area is the Gorai.

(20) Central Delta Basins

The Central Delta Basins are an area of approximately 1930 km^2 at the junction of the Moribund, Immature and Mature deltas. This area is low-lying, probably due to the absence of active distributaries and hence rapid deposition in this region of the delta coupled with steady subsidence (Rashid, 1991).

(21) Immature Delta

The Immature Delta lies to the south of the Moribund Delta and covers an area of land of approximately 4800 km2. The maximum elevation of the Immature delta is 0.91 m above sea level, which compares with an elevation of 3m for the southern edge of the Moribund delta. There are two possible explanations for the presence of such a large area of low elevation; insufficient deposition by the Ganges' distributaries which over the last 200 years have tended to follow course more to the east, or subsidence. Archaeological evidence exists to support the theory of large-scale subsidence in this region, many artifacts have been found buried in the alluvium well below sea level.

(22) Mature Delta

According to Rashid (1991), the Mature Delta is composed of four floodplains, the Old Ganges floodplain, the Padma-Madhumati floodplain, the non-saline tidal floodplain and the saline tidal floodplain. The old Ganges floodplain lies to the north of the current course of the Padma River, and receives flood water from both the Padma and Jamuna rivers. The Padma -Madhumati floodplain has a wide range of land levels from higher land in the north-west, which is generally only slightly flooded, to lower land in the south west which experiences more severe flooding. This part of the delta was built up by the Madhumati floodplain when it was the main channel of the Ganges River. When the Ganges River shifted its course, this process stopped. The non-saline tidal floodplain is very similar in many respects to the Padma -Madhumati floodplain but with the added effects of tidal currents. The non-saline floodplain is shallowly flooded every monsoon season, with the degree of flooding varying with the tidal conditions. In the saline tidal floodplain region of the Mature delta, the tidal effects are much stronger, and deposition is continuing at the mouth of the major rivers.

(23) Active Delta

The Active Delta lies at the mouth of the Meghna River and consists of four large islands; Bhola, Ramgati, Hatiya and Shondip. All of these islands are undergoing relatively fast rates of growth, with new chars continually being attached. The huge amount of sediment carried by the Meghna River shallows the estuary for a considerable distance into the Bay of Bengal.

(24) Chittagong Sub-Region

The Chittagong region of Bangladesh forms a very distinct area that is different in many respects to the rest of the country. It lies south of the Feni River containing many lakes, islands, mountain ranges and forests. It can be further sub-divided into 10 physiographic areas characterizing the coastal plains, islands and deltas, the central valley, the western hills and the mountain ranges to the east.

2.3 Topography of Bangladesh

Topography configuration of a land surface including its relief and contours, the distribution of mountains and valleys, the patterns of rivers, and all other features, natural and artificial, that produce the landscape. Although Bangladesh is a small country, it has considerable topographic diversity. It has three distinctive features (i) a broad alluvial plain subject to frequent flooding, (ii) a slightly elevated relatively older plain, and (iii) a small hill region drained by flashy rivers. On the south, a highly irregular deltaic coastline of about 600km fissured by many estuarine rivers and channels flowing into the Bay of Bengal. The alluvial plain is part of the larger plain of Bengal, which is sometimes called the Lower Gangetic Plain. Elevations of the plains are less than 10m above the sea level; elevation furthers decline to a near sea level in the coastal south.

The hilly areas of the southeastern region of Chittagong, the northeastern hills of Sylhet and highlands in the north and northwest are of low elevations. The Chittagong Hills constitute the only significant hill system in the country. It rises steeply to narrow ridgelines (average 36m wide), with elevation ranges between 600m and 900m above mean sea level. In between the hilly ridges lie the valleys that generally run north to south. West of the Chittagong hills is a narrow and wet coastal plain lying parallel to the shoreline.

Topographic map as presented in Figure 2-2 showing the surface features including relief, vegetation cover, water bodies or topography by means of contour lines, plastic shading, hatching, or other graphic devices. A large-scale topographic map even includes the locations of hats (market-places), petrol-pumps, education institutes, rural narrow roads, etc.

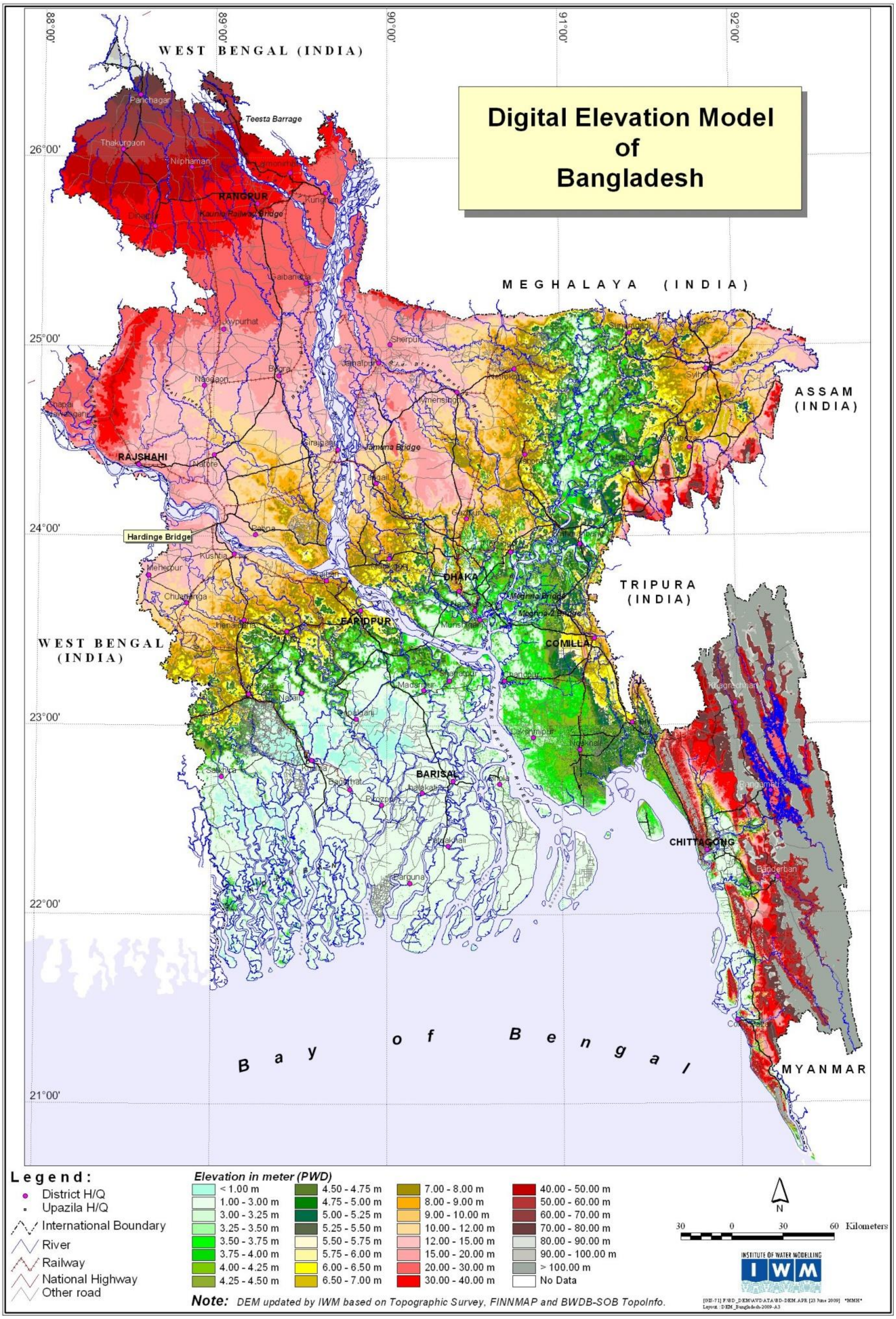


Figure 2-2: Topographic Map of the Study Area

2.4 Agro-Ecological Zones of Bangladesh

Agro-Ecological Zone land areas recognized on the basis of hydrology, physiography, soil types, tidal activity, cropping patterns, and seasons. In fact, an Agro-Ecological zone indicates an area characterized by homogeneous agricultural and ecological characteristics. This homogeneity is more prominent in the sub region and unit levels. The Agro-Ecological zones of Bangladesh have been identified on the basis of four elements such as physiography, soils, land levels in relation to flooding and agroclimatology. Bangladesh has been tentatively divided into 30 Agro-Ecological zones as shown in Figure 2-3. These 30 zones have been subdivided into 88 Agro-Ecological sub-regions, which have been further subdivided into 535 Agro Ecological units. The 30 AEZ of Bangladesh are given below - (according to the number)

1. Old Himalayan Piedmont Plain
2. Active Tista Floodplain
3. Tista Meander Floodplain
4. Karatoya-Bangali Floodplain
5. Lower Atrai Basin
6. Lower Purnabhaba Floodplain
7. Active Brahmaputra – Jamuna Floodplain
8. Young Brahmaputra and Jamuna Floodplain
9. Old Brahmaputra Floodplain
10. Active Ganges Floodplain
11. High Ganges River Floodplain
12. Low High Ganges River Floodplain
13. Low Ganges River Floodplain
14. Gopalganj Khulna Beels
15. Arial Beel
16. Middle Meghna River Floodplain
17. Lower Meghna River Floodplain
18. Young Meghna Estuarine Floodplain
19. Old Meghna Estuarine Floodplain
20. Esttern Surma Kushyara Floodplain
21. Sylhet Basin
22. Northern and Eastern Piedmont Plains
23. Chittagong Coastal Plain
24. Martin’s Coral Island
25. Level Barind Tract
26. High Barind Tract
27. North Eastern Barind Tract
28. Madhupur Tract
29. Northern and Eastern Hills
30. Akhaura Terrace

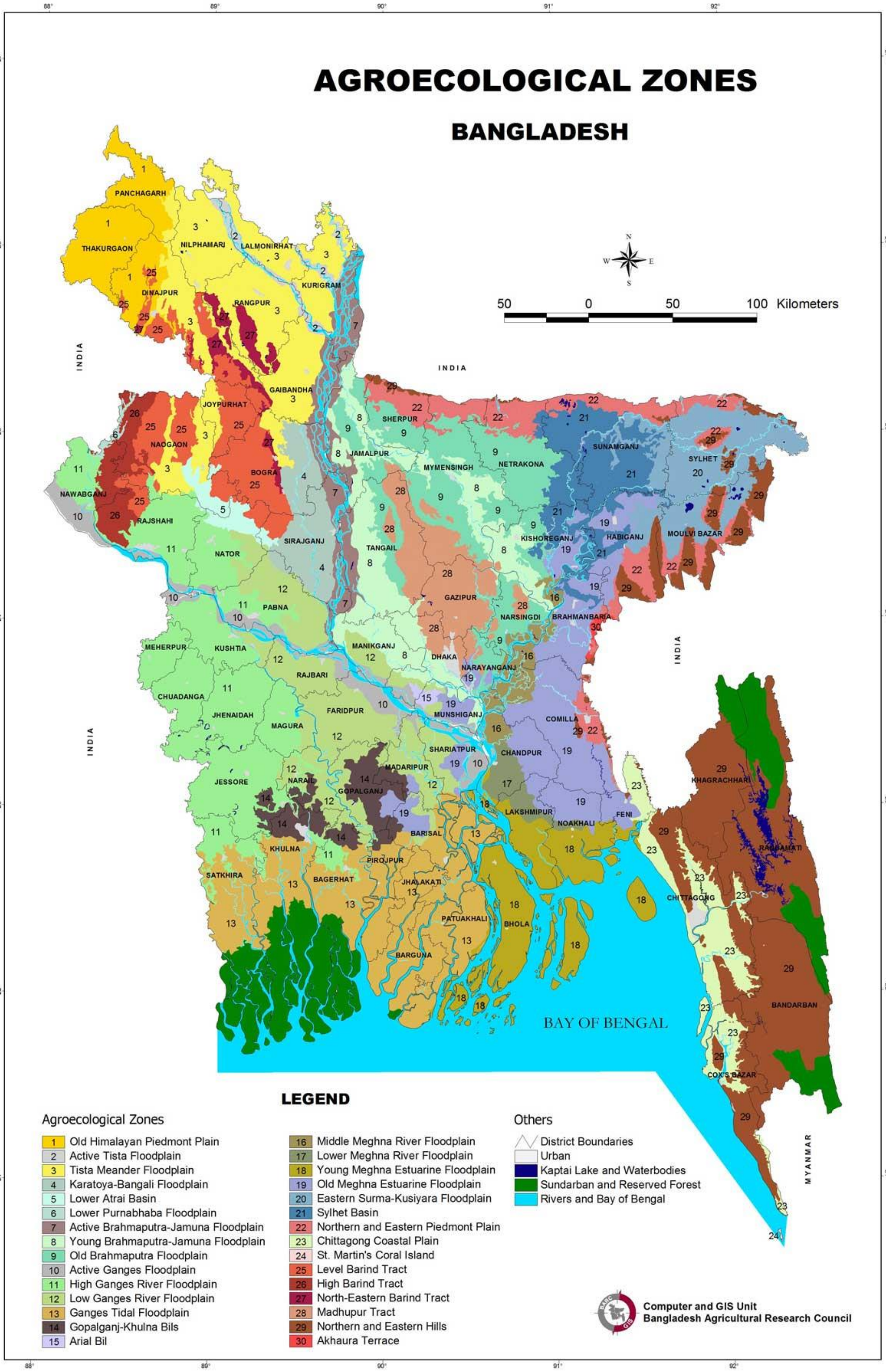


Figure 2-3: Agro-Ecological Zones of Bangladesh

Table 2-2: Characteristics of Different Agro-ecological Zones

Name of the AEZs	Location	Extent (Km^2)	Land Type	Organic matter Content	Fertility Level	Suitable crops
1. Old Himalayan Piedmont Plain	Most of Panchagarh and Thakurgaon districts and north-western parts of Dinajpur districts	4008	High: 58% Medium high: 34% Others: 8%	Low	Low to medium	**Kharif:** B. Aus, T. Aman, Jute, Summer vegetables, Summer pulse, Sesane **Rabi:** Pulses, Potato, Vegetables, Wheat, Mustard
2. Active Tista Floodplain	Narrow belts within and adjoining the chasnnels rivers in Nilphamari, Rangpur, Lalmonirhat, Kurigram and Gaibandha district	830	Medium high: 72% Others: 28%	Low	Medium	**Kharif:** B.aus, B. Aman, T. Aman, Jute, Kaon, GM **Rabi:** Tobacco, Mustard, Boro rice, Wheat, Grasspea, Chilli
3. Tista Meander Floodplain	Most greater Rangpur, eastern part of Panchagarh and dinajpur; northern Bogra and part of Jaipurhat, Naogaon and Rajshahi districts.	9468	High: 35% Medium high: 51% Others: 14%	Medium	Medium	**Kharif:** B.Aus, T. Aus, Jute, T. Aman, GM, Kaon **Rabi:** Wheat, Sugarcane, Potato, Mustard, Blackgram, Tobacco
4. karatoya-Bangali Floodplain	Eastern half of Bogra district and most of Sirajganj district	2572	High: 23% Medium high: 44% Medium low: 14% Others:19%	Medium to high	Medium	**Kharif:** Jute, B.Aus, T. aman, Kaon, GM **Rabi:** Wheat, Vegetables, Pulses, Mustard, Potato, Boro
5. Lower Atrai Basin	Most of this region lies in Naogaon and Natore districts. Small areas extend into Rajshashi, Bogra and sirajganj districts	851	Medium high: 21% Low:65% Others: 14%	Medium	Low to Medium	**Kharif:** B.Aman, B.Aus **Rabi:** Grasspea, Boro

Name of the AEZs	Location	Extent (Km^2)	Land Type	Organic matter Content	Fertility Level	Suitable crops
6. Lower Punarbhaba Floodplain	Extreme western part of Naogaon districta and the extreme northern part of Nawabganj district	129	Low: 60% Others: 40%	Medium to high	Medium	**Kharif:** B.Aman **Rabi:** Boro rice
7. Active Brhamaputra Jamuna Floodplain	Eastern part of Kurigram, Gaibandha, Bogra, Sirajganj and Pabna districts. Minor area also occur in Dhaka, Munshiganj, Narayanganj and Chandpur districts	3190	Medium high: 37% Medium Low: 20% Others: 43%	Low	Low to medium	**Kharif:** Jute, B.Aus, B.Aman, T.Aman, Kaon **Rabi:** Wheat, Mustard, Sweet Potato, Groundnut, Cheena
8. Young Brahmaputra and Jamuna Floodplain	Western parts of Sherpur, Jamalpur and Tangail districts, parts of Manikganj, Dhaka, Munshiganj and Gazipur districts and a belt of adjoin and old Brahmanputra channel through Mymensingh, Kishoreganj and Narsingdi districts	5924	High: 18% Medium high: 42% Medium low: 19% Others: 9%	Low to medium	Low	Kharif: B. Aus, T. Aman, T. Aus, Jute, Green manures, Fox tail millet Rabi: Wheat, Potato, Tobacco, Mustard, Boro
9. old Brahmaputra Floodplain	Large areas in Sherpur, Jamalpur, Tangail, Mymensingh, Netrokona, Kishoreganj, Narsingdi and Narayanganj districts. Small areas in the east of Dhaka and Gazipur districts	7230	High: 28% Medium high: 35% Medium low: 18% Others: 17%	Low to medium	Low	Kharif: B. Aus, T. Aman, T. Aus, Jute, Green manures Rabi: Mustard, Wheat, Pulses, Onion, Potato, Grasspea
10. Active Ganges Floodplain	The region extends along the Ganges and lower Meghna river Channels from the Indian border Nawabgang and Rajshahi District to the mouth of Meghna estuary in Lakhsmipur and Barisal District	3334	High: 12% Medium high: 33% Medium low: 18% Others: 37%	Low	Medium	Kharif: B. Aus, B. Aman, T. Aus, Jute Rabi: Boro, Wheat, Onion, Blackgram, Mustard
11. High Ganges River Floodplain	Nowabganj, Rajshahi, southern Pabna, Kushtia, Meeherpur, Chuadanga, Jhenaida, Magura, Jessor, Shatkhira, and Khulna	13205	High: 43% Medium high: 32% Medium low: 12% Others: 13%	Low	Low	Kharif: B. Aus, T. Aman, T. Aus, Mungbean, Jute, Cotton

Name of the AEZs	**Location**	**Extent (Km^2)**	**Land Type**	**Organic matter Content**	**Fertility Level**	**Suitable crops**
	district together with minor areas in Noagaon and Narail district.					Rabi: Wheat, Mustard, Chickpea, Lentil, Boro rice
12. Lower Ganges River Floodplain	Nature, Pabna, Goalanda, Faridpur, madaripur, Gopalganj and Sariatour, estern parts of Kushtia, Magura, and Narial, north-eastern parts of Khulna and Bagherhat, northern Barisal, and southo-western parts of Manikganj, Dhaka and Munshiganj districts.	7968	High: 13% Medium high: 29% Medium low: 31% Others: 27%	Medium to high	Medium	Kharif: B. Aus, B. Aman, T. Aman, Jute, Kaon, GM Rabi: Pulses, Wheat, Mustard, Linseed, Boro rice
13. Ganges Tidal Floodplain	All or most of Barisal, Jhalokati, Pirojpur, Patuakhali, Bagerthat, Barguna, Khuna and Shatkhira districts. It includes the Khulna and Bagerhat Sundarbans Reserve Forests.	17066	Medium high: 78% Others: 22%	Medium to high	High	Kharif: B. Aus, T. Aman, Green manures Rabi: Boro rice, Wheat, Mungbean, Grasspea, Cowpea, Chilli
14. Gopalganj-Khulna Beels	A number of seperete basin areas in Madaripur, Gopalganj, Narial, Jossore, Bagerhat and Khulna districts.	2247	Medium high: 13% Medium low: 41% Low: 28% Others: 18%	Medium To high	Medium	Kharif: T. Aman, Jute, T. Aus, Sesame, B. Aman Rabi: Boro rice, Bean, Wheat, Grasspea,
15. Arial Beel	Munshiganj and Dhaka district.	144	Medium high: 13% Low: 73% Others: 14%	Medium	Medium to high	Kharif: Aus rice, Jute, Rabi: Pulse, Mustard, Potato, Boro rice.
16. Middle Meghna River Floodplain	Parts of Kishoreganj, Brahmanbaria, Comilla, Chandpur, Narsindi and Narayanganj	1555	Medium high: 8% Medium low: 29% Low: 25% Very low: 11% Others: 27%	Low	Medium	Kharif: B. Aus+B. Aman, Jute Rabi: Boro rice, potato, wheat, mustard
17. Lower Meghna River Floodplain	Chandpur, Lakshimpur and Noakhali	909	High: 14 Medium high: 28 Medium low: 31 Others: 27	Medium	Medium to high	Kharif: T. aman, jute Rabi: Boro rice, Potato, Wheat, Mustard, Groundnut,

Name of the AEZs	Location	Extent (Km^2)	Land Type	Organic matter Content	Fertility Level	Suitable crops
						Lentil, Chickpea, Soybean, Chilli
18. Young Meghna Estuarine Floodplain	Chittagong, Feni, Noakhali, Lakshmipur, Bhola, Barisal, Patuakhali and Barguna.	9269	Medium high: 45% Others: 55%	Low	Medium	Kharif: B. Aus, T . Aus, T. Aman Rabi: Boro rice, Wheat, Mustard, Soybean, Mungbean, Grasspea, Cowpea, Lentil, Groundnut, Chilli
19. Old Meghna Estuarine Floodplain	Kishoreganj, Habiganj, Brahmanbaria, Comilla, Chandpur, Feni, Noakhali, Lakhsmipur, Narshingdi, Narayanganj, Dhaka, Shariatpur, Madaripur, Gopalganj and Barisal.	7740	Medium high: 24% Medium low: 33% Low: 21% Others: 27%	Medium	Medium	Kharif: B. Aus+B. Aman, T. Aman, Jute Rabi: Boro rice, Wheat, Potato, Mustard, Grasspea, Chickpea, Winter vegetable.
20. Eastern Surma-Kushiyara Floodplain	Sylhet, Moulvibazar, Sunamganj and Habiganj.	4622	Medium high: 25% Medium low: 20% Low: 36% Others: 19%	Medium	Medium	Kharif: B. Aus+B . Aman, T. Aus, T . Aman Rabi: Mustard, Country bean.
21. Sylhet Basin	Sunamganj, Habiganj, Netrokona, Kishoreganj, and Brahmanbaria	4573	Medium low: 19% Low: 43% Very low: 23% Others: 15%	High	Medium to High	Kharif: B. Aus, T . Aus, T. Aman Rabi: Boro rice, Mustard, Grasspea.
22. Northers and Eastern Piedmont Plains	Sherpur, Netrokona, sunamganj, Sylhet, Moulavibazar, Habiganj, Brahmanbaria and Comilla	4038	High: 33% Medium high: 31% Medium low: 16% Others: 80%	Medium	Low to medium	**Kharif:** T.Aus, T. aman, Jute **Rabi:** Boro rice, Wheat, Mustard, Potato, Grasspea, Black gram

Name of the AEZs	Location	Extent (Km^2)	Land Type	Organic matter Content	Fertility Level	Suitable crops
23. Chittagong coastal Plain	Feni, chittaging and cox's Bazar	3720	High: 17% Medium high: 43% Medium Low: 13% Others: 27%	Low	Medium	**Kharif:** T.Aus, T.Aman, Taro **Rabi:** Boro rice, Potato, Mustard. Tomato, Cowpea, Brinjal, Radish, Country bean, Yard long bean
24. St. Martin's Coral Island	St. Martin's Island	8	High: 33% Medium high: 63% Others: 4%	Medium to low	Low	**Kharif:** B. Aman, T. Aman **Rabi:** Grasspea, Onion, Garlic, Cucurbits
25. Level Barind Tract	Dinajpur, Gaibandha, Joypurhat, Bogra, Naogaon, Sirajganj and Natore	5049	High: 30% Medium high: 55% Others: 15%	Low	Low	**Kharif:** T.Aman, Sugarcane, Maize **Rabi:** Sugarcane, Potato, Maize, Mustard, Wheat, Tomato, Onion, Cabbage
26. High Barind Tract	Rajshashi. Nawabganj and Naogaon	1600	High: 93% Others: 7%	Low	Low	**Kharif:** T. Aus, T. Aman, Sugarcane, Maize **Rabi:** Boro rice, Wheat, Sugarcane, Cabbage/Cauliflower, Mize, Mustard, Potato, Chickpea, Black gram, Lentil, Ladies finger
27. North Eastern Barind Tract	Dinajpur, Rangpur, Gaibandha, Joypurhat and Bogra	1079	High: 36% Medium high: 56% Others: 8%	Low	Low	**Kharif:** T. Aus, T. Aman, Sugarcane, Jute, Sesame

Name of the AEZs	Location	Extent (Km^2)	Land Type	Organic matter Content	Fertility Level	Suitable crops
						Rabi: Boro rice, Wheat, Sugarcnae, Potato, Maize, Mustard, Black gram, Cabbage, Cauliflower
28. Madhupur Tract	Dhaka, Gazipur, Narsingdi, Narayanganj, Tangail, Mymensing and Kishoreganj	4244	High: 56% Medium high: 18% Others: 26%	Low	Low	**Kharif:** B.Aus, T.Aman, Jute, Sugarcane, Green maures **Rabi:** Boro rice, Sugarcane, Lentil/Mungbean, Mustard.Chickpea
29. Northern and Eastern Hills	Khagrachhari, Chittagong Hill Tracts. Bandarban, Chittagong, Cox's Bazar, Habiganj and Moulavibazar	18172	High: 92% Others: 8%	Low	Low	**Kharif:** B. Aus, T. Aman. Jhum cultivation **Rabi:** boro rice, Potato, Sweet Potato, Cucumber, Sweet ground, Snake gourd, Bitter gourd, Ridge gourd, Brinjal, Country bean, Coriander
30. Akhaura Terrace	Brahmanbaria district and minor areas in Habiganj district	113	High: 11% Medium high: 10% Medium low: 15% Others: 64%	Low	Low	Kharif: t. Aus, T. aman, Jute, Sugarcane+ Turmeric Rabi: Boro rice, Wheat, Mustard, Potato

T. Transplanting; B: Broadcasting

2.5 Flora and Fauna of Bangladesh

2.5.1 Flora of Bangladesh

The floral diversity of Bangladesh is extraordinary. Khan (1991) reported that the country possessed more than 5,000 species of angiosperms and many of which have several sub-species. Of these, only some 160 species are used as crops (Mondal 1990). The major crops are rice, wheat, jute, pulses, oilseed plants, minor cereals, sugar crops, fruits, vegetables root tubers, spices, beverage crops, flowers, medicinal and aromatic plants, forest tree species and other wild plants. The natural forests of Bangladesh consist of three major vegetation types occurring on the three distinctly different land types (Hassan 1994). The natural forests are richest in floristic composition and some 2,260 plant species are reported from the Chittagong region which falls between two major floristic regions of Asia (DoE 2015). The geographical location and the climate of the country support a rich biodiversity but, unfortunately the total flora of the country is not yet fully investigated. A checklist developed by Basak and Alam (2015) enlisted 1,048 tree species (gymnosperm, dicot and monocot) under 432 genera in 99 families that will give information of the tree species in Bangladesh. Recent publication of 'Encyclopedia of Flora and Fauna of Bangladesh' by Asiatic Society provides an enumeration of the plant and animal resources of the country (Ahmed et al. 2008, 2009). It recorded 3,611 taxa of angiosperms from the country. Exploration, identification and description of new species are being published by the Bangladesh National Herbarium (BNH). Another 64 angiosperms were added to the flora during June 2009 to June 2013 of which 8 species were described as new to science (Irfanullah 2013) and BNH has reported 40 angiosperm species very recently (Ara and Khan 2015).

Based on the country's geographic and bio-geographic features, Bangladesh has notable diversity in its ecosystems. Considering the main biophysical characteristics, the ecosystems of Bangladesh are broadly categorized as terrestrial, inland water, and marine and coastal ecosystems. The status and trends of biodiversity of the ecosystems are as follows:

Major Forest Ecosystems: Forests are one of the major biodiversity rich areas in Bangladesh.

Sundarbans Mangrove Forest: The Bangladesh portion of the Sundarbans (approximately 60% of the entire forest) is the largest productive and contiguous mangrove forest in the world (Siddiqi 2001, Hussain 2014). This was declared as 'Reserved Forest' during 1875-76 and The Sundarban Reserved Forest is internationally recognized as an important mangrove ecosystem of high biodiversity value. About 1,400 square kilometres of the forest was declared as a World Heritage Site by the UNESCO in 1997 of which 490 square kilometers is water. A part of Sundarbans has also been recognized as wetlands of international importance (Ramsar Site) under Ramsar Convention in 1992. Prain (1903a) recorded 334 species of plants for the Sundarbans and adjoining areas. Heinig (1892) reported 70 species from the entire Sundarbans. Chaffey and Sandom (1985) recorded 66 plant species from Bangladesh Sundarbans. However, Hussain and Acharya (1994) reported about 123 species of flora from the Bangladesh's portion of Sundarbans. Different assessments since 1903 reported as high as 122 angiosperms from the Sundarban along with 21 fern species, and many species of lower plant groups like mosses, lichens, cyano-bacteria, algae and fungi (Hussain, 2014).

Chittagong Hill Tracts (CHT): The CHT is situated in the south-eastern corner of Bangladesh bordering Myanmar in the south-east, the state of Tripura on the north and Mizoram on the east, and the district of Chittagong on the west. Area of CHT is 13,294 sq. km, which is about one-tenth of the country. Among the total area of the CHT, more than 75% is considered as forest area and the forests of CHT are ecologically classified as Tropical wet-evergreen, Tropical semi-evergreen, Tropical moist-deciduous, Tropical open deciduous and Savannah forests (Das 1990). The important reserve forests of CHT are Kassalong reserve forests (159,449.7 ha), Raingkheong reserve forests (76,331.0 ha), Sitapahar reserve forests (5,876.5 ha), 235.79 ha of Barkal reserve forests and Sangu and Matamuhury reserve comprises about 74,500 ha (Chowdhury 2006). There are three protected areas, e.g. Pablakhali Wildlife Sanctuary, Kaptai National Park, and Sangu Valley Wildlife Sanctuary. The CHT in Bangladesh supports almost 80% of the country's total biodiversity (Nishat & Biswas 2005, in Jashimuddin and Inoue 2012). The evergreen and mixed evergreen forests of CHT are the habitat of 1560 species of flowering plants (Heinig 1925). Rampahar along with Sitapahar were declared as the first reserve forest in the Chittagong Hill Tracts region in 1875 (Anonymous, 1960). Presence of 85 different tree species having dbh ≥10 cm was reported from the Sitapahar reserve forest is comparable to other rich tropical forests (Nath et al. 2000). Since much of the biodiversity in tropical forests resides in herbs, shrubs and small trees, Uddin et al. (1998) recorded 332 species (248 dicots and 84 monocots) from this area. Harun-Ur-Rashid and Chowdhury (2013) later on added 43 taxa (38 dicots and 5 monocots) from this forest. A survey from 2001 to 2008 revealed 89 monocots (Uddin and Hassan, 2012a) and 500 dicot species from Rampahar area (648 ha) under Kaptai Forest Range. Uddin and Hassan (2012a) also reported 41 pteridophyte species belonging to 26 genera from Rampahar and Sitapahar area, which constitutes 21% of total fern flora of the country. Similarly, the status and distribution pattern of natural regeneration of Sitapahar reserve forest reported 62 identified tree species and another 20 unidentified tree species with an average density of 15,618 seedlings/saplings per ha indicating the rich soil seed bank of the native tree species (Hossain et al. 1999).

Sal Forests: The moist deciduous Sal (also known as Gazari) forests are located in the greater Dhaka, Tangail and Mymensingh districts in the central region and in the greater Dinajpur, Rangpur, and Rajshahi districts in the northern region. The Sal forests originally comprise an area of 120,255 ha of which 104,616 ha (87%) are located in the central region and 15,639 ha (13%) in the northern region. Most of the sal forests are now severely degraded and poorly stocked and the area is now becoming to only 34,000 ha (Altrell et al.

2007). Madhupur National Park is one of the last remaining patches of old-growth Sal forest left in the country. Sal (Shorea robusta) is the dominant species with associates of Mallotus phillippenis, Schleichera oleosa, Protium serratum, Dillenia pentagyna etc. Alam (1995) recorded 260 woody plant species from sal forests of Bangladesh, whereas, Malaker et al. (2010) reported 174 plant species from Madhupur sal forests. Hossain et al. (2015) recorded 385 plant species from Madhupur National Park. At present, most of the forest areas in Madhupur has been denuded, degraded or encroached upon or taken over for the commercial production of pineapples, bananas, the industrial plantation of rubber and exotic fuel-wood species (Hossain et al. 2013, 2015).

Ratargul Swamp Forest: Ratargul is a small freshwater swamp in the haor basin of north-east region of Bangladesh. The ecosystem is some typical freshwater wetland forest rich with 73 species of flora and 230 species of fauna from Ratargul (Choudhury et al. 2004). Species diversity is very rich in this swamp. Mention worthy flora of the swamp are *Barringtonia, Pongamia, Crataeva, Salix, Clinogyne, Phragmites, Rosa, Saccharam, Phyllantus, Calamus, Ficus, Asclepias, Oryza, Cyperus, Nymphaea, Trapa, Vallesnaria, Echinochloa* and *Polygonum* species. This forest also harbors a number of medicinal plants such as *Asparagus racemosus, Centella asiatica, Craeteva magna, Hemidesmus indicus, Ipomoea fistulosa and Mimosa pudica. Calamus guruba (Rattan)* plantations have been raised at suitable locations of this forest.

Agro Ecosystems: Bangladesh has been divided into thirty agro-ecological zones and 88 subzones on the basis of physiographic, soil properties, soil salinity, depth, duration of flooding etc. The general agro-ecological variations of Bangladesh range from below sea level-basins to small hills. Farming practices in Bangladesh are complex and diverse and are largely controlled by physical, biological, climatologically and socioeconomic factors. In Bangladesh more than 300 different crops are presently cultivated of which many of them are endemic. However, the diversity of landraces for almost all the crops is decreasing with the increased priority of high yielding varieties.

Homestead Ecosystems: Homestead ecosystems, which in together is the largest manmade ecosystem in Bangladesh, act as the last refuge of wild flora and fauna of open woodland ecosystem. Most of the homestead ecosystems in the floodplains consist of a small pond, backyard jungles, bushes and kitchen gardens. Homesteads in the hilly terrain are usually tiny hillocks with its valley and hilly streams. Homesteads in the coastal zones have backyard mangroves with inter-tidal canals and ditches. Despite the conversion of natural bushes in the homestead ecosystems, a wide range of wild flora and fauna are still occurring in the homesteads with remarkable abundance (Islam et al. 2015, Nath et al. 2015).

Homesteads of Bangladesh have a long heritage of growing timber and fruit trees, along with other perennial shrubs and herbs. Species composition and number of species in the homesteads of Bangladesh are variable and sporadic. Abedin and Quddus (1990) reported that the number of plant species (excluding vegetable species) in the coastal areas was higher (70 species) than those found in the homesteads of Tangail (52 species), Ishurdi (34 species), Jessore (28 species), Patuakhali (20 species), Rajshahi (28 species) and Rangpur (21 species) districts. Homestead gardens are significant sources of fruits, timber, fuelwood, lumber, veneer logs and bamboo of Bangladesh. In this way, the homesteads of the country are vital sources of livelihood for many farmers and serve as the safety net during the time of hardship and natural disasters.

Inland Water Ecosystems: Bangladesh is a land of water and wetlands. Wetlands constitute more than 50% territory of the country and play significant role in social and economic livelihood of the population. The wetlands in Bangladesh encompass a wide variety of ecosystems including the main rivers (the Ganges, the Brahmaputra and the Meghna) and their 700-plus tributaries and distributaries; about 6,300 beels (permanent and seasonal shallow lakes in floodplain depressions); at least 47 major haors (deeply flooded depressions in the north-east), baors (oxbow lakes); vast areas of seasonally flooded land; and fish ponds and tanks (Nishat 1993, Khan 2001).

Floodplain in Bangladesh occupies a greater part of the landscape and offers important habitats of wide variety of wild flora and fauna. A total of 200-300 plant species in Bangladesh are considered to be wetland species for all or part of their life spans (Nishat 1993). The country has a praiseworthy achievement in conservation and sustainable uses of floodplain biodiversity and most of these have been through the activities of various projects of Government and the development partners. The 'community-based wetlands conservation model' was replicated creatively and it succeeded in cases of conservation and wise-use of wetlands biodiversity. The threatened species of flora and fauna were conserved successfully and the common species having economic value were used sustainably with a significant improvement of livelihoods of the local communities (DoE 2015).

2.5.2 Fauna of Bangladesh

Although it is not frequently recognized, Bangladesh supports a wealth of faunal diversity, including some 113 species of mammals, 628 birds, 126 reptiles, 22 amphibians, 708 species of freshwater and marine fish, about 400 species of mollusks, 70 bees and as many species of wasps. Unfortunately, altogether there are 10 species of mammals, two birds and one species of reptile are nationally extinct. In addition, according to the list given below 58 fish, 8 amphibians, 63 reptiles, 47 bird, and 43 mammal species are either critically endangered, or vulnerable in Bangladesh. Many of these species are globally threatened, such as the Asian elephant (*Elephas maximus*), Bengal tiger (*panther tigris*), Gangetic gharial (*Gavialis gangeticus*), Ganges river dolphin (*platanista gangetica*) and Hoolock gibbon (*Hylobates hoolock*). Moreover, five species of threatened marine turtles nest along Bangladesh coastline and two globally important migratory bird flyways (i.e. the East Asia-Australasian flyway and the central Asia-Indian flyway) converge here. Each year, some one million waterfowl winter in Bangladesh, including such globally endangered species as the Spoon-billed sandpiper (calidris pygmeus). A status of faunal diversity in Bangladesh is given in Table 2-3.

Table 2-3: Faunal Diversity in Bangladesh

Group	Total no. of Living species	Extinct (EX)	Threatened				Data Deficient (DD)	Not Threatened (NO)
			Critically Endangered (CR)	Endangered (EN)	Vulnerable (VU)	Total		
Fishes	7080	00	120	290	170	580	660	584
Amphibians	220	00	00	30	50	80	70	7
Reptiles	1260	10	130	280	270	630	390	24
Birds	6280	20	190	200	80	470	1620	413
Mammals	1130	100	210	150	70	430	530	17
Total	15970	130	650	940	590	2190	3270	1045

Source: IUCN Bangladesh, 2000

2.6 Hydrological Setting of Bangladesh

National Water Management Plan, 2004 has delineated the eight Hydrological Regions in Bangladesh, based on appropriate natural features, for planning the development of their water resources. The Hydrological Regions are Southwest (SW), Northeast (NE), North Central (NC), Northwest (NW), South Central (SC), Southeast (SE), Eastern Hills (EH), River and Estuary Region (RE) as shown in Figure 2-4.

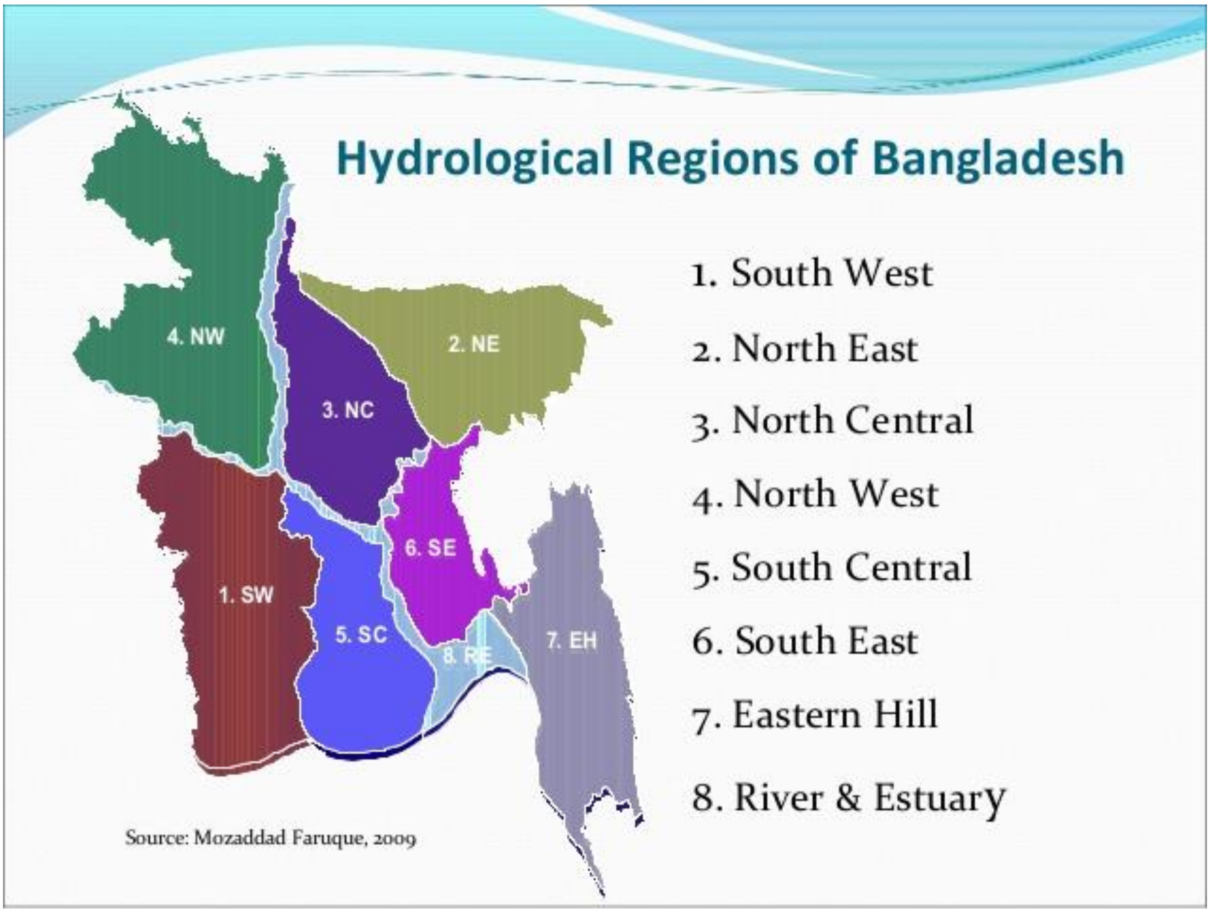


Figure 2-4: Hydrological Regions of Bangladesh (Source NWMP, 2004)

The major and specific characteristics of each Hydrological region have been given below:

i. South-West Hydrological Region

Major water related problems in this zone are

- Tidal Flood, Flash Flood, and Riverine Flood
- Drought in Dry season
- Water Pollution
- Water Logging
- Land Subsidence
- Salinity Intrusion in Ground water
- Arsenic Contamination in Ground water
- Sedimentation and drainage congestion
- River bank erosion
- Natural disaster such as cyclone, tidal surge etc.

- Climate Change and sea level rise etc.

ii. North-east Hydrological Region

Major water related specific issues in this zone are

- Environmental Management of the Haor Basin
- Flash Flooding and Remedial actions for existing FCD schemes
- Flood proofing of villages in the Haor Basin
- Erosion of Old Brahmaputra left Bank
- Drainage Congestion of Kalny-Kushiyara and other rivers
- Local development of hill irrigation

iii. North Central Region

Major Specific issues in this region are

- Bulk Water Supply and Pollution clean-up for Dhaka city
- Encroachment on Buriganga and other rivers and Channels in Dhaka
- Flooding and Drainage Problems in parts of the region
- Flood proofing needs in the Charlands and low lying areas
- Improvement of Flood Control, Drainage and Sewerage system of Dhaka City

iv. North West Hydrological region

Major specific Water resources issues in this zone are

- Erosion along the right Bank of Brahmaputra
- Flooding and Drainage Problems
- Remedial measures for existing FCD(I) schemes
- Drought in the western fringes, especially the High Barind
- Flood proofing needs in the Charlands and Low lying areas
- Improvement of Flood Control, Storm Drainage, Water Supply and Sanitation system of Rajsahi City

v. South Central Hydrological region

South Central Hydrological region suffers few similar problems to the South West Region. Major specific Water resources issues in this zone are

- Maintenance of the existing coastal embankment system
- Flood proofing needs in the Charlands and Low lying areas

- Siltation and Drainage congestion
- Improved Cyclone protection

vi. South East Hydrological region

This region is particularly affected by Arsenic contamination. Specific water resources issues in this zone are

- Gaseous aquifer
- Improved cyclone protection
- Maintenance of the existing coastal embankment system and drainage congestion
- Protection of newly accreted lands against tidal flooding
- Remedial action for existing inland FCD schemes
- Coastal afforestation

vii. Eastern Hill Region

The major water related issues in this region are

- Small-scale irrigation development in the CHT
- Mini-hydropower development in the CHT
- Improved cyclone protection in the CCP
- Maintenance of the existing coastal embankment system
- Optimum use of Kaptai reservoir
- Improvement of Flood Control, Storm Drainage, Water Supply and Sanitation system of Chittagong City

viii. Coastal protection and afforestation River and Estuary Region

The major water related issues are

- An affordable long-term strategy for erosion protection
- An affordable long-term strategy for regional Augmentation
- Flood proofing needs in the charlands and low-lying areas
- Improved cyclone protection in the Meghna Estuary
- Erosion of Meghna River
- Land accretion and Land reclamation
- Timely protected newly accreted Lands

2.7 Rivers of Bangladesh

The rivers of Bangladesh are very extensive and distinguish both the physiography of the country and the life of the people. Bangladesh is called a land of rivers as it has about 700 rivers including tributaries. The rivers are not, however, evenly distributed. For instance, they increase in numbers and size from the northwest of the northern region to the southeast of the southern region. The total length of all rivers, streams, creeks and channels is about 24,140 km. In terms of catchment's size, river length and volume of discharge, some of these rivers are amongst the largest on the earth. Usually the rivers flow south and serve as the main source of water for irrigation and as the principal arteries of commercial transportation. The rivers also provide sweet water fish, an important source of protein. A large segment of population is thus engaged in the fishing sector. On the other hand, widespread riverbank erosion and regular flooding of the major rivers cause enormous hardship and destruction of resources hindering development. But it is also true to say that the river system brings a huge volume of new silt to replenish the natural fertility of the agricultural land. Moreover, the enormous volume of sediments that the rivers carry to the Bay of Bengal each year (approximately 2.4 billion tons) builds new land along the sea front, keeping hope alive for future extension of settlement. Finally, during the monsoon, rivers also drain excess discharge to the Bay. Thus, this great river system is the country's principal resource as well as its greatest hazard. The system can be divided into four major networks (1) Brahmaputra-Jamuna river system, (2) Ganges-Padma river system, (3) Surma-Meghna river system, and (4) Chittagong region river system as shown in Figure 2-5.

The first three river systems together cover a drainage basin of about 1.72 million sq km, although only 7% of this vast basin lies within Bangladesh. The combined annual discharge passing through the system into the Bay of Bengal reaches up to 1,174 billion cu m. Most of the rivers are characterized by fine sandy bottoms, flat slopes, substantial meandering, banks susceptible to erosion, and channel shifting.

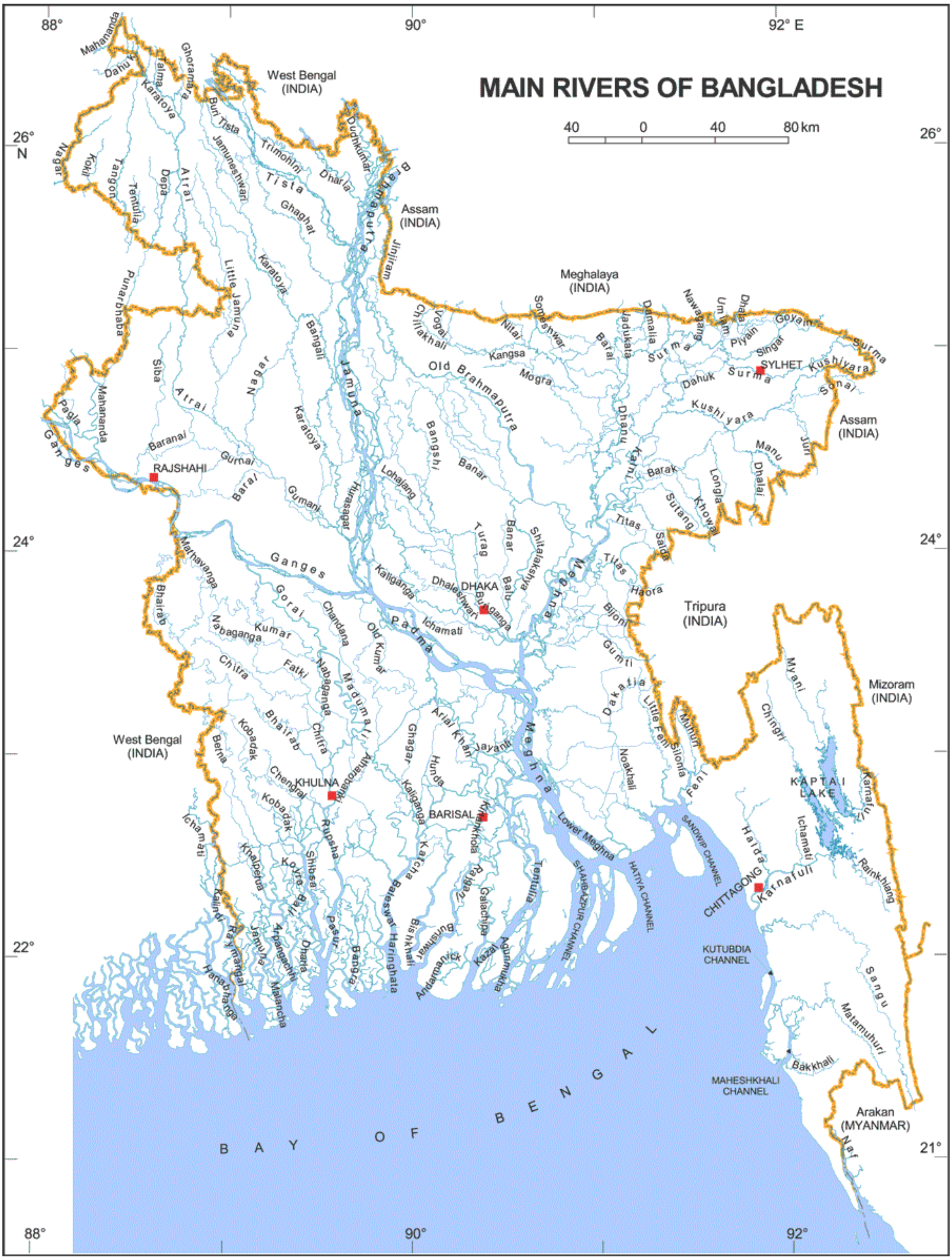


Figure 2-5: Major River System in Bangladesh

Brahmaputra-Jamuna System: The Brahmaputra-Jamuna river is about 280 km long and extends from northern Bangladesh to its confluence with the Ganges. Before entering Bangladesh, the Brahmaputra has a length of 2,850 km and a catchment area of about 583,000 sq km. The river originates in Tibet as the Yarlung Zangbo Jiang and passes through Arunachal Pradesh of India as Brahmaputra (son of Brahma). Along this route, the river receives water from five major tributaries, of which Dihang and Luhit are prominent. At the point where Brahmaputra meets the T eesta in Bangladesh, it is called the Jamuna. The Brahmaputra-Jamuna throughout its broad valley section in Assam and in Bangladesh is famous for its braided nature, shifting sub channels, and for the formation of chars (island/sandbars) within the channel.

The recorded highest peak flow of Brahmaputra-Jamuna is 98,000 cusecs in 1988; the maximum velocity ranges from 3-4 m/sec with a depth of 21-22m. The average discharge of the river is about 20,000 cusecs with average annual silt load of 1,370-tons/sq km. The average slope of the Jamuna is about 111,400; however, the local gradient differs quite considerably from the average picture.

Within Bangladesh, the Brahmaputra-Jamuna receives four major right-bank tributaries - the Dudhkumar, Dharla, Teesta and Hurasagar. The first three are flashy, rising in steep catchment on the southern side of the Himalayan system between Darjeeling and Bhutan. The Teesta is one of the most important rivers of the northern region. Before 1787 it was the principal water source for the Karatoya, Atrai and Jamuneshwari. A devastating flood of 1787 brought in a vast amount of sand wave through the Teesta and choked the mouth of the Atrai; as a result the Teesta burst into the course of the Ghaghat river. The Teesta has kept this course ever since. The present channel within Bangladesh is about 280 km long and varies between 280 to 550 m in width. It joins the Brahmaputra just south of Chilmari upazila. The Dharla and Dudhkumar flow parallel to Teesta. The Dharla is a fast-flowing river in the monsoon but with the fall of water level it becomes braided. The Dudhkumar is a small river and flows southeast to join the Brahmaputra. The combined discharge of the Atrai and Karatoya passes through the Hurasagar to the Jamuna.

The old Brahmaputra and the Dhaleshwari are the important left bank distributaries of the Jamuna. Prior to the 1787 Assam flood, the Brahmaputra was the main channel; since then the river has shifted its course southward along the Jhenai and Konai rivers to form the broad, braided Jamuna channel. The old course, named the Old Brahmaputra is now essentially a high-flow spill channel, active only during the monsoon. Taking off at Bahadurabad, the Old Brahmaputra flows southeast, passes by Jamalpur and Mymensingh towns and joins the Meghna at Bhairab Bazar. Its average gradient is 4.76 cm/km. Along its southeasterly journey, Dhaleshwari bifurcates at least twice. Two of its important branches are the Kaliganga and Buriganga. The Dhaleshwari eventually meets the Shitalakshya at Narayanganj.

The Ganges-Padma System: The Ganges – Padma system is part of the greater Ganges system. The Ganges has a total length of about 2,600 km and a catchment area of approximately 907,000 sq km. Within Bangladesh, Ganges is divided into two sections - first, the Ganges, 258 km long, starting from the western border with India to its confluence with Jamuna at Goalandaghat, some 72 km west of Dhaka. The second is the Padma, 126 km long, running from Goalandaghat confluence to Chandpur where it joins the Meghna. The Padma-Ganges is the central part of the deltaic river system with hundreds of rivers. The total drainage area of Ganges is about 990,400 sq km of which only 38,880 sq km lie in Bangladesh.

The recorded highest flow of Ganges was 76,000 cumec in 1981, and the maximum velocity ranging from 4-5 m/sec with depth varying from 20m to 21m. The average discharge of the river is about 35,000 cumec with an approximate annual silt load of 492 tons/sq km. The average gradient for the reach between Allahabad to Benaras is 110,500, from Farakka (India) to Rampur-Boalia in Rajshahi (Bangladesh) is 1 18,700, from Rampur-Boalia through Hardinge Bridge to Goalandaghat is 1 28,000. The slope flattens to 137,700 for a distance of 125 km from Goalandaghat to Chandpur. Within Bangladesh, the Mahananda tributary meets the Ganges at Godagari in Rajshahi and the distributary Baral takes off at Charghat on the left-bank. The important distributaries taking off on the right-bank are the Mathabhanga, Gorai-madhumati, Kumar, and Arial khan.

The Surma-Meghna System: The Meghna is the longest (669 km) river in Bangladesh. It drains one of the heaviest rainfall areas (eg, about 1,000 cm at Cherapunji in Meghalaya) of the world. The river originates in the hills of Shillong and Meghalaya of India. The main source is the Barak river, which has a considerable catchment area in the ridge and valley terrain of the Naga-Manipur hills bordering Myanmar. The Barak-Meghna has a length of 950 km of which 340 km lie within Bangladesh. On reaching the border with Bangladesh at Amalshid in Sylhet district, the Barak bifurcates to form the steep and highly flashy rivers Surma and Kushiyara. The Surma, flowing on the north of the Sylhet basin, receives tributaries from the Khasia and Jaintia hills of Shillong. Some of the important tributaries of these two rivers are Luba, Kulia, Shari-goyain, Chalti-nadi, Chengar-khal, Piyain, Bogapani, Jadhukata, Someshwari and Kangsa. The Surma meets the Meghna at Kuliarchar upazila of Kishoreganj district. The Kushiyara receives left bank tributaries from the tripura hills, the principal one being the Manu. Unlike the Surma, the tributaries of the Kushiyara are less violent, although prone to producing flash floods, due in part to the lesser elevations and rainfall of Tripura hills.

Between the Surma and Kushiyara, there lies a complex basin area comprised of depressions or haors, meandering flood channels, and abandoned river courses. This area remains deeply flooded in the wet season. The two rivers rejoin at Markuli and flow via Bhairab as the Meghna to join Padma at Chandpur. The major tributaries of any size outside the Sylhet basin are the Gumti and Khowai rivers, which rise in Tripura. Other hilly streams from Meghalaya and Assam join the Meghna. The total drainage area of the Meghna up to Bhairab Bazar is about 802,000 sq km, of which 36,200 sq km lie in Bangladesh. The peak flow of the Meghna is 19,800 cu m/sec, and the maximum velocity range from 1-2 m/sec with depth varying from 33m to 44m. The average discharge of the river is about 6,500 cu m/sec. It has a steep slope while flowing in the Indian hilly part. At flood stages, the slope of the Meghna downstream at Bhairab Bazar is only 1 88,000. In terms of drainage pattern, the Meghna exhibits a meandering channel, and at some places it reflects an anastomosing pattern.

The Chittagong Region System: The rivers of Chittagong and Chittagong Hill Tracts are not connected to the other river systems of the country. The main river of this region is Karnafuli. It flows through the region of Chittagong and the Chittagong Hills. It cuts across the hills and runs rapidly downhill to the west and southwest and finally to the Bay of Bengal. Chittagong port is located on the bank of Karnafuli. The river has been dammed upstream at Kaptai to create a water reservoir for hydroelectric power generation. Other important rivers of the region are the Feni, Muhuri, Sangu, Matamuhuri, Bakkhali, and Naaf.

The four mighty river systems flowing through Bangladesh drain an area of some 1.5 million sq km. During the wet season the rivers of Bangladesh flow to their maximum level, at about 140,000 cusecs, and during the dry period, the flow diminishes to 7,000 cusecs. All the estuaries on the Bay of Bengal are known for their many estuarine islands.

2.8 Climate of Bangladesh

The climate of Bangladesh is characterized by high temperature, high humidity, heavy rainfall and marked seasonal variations. It generally enjoys a sub-tropical climatic condition, greatly influenced by the presence of the Himalayan mountain range and the Tibet plateau in the north and the Bay of Bengal in the south. The maximum temperature recorded in summer months (March-June) is approximately 37^0C, although in some places, it occasionally rises up to 40^0C or more. Monsoon (July - October) accounts for 80% of the total annual rainfall in the country. The average annual rainfall varies from 1429 to 4338 mm. The maximum rainfall is recorded in the coastal areas of Chittagong and the northern part of Sylhet districts, while the minimum is observed in the western and northern parts of the country. In winter (November - February), there is minimum fluctuation in temperature, which ranges from minimum of approximately 7-12^0C to maximum of 23-31^0C (BBS, 2001).

Bangladesh is a small country in terms of land area, but the climatic variation is quite well marked. According to Rashid (1977), Bangladesh may be broadly divided into seven climatic zones: (i) Northern part of northern zone, (ii) Northwestern zone, (iii) Western dry zone (iv) Southwestern zone, (v) South-central zone, (vi) Northern zone and (vii) Southeastern zone.

2.9 Soils of Bangladesh

The major part of Bangladesh is on the delta formed by the three major rivers Brahmaputra, Ganges and Meghna. These rivers and many of the country's other minor rivers originate outside the national boundary of the country and make up the Ganges-Brahmaputra-Meghna river system.

The soil resources development institute (SRDI) has identified about 500 soil series in Bangladesh. Soil series is a group of soils formed from the same kind of parent material under similar conditions of drainage, vegetation, climate and time, and having the same sequence of soil horizons with similar differentiating properties. Each soil series is known after a name of locality (eg Tejgaon series, Sara series, Ishwardi series, etc). This is the starting point of soil classification in Bangladesh for creating a platform for its correlation with international soil classification systems (FAO or USDA - United States Department of Agriculture). All of these soil series have been mapped as soil association by the SRDI through reconnaissance soil survey carried out during 1965 and 1975. These soil series have been correlated with the FAO-UNESCO soil units of Fluvisols, Gleysols, Histosols, Planosols, Luvisols, Cambisols and Arenosols. According to the USDA soil taxonomy, these soil series are Entisols, Inceptisols, Histosols, Mollisols, Ultisols and Alfisols.

Floodplain soils are divided into different sub-types, such as - calcareous alluvium, non-calcareous alluvium, calcareous brown floodplain soils, calcareous grey floodplain soils, calcareous dark grey floodplain soils, non-calcareous grey floodplain soils, non-calcareous brown floodplain soils, non-calcareous dark grey floodplain soils, black terai soils, acid basin clays, acid sulphate soils, peat, grey piedmont soils, made-land. The general soil type and its details are given in Table 2-4 whereas the soil region and soil series are given in Figure 2-6 and Figure 2-7 respectively.

Table 2-4: General Soil Types of Bangladesh

General Soil Type	Area (ha)	(%)
Floodplain soils	9,718,722	78.96
Calcareous Alluvium	591,796	4.81
Non-calcareous Alluvium	562,242	4.57
Calcareous Brown Floodplain soils	478,518	3.89
Calcareous Grey Floodplain soils	170,767	1.39
Calcareous Dark Grey Floodplain soils	1,434,678	11.66
Non Calcareous Grey Floodplain soils	3,387,153	27.52
Non Calcareous Brown Floodplain soils	383,312	3.11
Non Calcareous Dark Grey Floodplain soils	1,599,645	13
Black Terai soils	83,408	0.68
Acid Basin clays	348,994	2.84
Acid Sulphate soils	226,647	1.84
Peat	130,005	1.06
Grey Piedmont Soils	215,279	1.75
Made-land	106,278	0.86
Hill soils (Brown Hill Soils)	1,561,472	12.69
Terrace soils	1,028,030	8.35
Shallow Red-Brown Terrace soils	72,549	0.59
Deep Red-Brown Terrace soils	189,380	1.54
Brown Mottled Terrace soils	34,235	0.28
Shallow Grey Terrace soils	265,427	2.16
Deep Grey Terrace soils	352,152	2.86
Grey Valley soils	114,287	0.93
Total soil area	12,308,224	100

Source: FAO/UNDP, 1988.

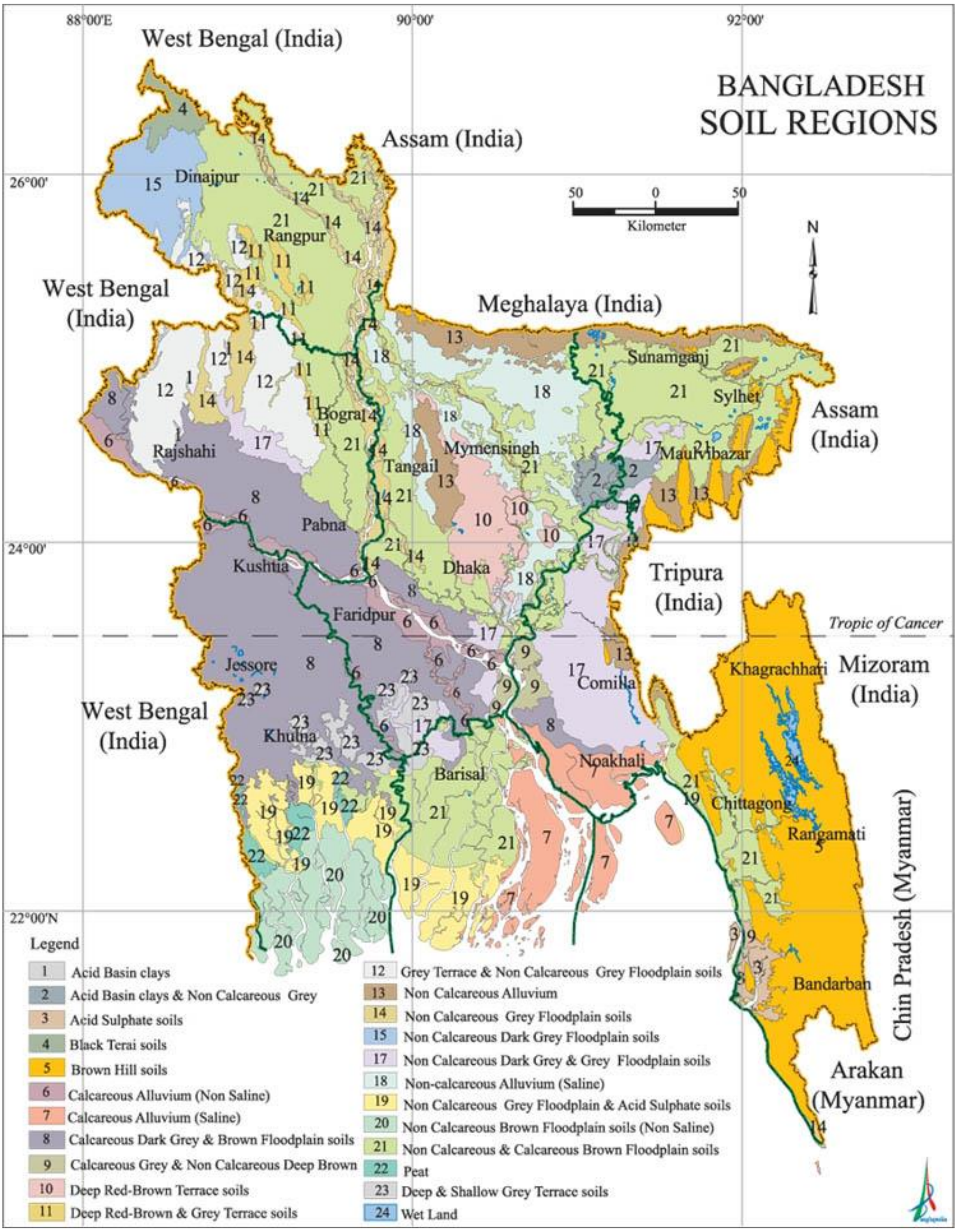


Figure 2-6: Soil Regions of Bangladesh (Source: Banglapedia)

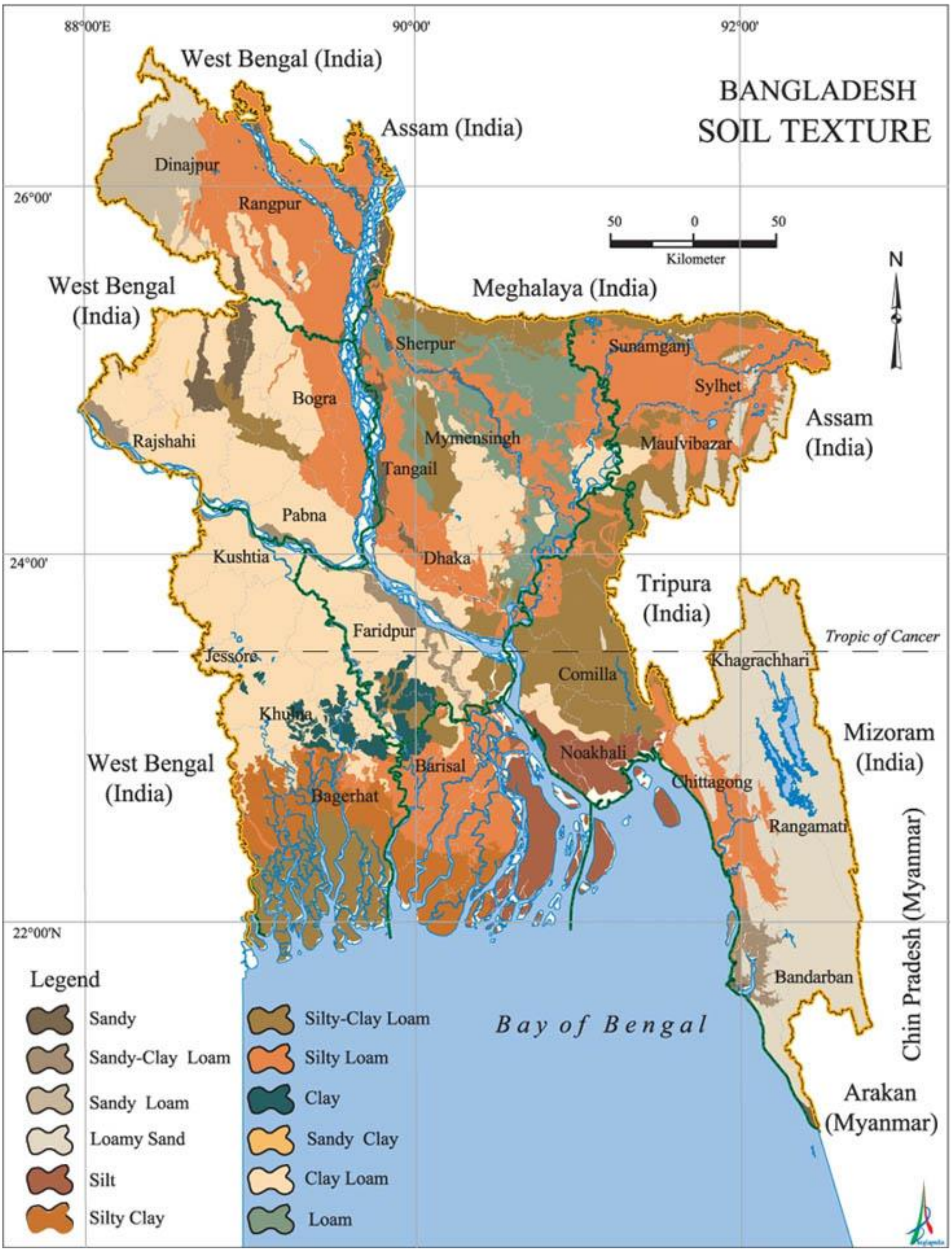


Figure 2-7: Soil Texture of Bangladesh (Source: Banglapedia)

2.10 Land Use Scenarios in Bangladesh

Land use in Bangladesh as shown in Figure 2-8 has evolved through natural forces as well as human needs. Cultivated land, forestland and settlements and homesteads are the major land use types in Bangladesh. With the growing population, and their increasing needs in various sectors, land use patterns are undergoing a qualitative change in which the areas under the net cropped land, and forest land is gradually shrinking. A large part of the forestland is now under different types of non-forest land use, for example, as shifting agriculture, illegal occupation for homestead, shrimp culture etc. Another important feature in land use in Bangladesh at present is the small area (only 3%) of fallow land, which indicates that land in this country is not allowed sufficiently long rest period for regaining their natural biophysical properties which is vitally needed for good maintenance of soil health. It is perhaps needless to say that for sustained agricultural production maintenance of good biophysical condition of soil is essential.

The land area under the head, not available for cultivation includes mainly urban, rural settlements, and industrial lands cover around one-fourth of the total national land area. Area covered by homestead is around 9.3% of the total land area and is characterized by intensively planted but is not efficiently managed (Bashar, 2001). The homesteads represent the agroforestry model in rural Bangladesh. In the face of diminishing trend in forest reserve the homestead agroforestry is playing an important role in mitigating the needs of rural masses. These rural homesteads are often uncared and underutilized and can be made more productive through application of better technology. Well planned marginal land management combining woody perennials with vegetables, fruits, livestock, poultry, fish and farming in tune with the farmers need will lead to sustainable livelihood.

In Bangladesh almost one-third of the land (29%) is classed as Highland and therefore is above normal annual inundation. Slightly lower land, known as the Higher Medium Highland or MH-1, occupies over one-tenth (11.5%) of the land surface. These lands are inundated to a depth of 30 cm, mainly due to the paddy field bunds (ails) and therefore it is largely a human-induced inundation. The next lower level is known as Lower Medium Highland or MH-2, where normal inundation is between 30 and 90 cm and is largely due to improper drainage of local rainfall. Of the total area 23.2% is classed as MH-2. Medium Lowland forms 12% of the total area and is inundated between 90 cm and 120 cm, mainly by rivers which flow through these lowlands and normally rise above bank-level every wet season. Lands inundated between 180 cm and 300 cm is known as Lowland and such land occupies 7.6% of the total area. Even lower land with inundation depths in excess of 300 cm forms 1.4% of the total area of the country. The remaining 15.3% of the land area is either water bodies or urban and rural settlements. This area is increasing because of continuous urban growth.

The single biggest landuse is agriculture but the basic physical features determining all types of land use are the watercourses and standing water bodies. Bangladesh is one of the world's largest wetland areas, and during the rainy season about two-thirds of the country can be classified as wetlands as defined in the Ramsar Convention. Rivers cover an area of approximately 7,700 sq km in the wet season; this includes rivers of all sizes, except very small seasonal khals. One of the problems in estimating landuse in Bangladesh is that the area covered by water bodies increases greatly in the monsoon but dwindles to half as much in the dry season.

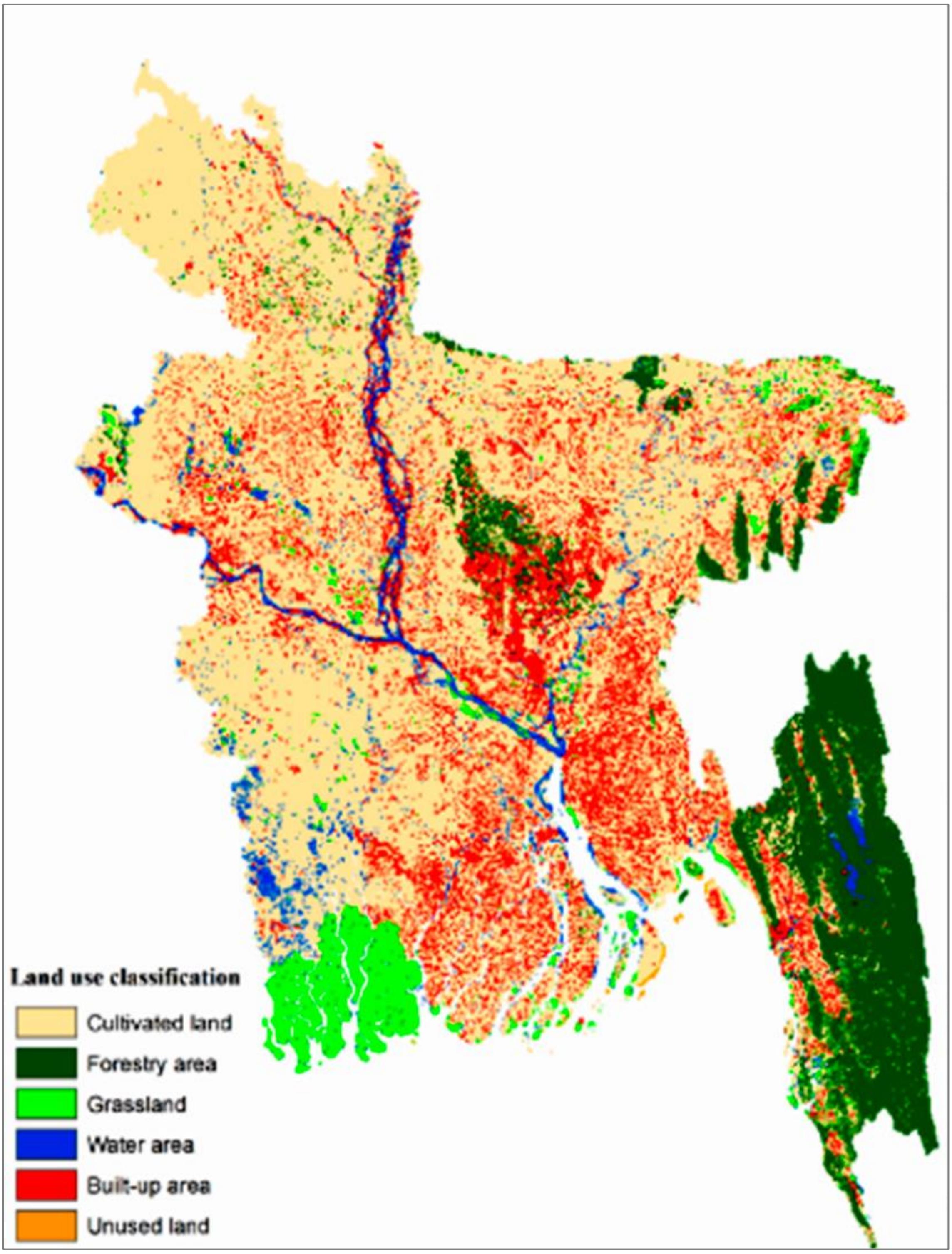


Figure 2-8: Land Use Scenarios in Bangladesh

Another complicating factor is the effect of tides on very low estuarine chars. The level of the Bay of Bengal impinging on the mainland of Bangladesh is approximately two meters higher in the monsoon season (May-October) than in the dry season (November-April).

Therefore, many chars and diaras, which are dry land, often, cultivated in the dry season, and go under water during the rainy season. In the coastal areas notable proportion of the agricultural land has come under shrimp culture. The details of sector wise land use are given in Table 2-5.

Table 2-5: Land Use Pattern Details in Bangladesh (area in sq. km)

No.	Classification	Dry Season (March)	Wet Season (September)
1	**Rivers**		
	Main rivers	2860	3940
	Rivers in Sundarbans	1660	1660
	Other rivers	1880	2100
2	**Standing water bodies**		
	Haors	450	3700
	Beels	177	1500
	Baors	55	560
	Ponds, tanks, ditches	3000	3500
	Kaptai Lake	563	740
3	**Forest**		
	Sundarbans (land area)	4110	4110
	Coastline forest	1400	1400
	Hill forest	6000	6000
	Hill scrub and grass	6900	6900
	Plainland forest and scrub	1200	1200
4	**Cultivated**		
	Field crops	51000	17140
	Tree crops	4900	4900
	Seasonal fallow	17000	16760
	Current fallow	4100	4100
	Seedbed only	600	600
5	**Brackish water aquaculture**	1900	1900
6	**Salt beds**	50	50
7	**Rural built-up**		
	Homesteads	5500	5500
	Institutional	1500	1500
8	**Non-cropped village land**		
	Culturable waste	5800	5800
	Bamboo groves	1250	1250
	Forest and woodland	1350	1350
9	**Urban**	7000	7000
10	**Infrastructure**	2100	2100
11	**Estuarine area**	8600	8600
Total		**147570**	**147570**

3 REWIEW OF PREVIOUS STUDY

Since the inception of the study, the consultants have been collected various reports, data, maps and related documents from relevant organizations. To obtain a preliminary idea on wetlands in Bangladesh and to assess the best wetland management practices for developing a cluster-wise national wetland management framework, the review of previous studies has been conducted. Some of the important study findings are briefly presented in the following sections.

3.1 Classification of Wetlands of Bangladesh by Prosoil Foundation Consultant Bangladesh, 2016

The primary objective of this study was to establish a wetland classification system for Bangladesh within the broad framework of Ramsar Classification System. Other objectives include preparation of maps at macro level for identifying wetlands and preparing lists of major wetlands in Bangladesh.

The wetland classification of Bangladesh has been made based on the Ramsar classification framework. However, some modifications have been made considering the conditions of Bangladesh. The classification system is particularly based on the central issue Hydrological Considerations. The Strategies of Classification of Wetlands of Bangladesh that has been used in this study are given below:

- Ramsar definition of wetland is followed.
- The classification is based on the central issue of wetland concept i.e. hydrology.
- The classification is based on overall system of Ramsar classification of wetlands.
- Country specific classification system, considering geographical and environmental situation will be developed within the broad framework of Ramsar.
- While Ramsar classification system has 3 broad types, classification system of Bangladesh will have 4 types. One new type ‘Reversible Wetland’ has been considered in classification of wetlands of Bangladesh.
- The plant and soil data which has collected during the study is recorded and presented in the annexures.
- Each system except the ‘Reversible Wetlands’ system is divided into two classes; Permanent and Non-permanent.

Classification of Wetlands of Bangladesh has been categorized 4 systems, 2 classes and 30 types as shown in Table 3-1.

Table 3-1: Wetland Types in Bangladesh

Systems	Classes	Types Symbols	Name of wetland types	Examples
Marine/Coastal Wetlands	Permanent	BA	Permanent shallow marine waters in most cases less than six meters deep at low tide; includes sea bays and straits	Entire coastal belt upto a depth of 6m
		BB	Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows	Entire coastal belt and islands which remain inundated and where aquatic plants are grown
		BC	Coral Reefs	St. Martin’s Island, some parts of Cox’s Bazar
		BF	Estuarine waters; permanent water of estuaries and estuarine systems of deltas	Estuaries of Meghna and Karnaphuli, Shahbazpur Channel etc.
	Non-Permanent	BE	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune	Sea beaches of Bay of Bengal
		BG	Intertidal mud, sand or salt flats	Sea beaches of Teknaf, Cox’s Bazar and other sea shores
		BI	Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests	Sundarbans
Inland Wetlands	Permanent	BL	Permanent inland deltas	Char lands of rivers
		BM	Permanent rivers/streams/creeks; includes waterfalls	Permanent rivers of Bangladesh,

Systems	Classes	Types Symbols	Name of wetland types	Examples
				waterfalls etc
		BO	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes	Beels, Baors
		BTp	Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season	Beels within haor areas
Inland Wetlands	Non-Permanent	BN	Seasonal/intermittent/irregular rivers/streams/creeks	Seasonal rivers of Bangladesh, hilly streams, springs etc.
		BP	Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes	Haors, Beels
		BTs	Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes	Lowland, potholes etc. within haor area
		BU	Non-forested peatlands; includes shrub or open bogs, swamps, fens	Peatlands within haor areas, beels of Satkhira, Khulna & Gopalganj
		BW	Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils	Seen within haor area
		BXf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded	Seen within haor area

Systems	Classes	Types Symbols	Name of wetland types	Examples
			swamps on inorganic soils	
		BXp	Forested peat lands; peat swamp forests	Forested peatlands of lowlands of Satkhira, Khulna & Gopalganj
Human-made Wetlands	Permanent	B1	Aquaculture (e.g., fish/shrimp) ponds	Dighi, ponds, shrimp ponds
		B2	Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha)	Small ponds, including ponds for fish culture
		B6	Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha)	Reservoir of Teesta & Kaptai, Dams of Muhuri & reservoirs of Magura etc.
		B8	Wastewater treatment areas; sewage farms, settling ponds, oxidation basins etc.	WWTP of Pagla (Dhaka WASA)
		B9	Canals and drainage channels, ditches	Madaripur Beel Route, Mongla-Ghashikhali Channel, Gab Khan Channel, Irrigation channels of BWDB, Teesta Irrigation Project
	Non-Permanent	B3	Irrigated land; includes irrigation channels and rice fields	Irrigation project areas of the BWDB

Systems	Classes	Types Symbols	Name of wetland types	Examples
		B4	Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)	Floodplains of the rivers
		B5	Salt exploitation sites; salt pans, saline etc.	Salt areas and salt cultivation areas of Teknaf and Barisal
		B7	Excavations; gravel/brick/clay pits; borrow pits, mining pools	Roadside borrow pits, Barapukuria Coal Mine etc.
Reversible Wetlands		Brvc	Coastal polders and embankments	139 coastal polders of the country
		Brvi	FCD and FCDI projects; flood protected inlands with embankments	All inland BWDB FCD & FCDI projects
		Brve	Environmentally degraded, but restorable wetlands	Polluted rivers, encroached rivers, khals, lowlands etc.

[Note 1:
BX – 'B' stands for Bangladesh, 'X' stands for corresponding X type of Ramsar wetland type
Example:
BA – 'B' stands for Bangladesh, 'A' stands for Ramsar type (A: Permanent shallow marine waters in most cases less
than six meters deep at low tide; includes sea bays and straits)
B1 – 'B' stands for Bangladesh, '1' stands for Ramsar type (1: Aquaculture (e.g., fish/shrimp) ponds)]

[Note 2:
Brvc – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands, 'c' stands for Coastal Polders andembankments Brvi – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands, 'i' stands for FCD and FCDI projects; flood
protected inlands with embankments.
Brve – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands, 'e' stands for Environmentally degraded, but
restorable wetlands.]

3.2 Studies carried out by IUCN (2015), National Framework for Establishing and Managing Marine Protected Areas (MPAs) in Bangladesh

This MPA framework is prepared by IUCN Bangladesh with support from Bay of Bengal Large Marine Ecosystem (BOBLME) project based on findings, discussions and suggestions from six regional workshops and six Focus Group Discussions (FGDs), various interviews of key informants at both regional and central level, two national level stakeholders consultation workshops (inception, where policy analysis was presented; and a final national workshop, where this document was validated together with other issues) and analysis of existing policies and documents on various Marine Protected Areas (MPAs). This project was implemented from April 2012 to April 2015. Relevant ministries i.e. Ministry of Fisheries and Livestock (MoFL) and Ministry of Environment and Forests (MoEF), their agencies namely Department of Fisheries (DoF), Bangladesh Fisheries Research Institute (BFRI), and Forest Department (FD), Department of Environment (DoE), other concerned government organization was Bangladesh NAVY,

Coast Guard, National Oceanographic Research Institute and Universities), local administration and civil societies were involved in the formation of this document. In addition to this framework, IUCN has prepared three documents viz. Policy gap analysis, Stakeholders analysis and Review of secondary literatures; which are also summarized in different sections of this framework.

The study was based on an analysis of the Bay of Bengal (BoB) basin, coastal configurations, ecosystems, habitats, current status and management of marine fisheries and foreseen socio-economic and ecological benefits which may originate from the protection of Ecologically Critical Areas (ECAs) and probable MPA declarations and implementation.

It is worth mentioning that the general framework is a broad outline, but each individual MPA should have its specific guideline or pathway. To establish a typical MPA, following steps are suggested in this framework:

Step 1: Identification of Areas of Significance (AoSs)
Step 2: Initial sieving of preliminary selected AoSs
Step 3: AoSs validation, assessment and suggestions
Step 4: Formulation of Management Plan for Candidate MPA Sites
Step 5: Designation or titling of MPA
Step 6: Management guideline for individual MPA within the framework
Step 7: Declaration of MPA
Step 8: Code of Conduct (CoC) for specialized MPAs

Implementation of the MPA framework can be done in 3 different phases to achieve the primary goal of AICHI targets to declare 10 percent of the marine area of Bangladesh worth 12,000 km^2 as MPA by 2020. It is difficult to forecast based on little information and facts to suggest 12,000 km^2 as future MPAs because of limited background information. If pilot initiatives appear successful, the area of MPA could be expanded. Even current PAs are not big enough to cover 12,000 km^2 and a mere declaration without proper studies will not be useful. However, this framework suggests a roadmap towards sustainable MPA management to implement it in three phases through a long term programme, beyond the primary goal of declaring 10% of EEZ by 2020 and targets to declare 15,000 km^2 by 2026.

Successful partnership and sharing responsibility by concerned public and private partners is required to implement the MPA framework. A coordinated approach is needed at national level on how the concerned agencies will work together. Cooperative agreements and joint planning exercises between Bangladesh and her BoB neighbors are also very important. Monitoring is vital for any programme implementation; therefore, it is essential to establish a Monitoring & Evaluation system to conclude whether the objective/s of a given MPA have been achieved successfully. The indifferent attitude to conserve marine ecosystem and biodiversity, irrational and unsustainable resource utilization, abusive harvest of threatened species, inadequate attention to critical habitats have made implementation of the MPA framework urgent in Bangladesh, with a commitment to protect marine ecosystems.

3.3 Studies carried out by IUCN (2005), Major Interventions for Sustainable Wetland Resource Management

The overall objective of the CBHFRM projects is to contribute to the improvement of the quality of life in general, coupled with attaining sustainable development, poverty alleviation and capacity building of the local communities for effective environmental management by involving the communities to a maximum extent. By doing so, the environmental restoration and community based sustainable resource management would be demonstrated in a participatory way in some selected degraded haor/floodplain ecosystems (IUCN Bangladesh, 2005). The specific project objectives were:

- Preventing and reversing the trends of wetland degradation
- Sustainable use of wetland resources
- Promoting sustainable development
- Ensuring people's participation in formulation and implementation of sustainable management plans
- Improving the quality of life with special focus on women
- Developing a replicable model for wetland resource management
- Keeping the objectives of the project in view, four specific outputs have been identified which should be in place at the end of the project tenure:
- Participatory resource management tools developed and practiced
- Ecosystem improved/restored/rehabilitated

- Local institutions for sustainable development established and made functional
- Capacity, skill and awareness levels enhanced

The CBHFRM components adopted a community based, participatory approach that integrates ecological protection and human needs to strengthen the fundamental connection between economic prosperity and environmental well-being in the haor and floodplain environments. This approach provides a framework bringing together the grassroots, the government, private sectors, public groups and other stakeholders. It is goal-driven and is based upon a collaboratively developed vision of idyllic future conditions that integrates ecological, economic, social as well as legal factors. It also includes community involvement, gender and special focus on livelihood.

In accordance with the benchmarks, Pagnar and Sanuar-Dakuar Haors of Jamalganj Upazila of Sumanganj District were selected for the Community Based Haor Resource Management Project. Subsequently, based on the commendable performance in project implementation and the constructive colloquia among IUCN, UNDP and GEF, FHakaluki Haor on the border of Sylhet and Maulvibazar Districts was included as an additional site under the project in October 2000. Physical interventions in the Hakaluki Haor area were officially initiated in July 2001, though preparatory awareness building and sensitisation campaigns with the local communities and the government officials had been carried out in the area, beginning at the end of 2000.

In the case of floodplains, two separate sites were primarily selected with locations in the Padma-Jamuna (Manikganj District) and Madhumati Floodplains (Gopalganj and Madaripur Districts) for the SEMP component 2.2.1/B (Community Based Floodplain Resource Management). Both these floodplains more or less feature all the essential characteristics of a floodplain. Furthermore, the project site had been extended in two selected beel areas of the Brahmaputra-Shitalakshya Floodplain from October 2000; however, the physical interventions began in July 2001.

Wetlands of Bangladesh have, of late, been suffering rapid degradation. Given people's dependence on wetlands and their resources, comprehensive initiatives are crucial and urgently needed to reverse the negative trends. Projects like CBHFRM, first of its genre in Bangladesh, are examples of such attempts. These projects were participatory in all senses. Resource inventorying, problem identification, solution prioritisation, planning needed interventions, and finally implementation of those in the field - all were done through the participation of all concerned stakeholders. These projects, however, only offered the opportunity to pilot a range of interventions deemed appropriate for improving the existing conditions prevailing in some selected haors and floodplains. Major interventions included baseline data establishment, PAPD, community organisation, enhancing livelihood options, financial incentives, awareness raising, demonstration, alternative energy options, plantation, wetland restoration, and biodiversity conservation.

But this is not the end of this novel initiative. Like any other development projects, a major challenge in the CBHFRM projects too lies in sustaining the project achievements after the 'phasing out' stage. During the implementation of the projects, the resource users at the five project sites were motivated, organised and urged to involve themselves in the whole development process with a view to strengthening their capacity to ensure the well-being of the ecosystem and as well as their livelihood even after the project tenure. In addition, the project also attempted assessing needs and developing programmes for enhancing the capacity of the NGOs and local government bodies/agencies.

To ensure the sustainability of the CBHFRM project outputs, a series of workshops was organised from the field to the national level. Workshops were held at haor and floodplain sites to develop linkages between CBOs and other stakeholders including government officials. A national level workshop was organized in 2002 for developing the exit strategy for the CBHFRM projects. In March 2005 another workshop was organised to finalise the exit plan and delineate the activities to be taken, up to sustain the SEMP initiatives. The exit strategy is detailed out in a separate document.

It is expected that a replicable, comprehensive model on participatory wetland resource management practices will be developed after the completion of this medium-term project. It is envisaged that lessons learnt from these projects will present the government with an opportunity to replicate such initiative in other areas of the country. Such replication will certainly ensure the access of the poor to the natural resources, thereby affording the local communities the much-needed uplift in their quality of life and livelihoods, and at the same time wetlands shall be sustainable in a wiser manner.

3.4 The Study of Approaches to Sustainable Wetland Resource Management by IUCN (2005)

The Community Based Haor and Floodplain Resource Management components of the SEMP have adopted a participatory approach that integrates ecological protection and human needs to strengthen the fundamental connection between economic prosperity and environmental well-being in the haor and floodplain environments. This approach provides a network, drawing together the government, the private sectors, public groups and other stakeholders. It is goal-driven and is based on a collaboratively developed vision of desired future conditions that integrates ecological, economic, social and legal factors.

Participatory methods have been used in planning and managing the field level activities as well as to assess wetland sustainability. The communities have been involved in all stages of environmental action, from setting objectives and designing activities to doing the work and evaluating the results.

Pagnar and Sanuar- Dakuar Haors under Jamalganj Upazila of Sunamganj District were selected as Community Based Haor Resource Management sites. For floodplain areas, two separate sites in the Padma- Jamuna Rivers Floodplain of Shivalaya and Harirampur upazilas, Manikganj District; and the Madhumati River Floodplain of Muksudpur, Gopalganj and Rajoir Upazilas under Gopalganj and Madaripur Districts were selected.

Practicing participatory approaches in the Community Based Haor and Floodplain Resource Management projects issued positive signals for the environmental practitioners engaged in the project and the donors and the relevant departments of the government were afforded potential knowledge of the grassroot stakeholders' capacity for planning, implementation and management of ecosystem in a sustainable manner. It was understood from the very beginning of the project that people living in an ecosystem must have the capacities necessary to generate and maintain livelihoods, while enhancing their own well-being and that of the generations to come. These capacities should be based on equity, ownership of resources and participatory decision-making. A successful community-based wetland resource management, thus, develops local resources, viz. forestry, fisheries, agriculture and tourism, leading to overall improvement of the community and environmental conservation.

Community based wetland resource management approaches deployed in the project implementation seriously considered and tested the following components for sustainability of activities and interventions at the local level, viz.

- Institution building at the local level provenly enhances organizing capacity of the community people,
- Educational and awareness raising messages on environmental and ecological integrity, when disseminated meaningfully, ensures the long-term sustainability of the natural resources,
- Legal and institutional frameworks ensure establishing and supporting the community's rights to the usage and protection of the resources,
- People would be motivated to support resource conservation when they are provided with livelihood alternatives, and
- Participation ensured in practice eventually and certainly enhances the sense of ownership of the community.

Besides, some area specific factors such as socio-political conditions, accessibility to the common properties, marketability of local products, religions and customs were considered carefully for effective implementation of the project. It was experienced from the project that hurdles could be overcome through effective participation of those people who traditionally had stake in the management and conservation of resources

3.5 A Plan for Ensuring Sustainability of Community Based Haor and Floodplain Resource Management Projects by IUCN, 2005

The local communities are the key stakeholders for undertaking any effective management of the wetland resources, their participation has been considered essential for sustainable management of the wetland resources. Hence community participation has been made mandatory in all stages of the subject project planning as well as implementation. The specific project objectives are:

- Preventing and reversing wetland degradation trends
- Sustainable use of wetland resources
- Promoting sustainable development
- Ensuring people's participation in formulation and implementation of sustainable management plans

Considering the trend of degradation of the wetland ecosystems, parts of Pagnar and Sanuar-Dakuar Haors in Sunamganj District and Hakaluki Haor of Moulvibazar District were selected for management of the wetland resources under the project SEMP. The project area in this floodplain includes Arua Union of Shibalya Upazila and Gopinathpur and Kanchanpur Unions of Harirampur Upazila in the district of Manikganj, Bangladesh.

The basic four outputs were:

- Participatory resource management tools developed and practiced
- Ecosystem improved / restored/rehabilitated
- Local institutions for sustainable development established and made functional
- Capacity, skills and awareness levels enhanced

The plan for ensuring sustainability of Community Based Haor and Floodplain Resource Management Projects or the exit plan is unique in its approach of being participatory, involving the effort of community people. These plans of action reflect specific need-based actions for five specific locations that should be taken care of by the end of this project and are entirely based on the recommendations of the community members.

As the community members are the actual implementers of the project activities, acceptability of these recommended plans of actions are likely to be higher. Their acceptance would eventually lead a sense of ownership amongst them and motivate them to continue the sustainable trend in the future.

Although IUCN and its associating organizations have implemented the project, credits should be given to the motivated and devoted community people, without whom this monumental task would not be possible.

It is a plan of the community people who have put their heart and soul, time, effort as well as their experiences to develop it. Given their level of awareness and their positive drive, it is expected that the project activities will continue in future even without the technical or financial assistance provided by IUCN and its associating organizations.

3.6 Re-excavation: A Major Step in Wetland Restoration in the Haors by IUCN, 2005

The study was formulated with a view to:

- Establish micro fish sanctuaries for conservation of breeding stocks of fishes and enhanced production
- Conserve fish diversity, increase fish population and restore threatened species
- Promote sustainable management and use of aquatic haor resources through the direct participation of the local people
- Maintain and ensure the optimum environmental flow in the project area
- Ensure increased stock of water to support irrigation during the dry season
- Rehabilitate and restore wetland habitats for brood fishes
- Rebuild and reestablish connectivity among rivers, canals, heels and floodplains
- Ensure dry season habitat for fish and aquatic flora and fauna

Pagnar and Sanuar-Dakuar Haors, Hakaluki Haor were the project sites.

The re-excavated water bodies and sanctuaries have been potential resources of the communities. Concerned Village Committee (VC)s has been very careful about managing these resources so far. After phasing out of the project, they will assume fuller responsibilities of operating all these resource bases. The VCs have been in physical possession of the resources but they have no legal title showing that they own these lands, as the land containing the water bodies is considered as khas land. Measures have been taken to have these water bodies on long-term lease from the Ministry of Land in favour of the VCs. The issue of settling the pending lease has to be resolved before the phasing out of the project.

The capacity of the VCs in regard to the promotion of organisational activities, resource management, AIGA etc. has to be enhanced for proper functioning after the phase out.

The VCs might extend the resource base in the future. They should generate fund from fishing as well as AIGA activities. They should also explore and utilize the services available with the local government bodies, especially at the upazila level.

The project has been a government intervention and there had been high government support in favour of the poor community, which really paved the way for smooth implementation of the interventions. The said government patronization should continue even after phasing out or otherwise, in the struggle for existence, these poor communities would be just driven away again from these ready resource bases and the real benefit would again be harvested by the privileged, which should not be allowed to happen.

3.7 Re-excavation: A Major Step in Wetland Restoration in the Floodplains by IUCN, 2005

The project area was in the Padma-Jamuna floodplain includes Arua Union of Shibalya Upazila and Gopinathpur and Kanchanpur Unions of Flarirampur Upazila in the district of Manikganj, Bangladesh. Boka and Nali beels are two wetlands which had been selected in the Brahmaputra- Shitalakshya floodplain for carrying out SEMP activities. The project was conceived with a view to:

- Open/construct and ensure maintenance of the migratory routes for fish and other aquatic organisms.
- Create a micro-sanctuary with a view to providing shelter for the brood fish stock and other aquatic fauna.
- Ensure optimum water flow between the different canals and beels system for the improvement of wetland ecosystem processes.
- Drain excessive water in order to increase the land availability for seasonal agriculture.
- Ensure water supply for irrigation in the crop field during the dry season.
- Maintain inflow and recession of water when needed seasonally, so that fishery resources should be enhanced.
- Enhance livelihoods support by ensuring increased agricultural yields and fish products.

Restoration and conservation of wetlands biodiversity through re-excavation of degraded sites and migration routes have generated a great deal of interest amongst the local communities, as it involved them closely in its planning, design, implementation and management, playing pioneering role in utilizing the local natural wetland resources in a sustainable manner. Communities, particularly, the fishers and farmers have heartily accepted these kinds of activities as helpful for enhancing their livelihood systems.

In the project areas, diverse habitats and the flora and fauna that inhabit them are the most precious resources. Their values are now increasingly being recognized by the people of the project areas who have embarked on implementing strenuous conservation efforts in their respective areas.

In the wetlands where there was no previous connecting canal, no non-migratory aquatic organisms, and no dependence on seasonal agriculture, re-excavation just for connecting canals might not be successful in ecosystem rejuvenation.

In order to successfully implement the project, the following recommendations are provided:

- Re-excavation Management Committee (RMC) membership should be such as would have the capacity to ensure the sustainability of the re-excavation intervention through providing technical as well as financial support.
- Research work, particularly the impact study should be continued and the findings to be disseminated widely for the benefit of other wetlands.
- Continue technical support, monitoring and supervision needed.
- Development and renovation work by the conservation committee to be continued essentially for the sustainability and optimum water flow through the rejuvenated water bodies and migration routes.
- Conservation practices should be so integrated way such as they address pollution, habitat protection, exploitation including hunting, land use management, recreation and other relevant and diverse factors.
- Role of the local Government bodies to be clearly delineated and systematized for sustainability of the executed activities.

3.8 Hydro-Meteorological Characteristics of Hakaluki Haor by IUCN, 2005

The Community Based Haor Resource Management project, which fell under the broad theme of participatory ecosystem management, has been implemented by IUCN - The World Conservation Union, Bangladesh Country Office since October 1998. Hakaluki haor has been included in 2001 as an additional site for implementing the project activities.

The overall objective of the project is to contribute to the improvement of quality of life in general, coupled with sustainable development, poverty alleviation and capacity building of local communities for better wetland resource management. However, the specific objectives are:

- Prevent and revise the trend of wetland degradation
- Sustainable use of wetland resources
- Promote sustainable development
- Ensure people's participation in formulating and implementing the management plan
- Improve quality of life with special focus on women

It is suggested to include the following activities in the Hakaluki haor Management Plan:

- Agriculture development through the development of irrigation systems.
- Increasing the conveyance capacity of the internal rivers by excavation/dredging.
- Checking sedimentation in the beels by undertaking suitable interventions.
- Declaring Chatla, Sakia, Nagura, Haorkhal and Jingla BeeI as fish sanctuary.

- Stocking fish and stopping overfishing by the lessees.
- Stabilizing the existing lowland forest remnants and ensuring their regeneration
- Developing new forest sites.
- Developing an area for brush and reeds as sanctuary.
- Developing pasture and improving livestock.
- Eco-tourism and preparing booklets etc. to raise awareness about the wetland

3.9 Wetland inventory, Ramsar Handbooks for the Wise Use of Wetlands 4th Edition, Handbook 15, 2010

The Ramsar Convention on Wetlands has always recognized the importance of national wetland inventories as a key tool for informing policies and other actions to achieve the conservation and wise use of wetlands. This framework provides guidance for planning and designing an appropriate wetland inventory, recognizing that the actual inventory approach adopted will depend on its purpose and objectives, as well as the capacity and resourcing for undertaking the inventory. A structured framework for planning and designing a wetland inventory is illustrated under this guideline which comprises 13 steps that provide the basis for making decisions in relation to the purpose (and objectives), and the available resources, for an inventory. The steps are:

Step 1: State the purpose and objective
Step 2: Review existing knowledge and information
Step 3: Review existing inventory methods
Step 4: Determine the scale and resolution
Step 5: Establish a core or minimum data set
Step 6: Establish a habitat classification
Step 7: Choose an appropriate method
Step 8: Establish a data management system
Step 9: Establish a time schedule and the level of resources that are required
Step 10: Assess the feasibility and cost effectiveness of the project
Step 11: Establish a reporting procedure
Step 12: Review and evaluate the inventory
Step 13: Plan a pilot study

4 REVIEW OF LAWS, POLICIES & GUIDELINES

4.1 Key Policies and Acts

4.1.1 Environment Policy 92

The national Environment Policy 1992 embraces several related different sectors including agriculture, industry, health, energy, water, land, forest, fisheries, marine, transport, housing, population, education and science. The central theme of the policy is to ensure the protection and improvement of the environment. It delivered required actions in the development sectors of the country to facilitate long term sustainable use of all natural resources.

It also gave the direction of amending the existing laws, formulating the new laws and implementing the same. It also assigned the Ministry of Environment and Forests to coordinate the implementation of the policy and to constitute a high level National Environmental Committee (NEC) with the head of the government as the chairperson exercising the direction, supervision, and overseeing the implementation of the policy.

Environmental policy of Bangladesh addressed 15 broad sectors to deal with overall environmental issues. For each of the sectors some goals and target were set and action plan to achieve targets.

It is learnt from DoE that it has revised the Environment Policy’92 to make it updated and compatible with the current national and international situation.

4.1.2 Environmental Conservation Act 1995 (Revision up to 2012)

Environment Conservation Act 1995 (ECA 1995) is currently the main act governing environmental protection in Bangladesh, which replaced the earlier environment pollution control ordinance of 1992 and provides the legal basis for Environmental Conservation Rules, 1997 (ECR'97). The main objectives of ECA’95 are conservation of the natural environment and improvement of environmental standards, and control and mitigation of environmental pollution. The main strategies of the act can be summarized as:

- Declaration of ecologically critical areas, and restriction on the operation and process, which can be continued or cannot be initiated in the ecologically critical areas.
- Regulation in respect of vehicles emitting smoke harmful for the environment.
- Environmental clearance.
- Remedial measures for injury to ecosystem
- Regulation of the projects and other development activities - discharge permit.
- Promulgation of standards for quality of air, water, noise and soil for different areas for different purposes.

- Promulgation of standard limit for discharging and emitting waste.
- Formulation and declaration of environmental guidelines.

Bangladesh Environmental Conservation Act (Amendment 2000) focuses on: (1) ascertaining responsibility for Compensation in cases of damage to ecosystems, (2) increased provision of punitive measures both for fines and imprisonment and (3) fixing authority on cognizance of offences.

Bangladesh Environmental Conservation Act (Amendment 2002) elaborates on: (1) restriction on polluting automobiles, (2) restriction on the sale and production of environmentally harmful items like polythene bags, (3) assistance from law enforcement agencies for environmental actions, (4) break up of punitive measures and (5) authority to try environmental cases.

Bangladesh Environmental Conservation Act (Amendment 2010) elaborates on (1) demarcation of wetlands and water bodies, (2) Hazardous waste import, transportation, storage etc., (3) Cutting of hills, mountains (4) Ecologically Critical Areas.

4.1.3 Environmental Conservation Rules 1997

Environmental Conservation Rules 1997 consists of a set of the relevant rules to implement the ECA’ 95, which specify:

- Categorized list (green, orange and red) of the projects,
- Procedure to take environmental clearance,
- Ambient standards in relation to water pollution, air pollution and noise, as well as permitted discharge/emission levels of water and air pollutants and noise by projects Environmental Categories.

ECR 97 classifies projects by potential environmental impact and assigns different assessment and management requirements as follows:

Green List projects are those with positive environmental impacts or negligible negative impacts such as plantation and nursery. Clearance for these is obtained on the basis of project description, initial screening and No Objection Certificate (NOC) by the local authority.

Orange List projects fall into two categories. Orange A projects are those with minor and mostly temporary environmental impacts for which there are standard mitigation measures, such as the installation of tube wells, pond sand filter (PSF), tank/reservoir, sanitary latrines etc. Application for DOE’s environmental clearance requires general information, a feasibility report, a process flow diagram and schematic diagrams of facilities, environmental screening form, NOC from local authority.

Orange B projects are those with moderately significant environmental impacts for which mitigation measures are easily identified, such as construction/re-construction of earthen roads, culverts, community center, office building for general services, re-excavation of canal, repairing embankment, and school field, etc. These require Environmental Clearance Certificate from DOE, for which an Initial Environmental Examination (IEE) report, Environmental Management Plan, along with the information and papers specified for Category A projects.

Red List projects are those which may cause 'significant adverse' environmental impacts such as the construction of bridge, industrial factories, flood shelter, embankment, water control structure, etc. They require IEE report to obtain the Site Clearance Certificate, and subsequently a full EIA report for ECC, along with the information required for other Categories. A good number of sectoral EIA guidelines have been prepared to assist the EIA process.

Environmental standards also promulgated under the Environment Conservation Rules 1997 are prescribed for varying water sources, ambient air, noise, odor, industrial effluent and emission discharges, vehicular emission, etc. with the main aim of limiting the volume and concentrations of pollution discharged into the environment. A number of surrogate pollution parameters like Biochemical Oxygen Demand, or Chemical Oxygen Demand; Total Suspended Solids, etc. are specified in terms of concentration and/or total allowable quality discharged in case of waste water and solid waste. Additionally, specific parameters are specified such as phenol, cyanide, copper, zinc, chromium, and various types of particulate, sulfur dioxide, nitrogen oxides, volatile organic compounds and other substances.

4.1.4 Jalmohal Policy – 2009

The preamble of the latest Jalmohal policy-2009 enacted in June 2009, clearly states that the policy aims at earning revenue alongside facilitating preferential access to Jalmohals by the real fishers following the principles of conservation and enhancement of fisheries production and wetland biodiversity. However, some issues that are identified by different relevant stakeholders both at field and central levels demand revisiting the policy to make it pro-poor and pro-environment.

"Jal Jar, Jola Tar" principle - The preamble of section 5 of the policy used a popular slogan "jaal jar, jola tar (owners of fishing nets will be the owners of Jalmohals).

Section 5, Clause 4- Ka of the policy says that if more than one local fisher society comes up with proposals for a particular Jalmohal having more or less similar credentials then the District Jalmohal Management Committee will lease out the Jalmohal for 3 years period through "*discussions and consensus*".

4.2 Key Strategies & Plans

4.2.1 National Conservation Strategy (NCS)

National Conservation Strategy was drafted in late 1991 and submitted to the Government in early 1992. This was approved in principle; however, the final approval of the document is yet to make by the cabinet.

For sustainable development in the energy sector, the strategy document offered various recommendations but none was there concerning the present specific project execution program or related matter.

Major relevant recommendations are:

- To use minimum possible area of land in exploration sites;
- Rehabilitate site when abandoned;
- To take precautionary measures against Environmental Pollution from liquid effluent, condensate recovery and dehydration plants; and
- Technology assessment for selection of appropriate technology.

4.2.2 National Environment Management Action Plan (NEMAP)

The National Environmental Management Action Plan (NEMAP) is a wide ranging and multifaceted plan, which builds on and extends the statements set out in the National Environmental Policy, NEMAP was developed to address issues and management requirements for a period between 1995 to 2005 and set out the framework within which the recommendations of the National Conservation Strategy are to be implemented.

NEMAP has the broad objectives of:

- Identification of key environmental issues affecting Bangladesh.
- Identification of actions necessary to halt or reduce the rate of environmental degradation.
- Improvement of the natural and built environment.
- Conservation of habitats and bio-diversity.
- Promotion of sustainable development; and
- Improvement in the quality of life of the people.

4.2.3 Sustainable Environment Management Plan (SEMP)

A segment of NEMAP, centered on green initiatives, was launched in 1998 by MoEF through the implementation of a US $ 26 million ‘umbrella’ programme called the “Sustainable Environment Management Programme (SEMP)” which lasted until 2006. The

SEMP was unique in the sense that it was the largest single initiative under the environment sector, the first initiative launched under "programme approach", aimed at a larger national objective in the area of environment with the participation of a host of government departments, agencies and ministries, NGOs, CSOs and international bodies like IUCN. They implemented 26 individual projects addressing various aspects of NEMAP under 5 thematic areas as follow:

- ✓ Environmental Policy & Legislation
- ✓ Participatory Eco-system Management
- ✓ Community Based Environmental Sanitation
- ✓ Advocacy & Awareness Campaigns
- ✓ Training & Education

The plan proposed to adhere to six areas of concentration:

- Enhancement of environmental compliance
- Mitigation of potential environmental impacts through the environmental assessment and clearance process
- Spreading of efforts to address critical urban air quality and water quality problems
- Facilitation of meaningful stakeholder participation in environmental management
- Natural resources conservation through identification of ecologically critical areas and
- Ensuring effective, efficient and accountable DoE's service.

The main elements of the Strategic Plan are

- Development of a comprehensive enforcement and compliance policy and related strategies
- Development of improved EIA procedure and guidelines
- Standards and guidelines related to EC, inspection and legal enforcement
- Development of associated enforcement and compliance information system
- Bolstering the environmental monitoring capacity of DOE
- Innovative approaches to promote compliance
- Ensuring Bangladesh commitments to international instruments
- Enhancing DOE's role in designation and management of ECA
- Improving coordination and reporting function of DOE
- Improving DOE's outreach activities.

4.2.4 National Biodiversity Strategy and Action Plan for Bangladesh (NBSAP)

The NBSAP provides a framework for conservation, sustainable use and sharing the benefits of biodiversity of the country. A major focus of the plan is to ensure cross-sectoral linkages, reflecting the fact that in Bangladesh, more so than most other countries, biodiversity conservation is closely inter-woven with social and economic development. Thus, the NBSAP also provides a framework for securing the necessary environmental settings to reduce poverty, ensure sustainable development and implementation of Poverty Reduction Strategy Paper (PRSP). Sixteen strategies have been developed to shape and direct the actions towards achieving the goals and objectives of the NBSAP.

The Ministry of Environment and Forests is to coordinate the implementation of the NBSAP. All relevant Ministries/ Divisions, government agencies, institutions, academic institutions, non-governmental organisations and communities would be responsible for activities that fall within their mandate. An ‘Apex Body’ was proposed to coordinate the implementation of the NBSAP. A financing strategy was proposed for re-sourcing the implementation of the NBSAP. This focused on increasing of public budget allocations, use of domestic instruments like taxes on water, timber, levies from road, rail and air passenger tariffs, debt swap trust funds and development partners’ contribution. A communication strategy was also incorporated in the plan for effective awareness raising and information dissemination.

4.3 Sectoral Policies

4.3.1 National Forest Policy (1994)

The National Forest Policy of 1994 is the amended and revised version of the National Forest Policy of 1977 in the light of the National Forestry Master Plan. The major target of the policy is to conserve the existing forest areas and bring about 20% of the country's land area under the Forestation Program and increase the reserve forest land by 10% by the year 2015, through coordinated efforts of GO-NGOs and active participation of the people.

The priority protection areas are the habitats which encompass representative flora and fauna in the core area of national parks, wildlife sanctuaries, and game reserves. Multiple-use of forest, water and fish of the Sundarbans through sustained management will be ensured, keeping the bio-environment of the area intact.

4.3.2 Wetland Policy, 1998

The Policy is relevant to the Project because it seeks to conserve wetlands to sustain their ecological and socio-economic functions and further sustainable development; establish key principles for wetland sustainability and unsustainable practices; maintain existing levels of biodiversity; maintain wetland functions and values; and actively promote integration of wetland functions in resources management and economic development decision taking.

4.3.3 National Fisheries Policy

The National Fisheries Policy provides the framework for the conservation and management of fisheries resources to ensure supply and enhance production. All the water bodies suitable for fisheries production and their fisheries resources conservation, development and management are addressed under this policy. These include rivers and canals, haor and baor, floodplains, open and coastal water systems.

4.3.4 Land Use Policy

The National Land Use Policy 2001 of the Ministry of Land highlights the need, the importance and modalities of land zoning for integrated planning and management of land resources of the country. Many other policies, strategies, plans of the government have also recommended for land zoning since long. The National Land use Policy 2001 also mentioned the need of formulating a Zoning Law and Village Improvement Act for materializing the identified land zoning area.

4.3.5 National Water Policy (2012)

The National Water Policy of 1999 was passed to ensure efficient and equitable management of water resources, proper harnessing and development of surface and ground water, availability of water to all concerned, and institutional capacity building for water resource management. It has also addressed issues like river basin management, water rights and allocation, public and private investment, water supply and sanitation and water need for agriculture, industry, fisheries, wildlife, navigation, recreation, environment, preservation of wetlands, etc. The water policy, however, fails to address issues like consequences of trans-boundary water disputes and watershed management.

It provides the framework for the management of water resources of the country in a comprehensive, integrated and equitable manner. The NWP recognizes that water is essential for human survival, socio-economic development of the country, and preservation of its natural environment. It is vital that the continued development and management of the nation's water resources should include the protection, restoration, and preservation of the environment and its bio-diversity.

4.3.6 Coastal Zone Policy

The Coastal Zone Policy (CZP) 2005 aims to ensure that a participatory and integrated approach is taken in the management and development of the coastal zone, to reduce conflicts in the utilization of coastal resources and to optimize exploitation of opportunities. This is in view of the complexity of the coastal zone, which encompasses both the terrestrial and aquatic environment and transcends a wide variety of human activities.

4.3.7 National Agricultural Policy, 1999

The overall objective of the National Agriculture Policy is to make the nation self-sufficient in food through increasing production of all crops including cereals and ensure a dependable food security system for all. One of the specific objectives of National Agricultural Policy is to take necessary steps to ensure environmental protection as well as „environment-friendly sustainable agriculture. Through increased use of organic manure and strengthening of the integrated pest management program. The policy also suggests creating awareness so that the chemical fertilizers and pesticides used for increased crop production do not turn out to be responsible for environmental pollution. Water logging and salinity are identified as one of the serious problems in some parts of the country including the coastal areas for agricultural activities and environmental damage. The policy recommends for crop rotation and salt tolerant crop varieties.

5 METHODOLOGY

The main objectives of the study are to prepare an inventory of the wetlands through classification of satellite images, delineations of wetlands and LiDAR survey of Tanguar haor for an area of approximately 120 sq. km. for empirical data collection. This chapter deals with the approach and methodology that has been adopted to address the objectives of the study. To achieve the study objectives, the following major scope of works have been conducted:

- Establishment of structured framework.
- Clustering of wetlands.
- Collection of detail information on wetlands.
- Identification of connectivity of wetlands.
- Finalization of wetland inventory.
- Evaluation of the value of wetlands.
- Identification of best wetland management practice.
- Selection of sites for piloting.
- Implementation, evaluation and monitoring of piloting.
- Development of cluster-wise wetland management framework.
- Dissemination of knowledge to stakeholder.
- LiDAR survey for Comprehensive assessment of Tanguar haor area.

The major scope of works will establish a comprehensive national wetland inventory which is the vital basis for many activities necessary for achieving the wise use of resources of wetlands, including policy development, new identification and designation of Ramsar sites, documentation of wetland mapping & losses and identification & categorization of wetlands with potential for restoration. Therefore, a comprehensive wetland management framework is needed based on established wetland inventory and to ensure its implementation in future through a co-management approach to protect and conserve the wetlands from degradation. Interaction between haor and river ecosystem will also be assessed and designed in such a way so that it can play an important role for future protections of wetlands.

To develop a wetland inventory and region/cluster-wise wetlands management framework following the Ramsar guidelines, the following general approach as shown in Figure 5-1 has been proposed which are elaborately described below:

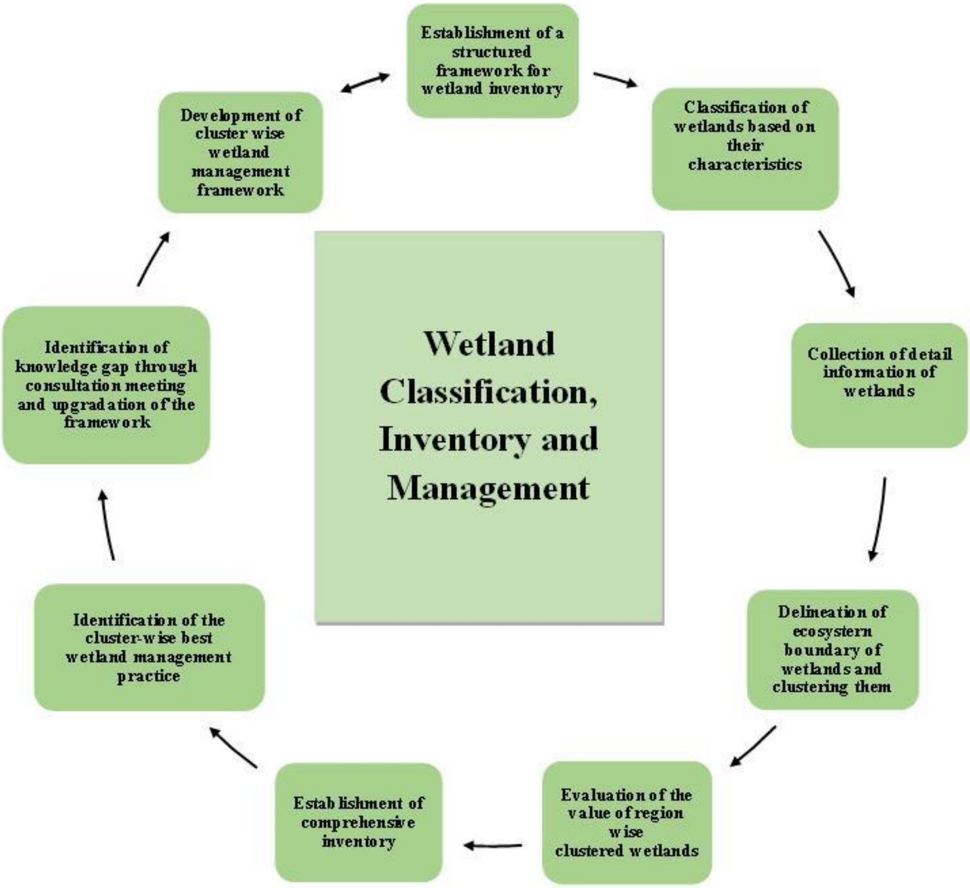


Figure 5-1: General Approach for Wetland Classification, Inventory and Management

Task-1: A Review of the Available Published Literature & Documents to Determine the Extent of Knowledge and Information Available for Wetland Inventory and Wetland Management

Review of literature acts as a stepping-stone towards achievement of the study objectives. The review plays a critical role in analyzing the existing literature and giving justification as to how the study fits into the existing body of knowledge. The literature review provides the general understanding which gives meaning to the discussion of findings, conclusions, and recommendations. In general terms, the literature review helps to provide a context for the study, justify the study, illustrate how the subject has previously been studied, highlight flaws in previous study, outline gaps in previous study, help refine, refocus the study objectives.

To recognize the best practice of managing wetlands, available scientific and technical information, literatures, guidelines relevant to the wetlands management has been collected. After categorizing them the existing international management practices has been systematically assessed and international wetlands management guidelines such as the Ramsar guideline is thoroughly reviewed. Some regional community-based wetland management practices have been developed by the IUCN, MACH, CNRS, CARITAS, CBFM, Department of Fisheries and others, which will also be reviewed and compared with the international practices to primarily select a management practice for the wetlands of Bangladesh. Then, consultation meetings with local stakeholders will be arranged to identify the best practices ever established at local level or to find out indigenous knowledge developed by any community to protect the resources of wetlands and manage the sustainable use and equitable share of wetland resources. The selected management practice will be discussed with them to justify its suitability, identify the gaps and update the information to develop and finalize the selected management framework based on the overall assessment of their advantages & disadvantages.

***Task-2:* A Comprehensive Review of Existing Policies, Strategies and Plans Related with Wetland Management**

The following Policies, strategies and Regulations will be reviewed under this study:

- Environment Policy 92
- Environmental Conservation Act 1995 (Revision up to 2012)
- Environmental Conservation Rules 1997
- The Environment Court Act, 2000
- National Conservation Strategy (NCS)
- National Environment Management Action Plan (NEMAP)
- Sustainable Environment Management Plan (SEMP)
- National Biodiversity Strategy and Action Plan for Bangladesh (NBSAP)
- Draft Roadmap for National Adaptation Plan (NAP)
- Perspective Plan 2010-2021
- National Forest Policy (1994)
- Wetland Policy, 1998
- National Fisheries Policy
- Land Use Policy
- National Water Policy (2012)
- Coastal Zone Policy
- National Agricultural Policy, 1999

***Task-3:* Finalization of the Proposed Inventory Methods to Fulfill the Specific Objectives and Following the Ramsar Convention along With Other International Standards**

The main purpose of this study is to establish a comprehensive wetland inventory which necessitates the formation of a structured framework. The inventory of wetlands includes the production of hierarchical and map-based outputs. The level of detail is related to the scale of the maps that are contained within a standardized GIS format with a minimum core data set. The hierarchical approach comprises a progression in scale from river basins to individual sites. The initial analysis (level 1) involves delineation of geographical regions (major river basins) and encompasses a description of the geology, climate and ecology of each based on existing information sources. Level 2 analysis concerns delineation of wetland regions within each geographic region. This is done on the basis of similar climatic, hydrologic and vegetation features. Several meetings and discussion were held among the different stakeholders to finalize the inventory method. The outcomes from the meetings and discussion are to develop the inventory based on hydrological region of Bangladesh and prepare the map-based outputs in 1:10000 scale. As per the comments and suggestions from the expert, the inventory is in tabular format including the location (districts, upazila, union and mouza), area and other physical features such as agro- ecological zone and bio-ecological zone and others.

***Task-4:* Procurement of Currently Available Remotely Sensed Images of Recent Years to Identify the Exact Locations and Boundaries of Wetland, Calculate Their Area and also Determine their Types, Status and Characteristics**

Satellite image is an important component of the project. High resolution image of recently captured has been purchased to identify the locations and boundaries of wetlands, calculate their area and to determine their types, status incorporating their underlying characteristics.

In order to meet with the study objectives, a total of 339 Nos. of high-resolution satellite imagery has been procured from DigitalGlobe covering the whole country. The specifications of satellite image are as follows:

Item	Specification
Total Image Scene	339 Nos.
Number of Blocks	18 Nos.
Type	Optical
Bands	Red, Green, Blue, Infra-red
Cell Size	0.5 m
Processing level	Orthorectified
Cloud cover	<= 15%, calculated over the whole country
Imagery date	January 1, 2009 to 18 May 20 2017
Coordinate System	BUTM
File Format	GeoTIFF

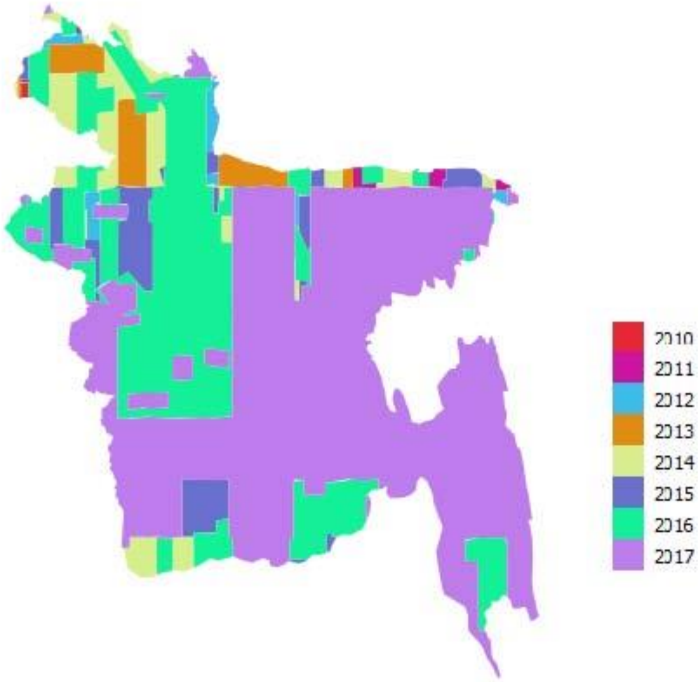
Data Sources: Data for this project is from the following satellites;

- GeoEye-1
- WorldView-2
- WorldView-3

These satellites are owned and operated by DigitalGlobe, with headquarters in Colorado in the United States.

Image Dates: Satellite imagery shall be from 2010 or newer. More than 80% of the imagery will be < 2 years old, according to the following table;

YEAR	%
2017	58.15%
2016	26.26%
2015	5.08%
2014	5.58%
2013	3.33%
2012	1.15%
2011	0.99%
2010	0.07%



Coordinate System

Name:	Bangladesh UTM “BUTM”
Datum:	WGS84
Projection:	Transverse Mercator
False Easting:	500000.0
False Northing:	0.0
Central Meridian:	90.0
Scale Factor:	0.9996
Latitude of Origin:	0.0
Unit:	Meter

***Task-5:* Geo-referencing of the Satellite Images Using GIS Software and Ground Truthing by Field Survey to Validate the Different Features of Wetlands (Absolute and Relative Locations, Area etc.) From the Satellite Images Compared with the Real World**

The onshore and offshore of whole Bangladesh is divided into 18 grids as shown in Figure 5-2 while delivering the satellite imageries. According to the grid division, 250 GCPs (10-12 GCPs per grid) has been proposed to fulfill the ground truthing objective and validation purpose. Finally, 215 GCPs among pre-selected 250 has been captured for ground truthing and accuracy assessment. 35 GCPs are cancelled due to several reasons like inaccessibility, security issue, prior permission; changes over time in the land cover and land use, etc.

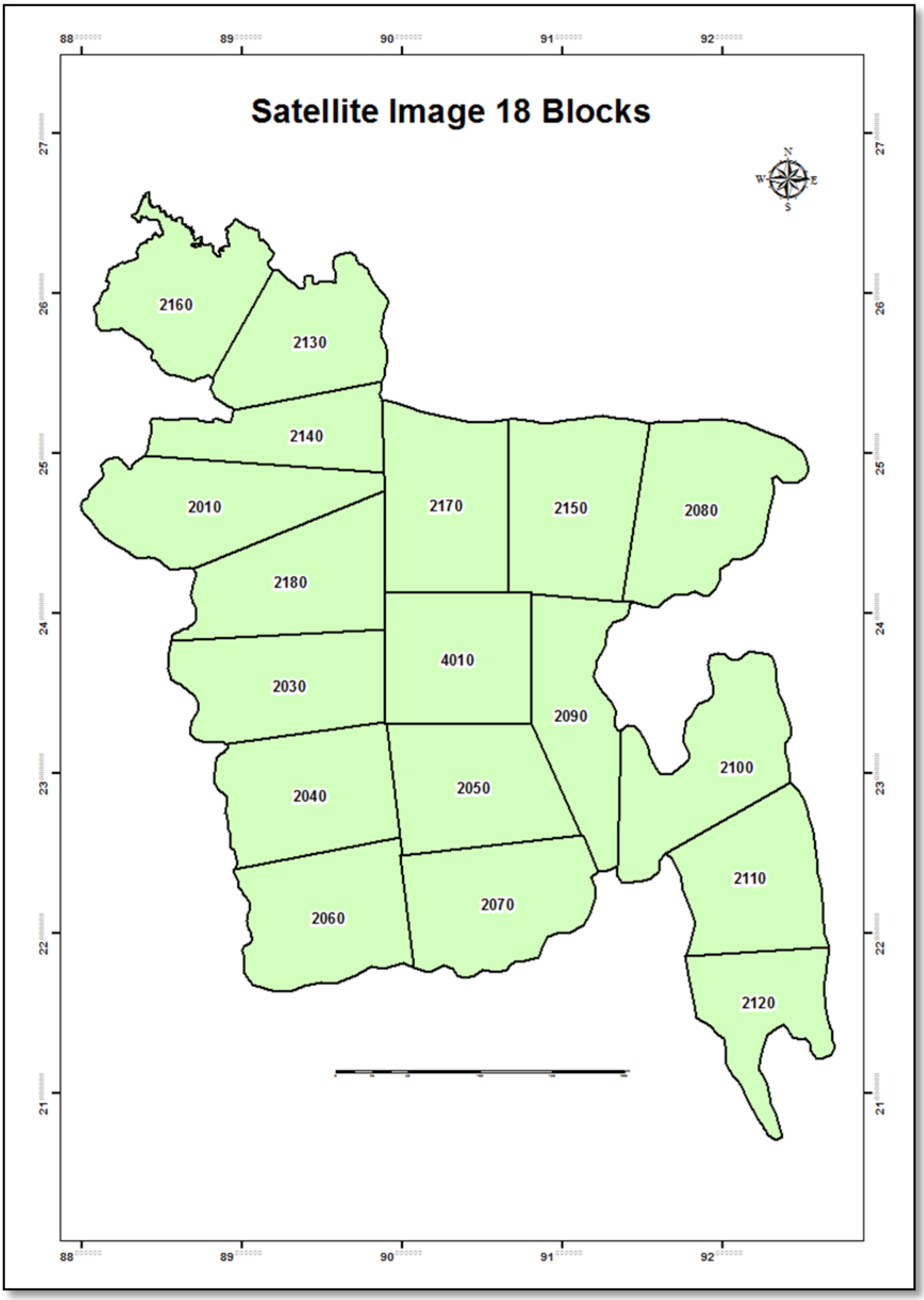


Figure 5-2: Map Showing 18 Satellite Image Delivery Blocks

Field Survey for Ground Truthing: For field survey, the survey team mainly followed the traditional RTK GPS survey which is a standard single-baseline solution between a base station and a rover unit. Besides for ground truthing survey, in few locations GNSS CORS network in 4 out of 6 stations of Survey of Bangladesh (SoB) as shown in Figure 5-3 and static observation method has been used as shown in Figure 5-3. The details of the survey methodology for ground truthing and survey findings are given in Volume-II: Appendix-A.

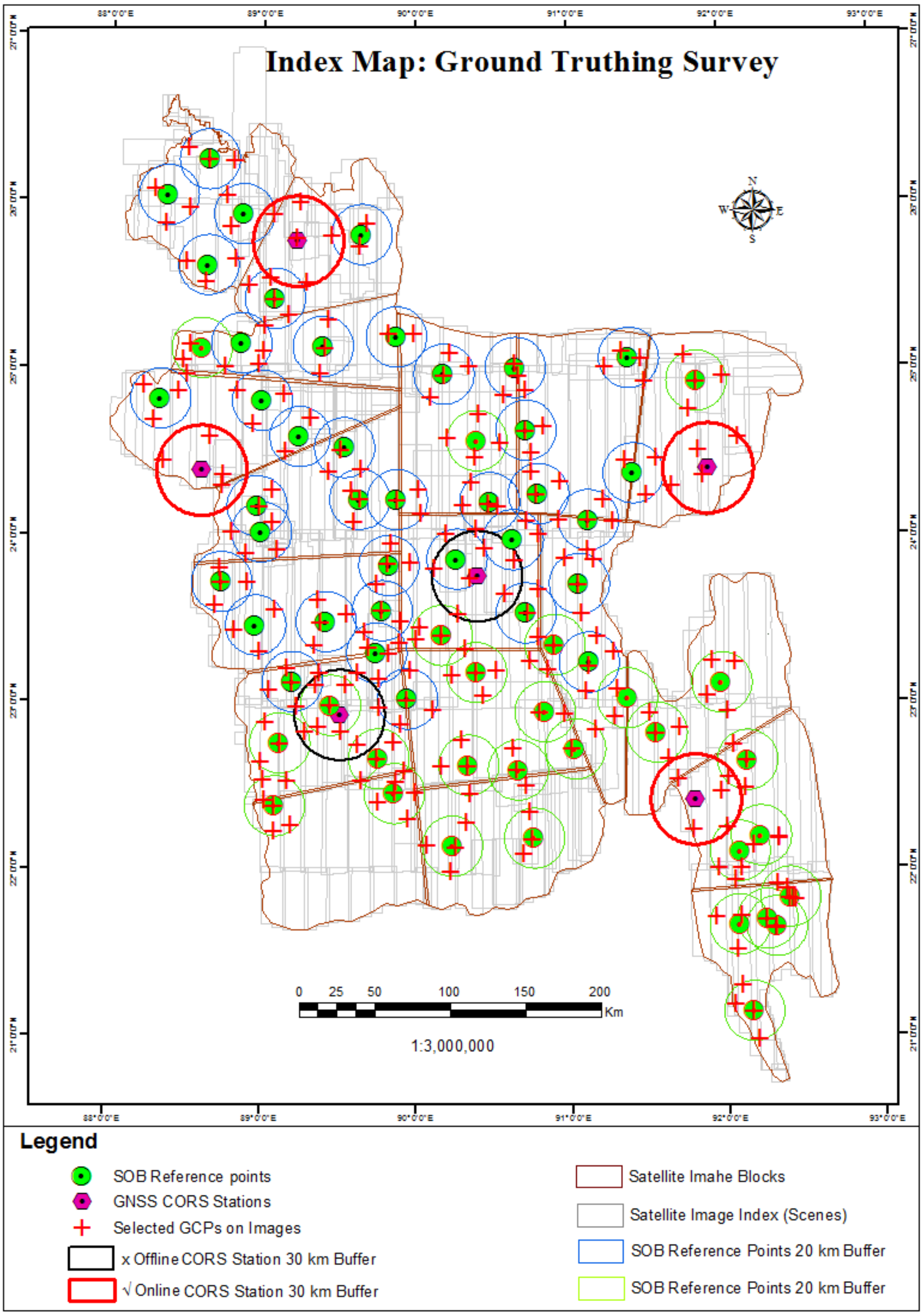


Figure 5-3: Map Showing Index Map for Ground Truthing Survey

Figure 5-4: RTK Base Station, SOB Geodetic Pillar (Left) and RTK Survey at Corner of a Plot (Right)

Geo-referencing Method: To create accurate image maps using satellite imagery, the imagery must be corrected to a map projection. This correction process is called orthorectification or geometric correction. The process requires the use of a rigorous geometric model, and a digital elevation model (DEM). Since the introduction of Rational Polynomial Coefficients (RPC) method to correct satellite imagery data, this method has become the most popular method to correct satellite data as it gives very good results without Ground Control Points (GCPs).

Imagery was received from DigitalGlobe as an ortho-ready standard product. The satellite image has been ortho-rectified using the "Rational Function Model (RFM)", which uses "Rational Polynomial Coefficients" (RPC) supplied by DigitalGlobe. The flow diagram of Orthorectification Process is shown in Figure 5-5. A 30m resolution DEM from the Shuttle Radar Topographic Mission (SRTM) has been used to compensate for terrain errors. Ground Control Points (GCPs) are not used as part of the Rational Function Model (RFM) as a high level of accuracy can be achieved with the RFM alone.

For checking, adequate number of ground truthing points has been measured in the field to ensure that the accuracy as stated has been achieved. All image processing has been performed using specialized image processing software called "PCI Geomatica".

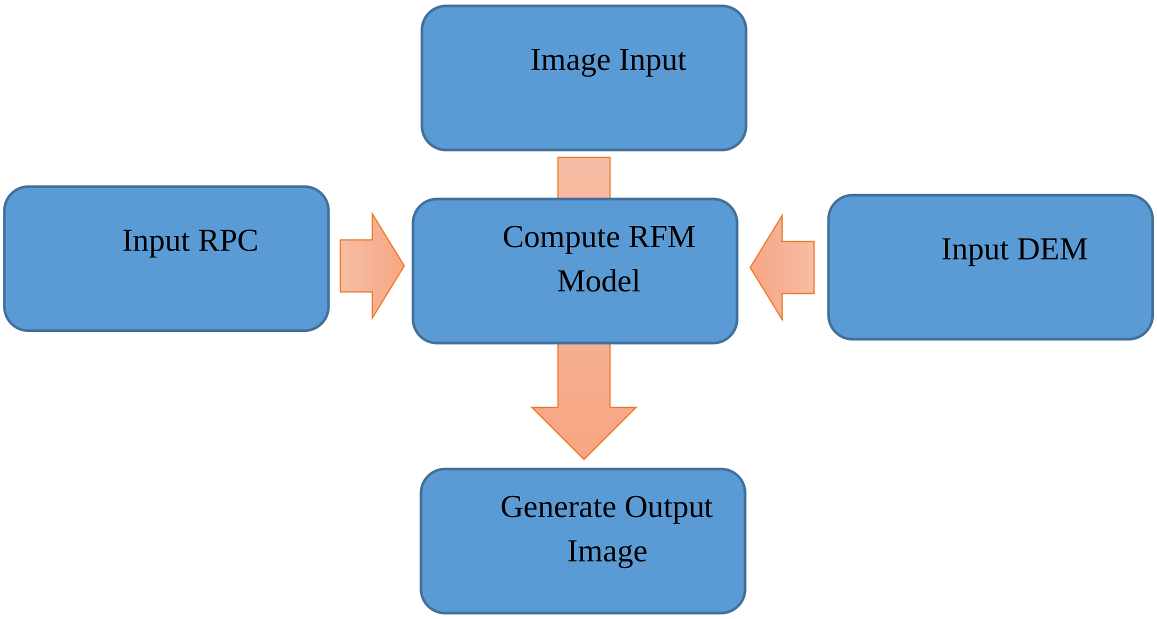


Figure 5-5: Orthorectification Process of Remote Sensed Image Data

***Task-6:* Classification of the Satellite Images Using Remote Sensing Software and Characterizing Connectivity Status with Other Channels**

Four types of classification can be done on satellite image. Those are (a) unsupervised classification, (b) supervised classification, (c) index-based classification and (d) object-based classification. Under this study exercise being done with first three type of classifications.

Unsupervised Classification: Unsupervised classification is computer automated pixel-based classification. Unsupervised Classification is for tentative estimation of waterbody and to get an overall idea for the study area. It helps to define signature that is required for supervised classification. Figure 5-6 exhibits image interpretation using Unsupervised Image Classification technique. For the purpose of classification technique, it was taken a small sample block sized about 9.49 Sq. Km. In the sample block image, observed wetland area (i.e., on-screen digitized area) is calculated about 3.41 Sq. Km. Whereas by using unsupervised image classification method, total wetland area was observed about 3.18 Sq. Km, which is near about 93.25 % of observed wetland area.

Supervised Classification: In supervised classification, it is required to select representative samples for each land cover class. The image processing software then uses these "training sites" and applies them to the entire image. Supervised classification uses the spectral signature defined in the training set.

Satellite images are being processed in Erdas Imagine Software. First, it needs that classify the image using unsupervised classification technique and then identify rough waterbodies for creation of signature file. After signature selection and evaluation, supervised classification is done for entire image.

Figure 5-7 illustrates image interpretation using Supervised Image Classification. In the sample block image, observed wetland area is about 3.41 Sq. Km. whereas by using Supervised Image Classification method total wetland area was found about 2.53 Sq. Km, which is near about 74.19 % of observed wetland area.

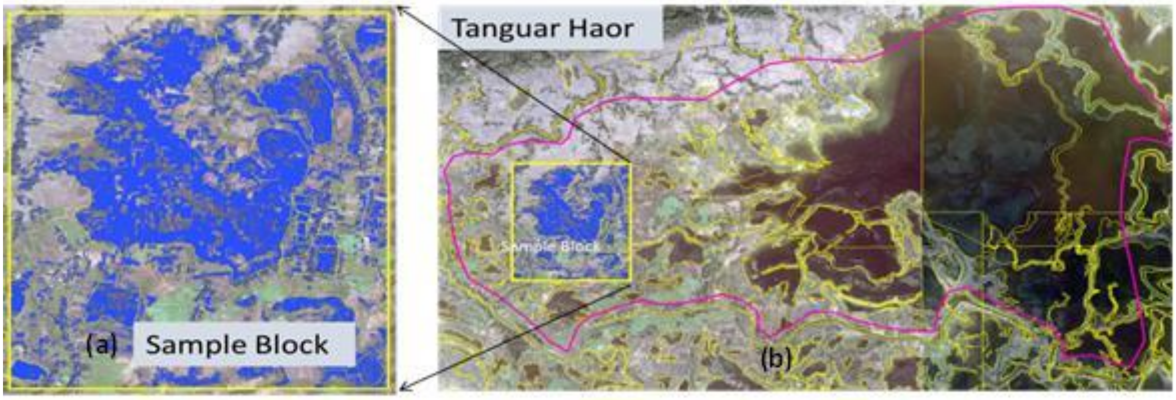


Figure 5-6: (a) The Result for Unsupervised Classification Technique (enlarged) for the Sample Block; (b) The Area of Sample Block (Shown in Rectangle Marked by Yellow Line) for Which Unsupervised Classification was Conducted

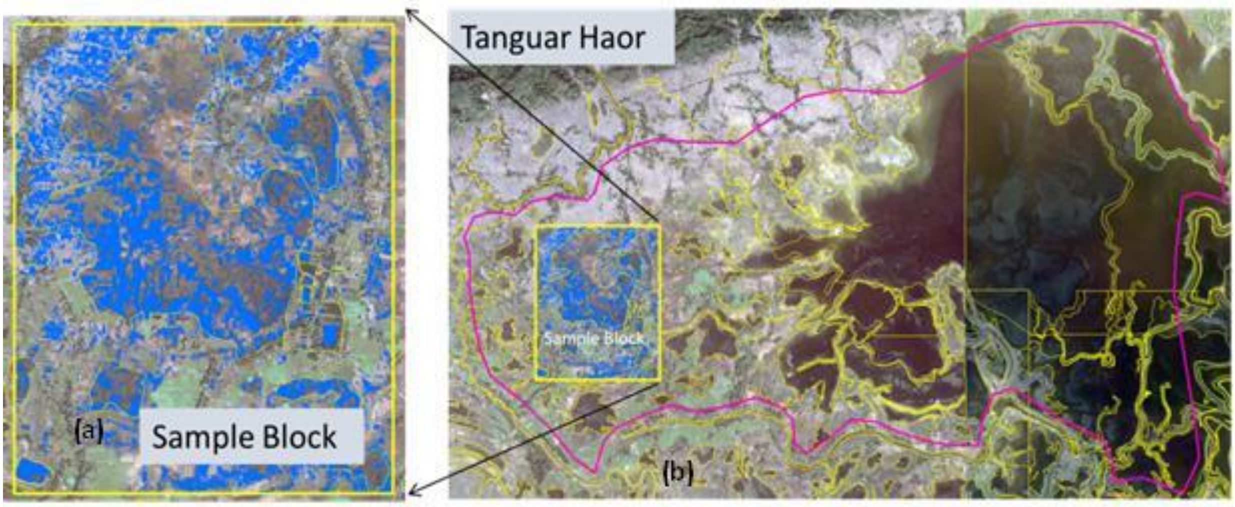


Figure 5-7: (a) The Result for Supervised Classification Technique (enlarged) for the Sample Block; (b) The Area of Sample Block (shown in Rectangle Marked by Yellow Line) for Which Supervised Classification was Conducted

Index Based Classification: The Normalized Difference Water Index (NDWI) is index-based wetland identification system. The wetland has strong absorbability and low radiation in the range from visible to infrared wavelengths. The index uses the green and Near Infra-red bands of remote sensing images based on this phenomenon. The NDWI can enhance the water information effectively in most cases.

$$\text{NDWI} = \frac{NIR - Green}{NIR + Green}$$

The lowest value of NDWI means more possibility of waterbody. Waterbodies are delineated using an acceptable threshold value of NDWI.

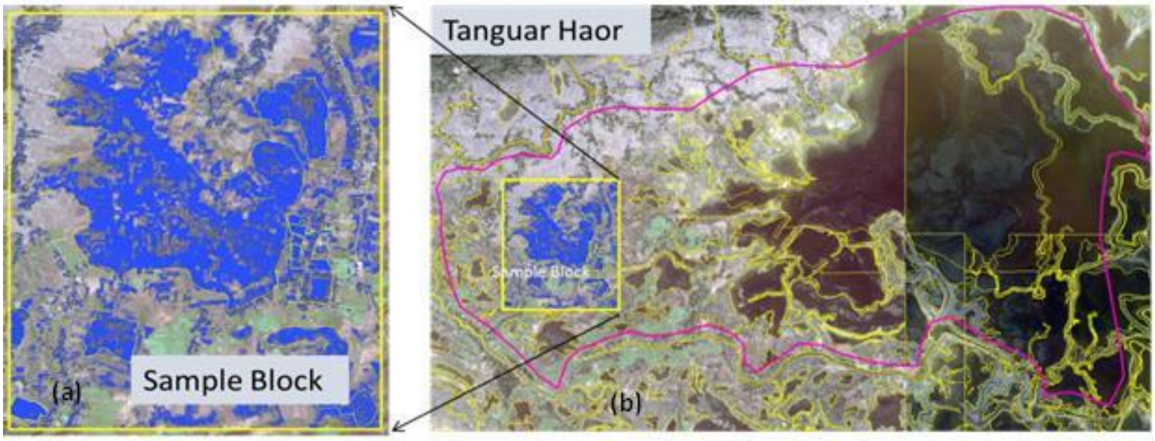


Figure 5-8: **Provides Image Interpretation Using NDWI. in the Sample Block Image Observed Wetland Area is About 3.41 Sq. Km. Whereas by Using NDWI Method Total Wetland Area is Found About 3.04 Sq. Km, which is near about 89.15% of Observed Wetland Area**

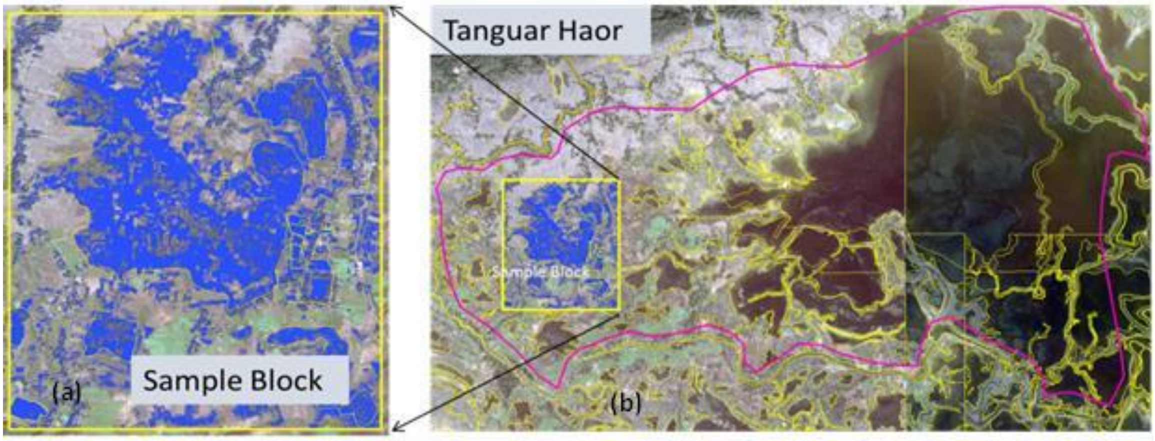


Figure 5-8: (a) The Result for NDWI for the Sample Block; (b) The Area of Sample Block (Shown in Rectangle Marked by Yellow Line) for Which NDWI was Calculated

***Task-7:* Delineation of Wetlands from Classified Images to Categorize Wetlands According to their Habitat Characteristics that Suits the Purpose of Wetland Management Framework**

As one of the major tasks of this project is to delineate wetland and to show its interactions with surrounding river network, the extent of wetlands for two seasons: dry season and wet season has been delineated. The image data showing the driest period is required to map the perennial waterbodies and the image representing wet season is required to show wetland's connectivity with surrounding river network.

For monsoon wetland delineation, average year (1:2.33 year) water levels in the major rivers have been considered. About 30 years time series water level data has been processed for several BWDB gauges in each region to find the closest date of average year flood. The mages of that date or closest to that date has been used for wetland delineation.

Collected high resolution images have been used for delineation of rivers and satellite images from other sources (e.g., Sentinel, Landsat etc.) also used to delineate the wetlands.

Considering the above-mentioned approach, the extent of wetlands has been produced for the driest and wettest periods using collected high resolution images. The Sentinel-1 and Sentinel-2 image have been used in wetland delineation for both wet and dry seasons. These images were duly pre-processed and later were classified in Erdas Imagine environment by using unsupervised classification technique. Finally, the classes resembled water were recoded and vectorized to get the wetland boundary for the dry and wet period.

***Task-8:* Re-delineation of Wetlands Using Historical Maps, Digital Elevation Model (DEM) and Available Existing Boundaries of Wetlands and Overlapping the Outcomes with the Findings of the Satellite Images to Determine the Accuracy and Reliability of the Data**

Re-delineation of wetland boundary involves collection of historical maps, Digital Elevation Model (DEM) and administrative boundaries. In this stage, the classified images have been overlaid with historical maps, DEM and administrative boundaries to demarcate the boundary of the wetlands. The wetland boundary has been further refined through application of the Participatory Resource Mapping (PRM) approach in consultation with local officials and stakeholders. Several number of field visits have been made in this regard to verify the delineated wetland boundary.

Re- delineation of wetlands using historical maps- The outline of the wetlands has been digitized from high resolution georeferenced up-to-dated satellite imagery complying with the guidelines from *"Module 1 of the National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia"*. The following steps have been followed to re-delineate the wetland boundary:

- Prepare geo-database
- Collection of Ground Control Point (GCP)
- Draw outline of wetland using Remote Sensing technology
- Quality Assessment & Field validation

The available historical data/maps have been used as reference of the wetland boundary.

A. Digital Elevation Model (DEM) - The digital elevation model has been generated using national DEM that was collected from Survey of Bangladesh (SoB). SoB is now implementing a project to produce 1:25,000 scale digital topographic maps and data covering whole Bangladesh territory using digital aerial photos and satellite images. In this connection, 980 sheets in total for open series map of 1: 25,000 scale in digital Form of Geo-database format (*.gdb) has been purchased from SOB. Appropriate interpolation method (IDW/ Kriging) has been adopted for generating DEM. A series of data quality assessment has been performed to ensure on preparing quality surface raster which includes-

i. <u>Checking the spatial distribution pattern</u> by plotting the data. A random, regular and discrete distribution patterns are fine, but in case of cluster distribution data has been rechecked as there is possibility of occurring void spaces between the cluster points.

ii. <u>Checking the high-low values of in RL</u> (Reduced Level) field if there is any abrupt or abnormal value in this field.

iii. <u>Frequency distribution of RL value</u> to check if there is any skewness in the curve. An ideal frequency destruction curve looks like as shown in Figure 5-9. But if any skewness is observed, then data has been further examined.

Figure 5-9: An Ideal Frequency Distribution Curve

iv. <u>Checking correlation</u> between horizontal and vertical data. A positive correlation represents a higher validity and reliability on the data source.

Task-9: **LiDAR Survey of Tanguar Haor for an Area of Approximately 120 sq. km. for Empirical Data Collection**

After completion of the full country coverage first by satellite imagery, a pilot study of approximately 120 square kilometers area located in Tanguar haor has been implemented by using LiDAR and simultaneous aerial photography survey.

The LiDAR & photo survey was conducted with a Riegl Q680i lidar equipment and Hasselblad H60 medium format aerial camera as shown in Figure 5-10. The project was surveyed with a Cessna 208 - Grand Caravan aircraft as shown in Figure 5-10.

Figure 5-10: LiDAR (Left), Camera (middle) and AVION (Right)

LiDAR Survey and Aerial Images Data Processing

Airborne laser scanner surveys are realized in three main phases as shown in Figure 5-11– the mission planning, the survey flight and the data processing (assuming the airborne laser scanning system is already calibrated).

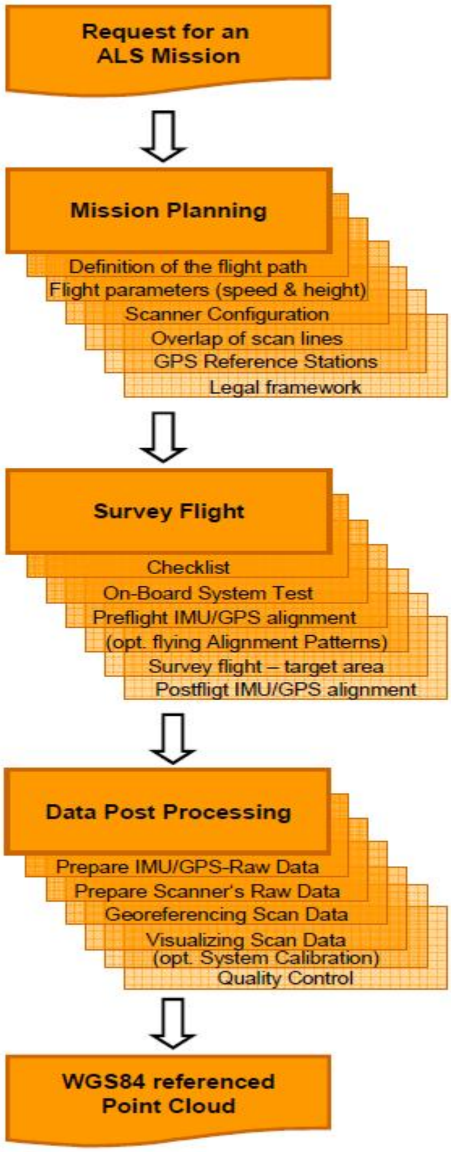


Figure 5-11: Flow Chart for LiDAR Survey and Image Processing

Task-10: **Classification of Wetlands of Bangladesh According to their Hydrological Functions, Important Ecosystem, Ecosystem Services, Physiographic Characteristics and Demography Through Reviewing Existing Literature, International Guidelines (e.g. Ramsar Guidelines) and other Relevant Documents**

In Bangladesh, traditionally the wetlands have been identified and given well defined names, such as rivers, haors, beels, lakes, ponds, dighis etc. The Ramsar Classification System of wetlands includes 42 types of wetlands, grouped into three categories: Marine and Coastal Wetlands, Inland Wetlands, and Human-made Wetlands. There are generally recognized 5 major types of wetlands (Ramsar, 1971). They are:

- Marine (coastal wetlands including coastal lagoons, rocky shores, and coral reefs);
- Estuarine (including deltas, tidal marshes, and mangrove swamps);

- Lacustrine (wetlands associated with lakes);
- Riverine (wetlands along rivers and streams); and
- Palustrine (meaning “marshy”; marshes, swamps and bogs).

The classification system of wetlands of Bangladesh has been developed earlier by DBHWD on the broad framework of Ramsar classification system of wetlands. As, Ramsar classification is a global system, it incorporates all types of characteristics of wetland existing all over the earth. Whereas, the classification system of Bangladesh is developed by specifically taking the characteristics of wetlands of Bangladesh into consideration. It can be mentioned that there are some other types of wetlands included on the Ramsar system that do not exist in Bangladesh, such as Tundra wetlands, Alpine wetlands or Karst Topography.

The notation of each type in the classification system of Bangladesh corresponds to the same type of wetland in Ramsar classification system. For example, for the type BA- ‘B’ stands for Bangladesh, ‘A’ stands for Ramsar type (Permanent shallow marine waters in most cases less than six meters deep at low tide; include sea bays and straits). The Ramsar system considered 3 systems of wetlands i.e., Marine and Coastal Wetlands, Inland Wetlands and Human-made Wetlands. But in Bangladesh wetlands classification system, a fourth system i.e. ‘Reversible Wetlands’ has been introduced. So, there are 4 systems in the Classification system of wetlands of Bangladesh. The classification system of wetlands that has been followed under this study can be summarized as shown in Table 5-1.

Table 5-1: Classification System of Wetlands of Bangladesh

Systems	Classes	Types Symbols	Name of wetland types
Marine/Coastal Wetlands	Permanent	BA	Permanent shallow marine waters in most cases less than six meters deep at low tide; includes sea bays and straits
		BB	Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows
		BC	Coral Reefs
		BF	Estuarine waters; permanent water of estuaries and estuarine systems of deltas
	Non-Permanent	BE	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune
		BG	Intertidal mud, sand or salt flats
		BI	Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests
Inland Wetlands	Permanent	BL	Permanent inland deltas
		BM	Permanent rivers/streams/creeks; includes waterfalls
		BO	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes
		BTp	Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season
	Non-Permanent	BN	Seasonal/intermittent/irregular rivers/streams/creeks
		BP	Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes
		BTs	Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes
		BU	Non-forested peatlands; includes shrub or open bogs, swamps, fens
		BW	Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils
		BXf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils
		BXp	Forested peatlands; peatswamp forests

Systems	Classes	Types Symbols	Name of wetland types
Human-made Wetlands	Permanent	B1	Aquaculture (e.g., fish/shrimp) ponds
		B2	Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha)
		B6	Water storage areas; reservoirs/barrages/dams/ impoundments (generally over 8 ha)
		B8	Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.
		B9	Canals and drainage channels, ditches
	Non-Permanent	B3	Irrigated land; includes irrigation channels and rice fields
		B4	Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)
		B5	Salt exploitation sites; salt pans, salines, etc
		B7	Excavations; gravel/brick/clay pits; borrow pits, mining pools
Reversible Wetlands		Brvc	Coastal polders and embankments
		Brvi	FCD and FCDI projects; flood protected inlands with embankments
		Brve	Environmentally degraded, but restorable wetlands

[Note 1:
BX – 'B' stands for Bangladesh, 'X' stands for corresponding X type of Ramsar wetland type
Example:
BA – 'B' stands for Bangladesh, 'A' stands for Ramsar type (A: Permanent shallow marine waters in most cases less than six meters deep at low tide; includes sea bays andstraits)
B1 – 'B' stands for Bangladesh, '1' stands for Ramsar type (1: Aquaculture (e.g., fish/shrimp) ponds)
Note 2:
Brvc – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands; 'c' stands for Coastal Polders and embankments.
Brvi – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands, 'i' stands for FCD and FCDI projects; flood protected inlands with embankments.
Brve – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands, 'e' stands for environmentally degraded, but restorable wetlands.]

Task-11: Prioritize of the Most Appropriate Wetland Classification Criteria for Bangladesh and Clustering them

After reviewing the classification systems of wetlands i.e Ramsar, FGDC of the USA, Vietnamese, Indian etc. and also considering perceived concept of wetlands, the Strategy for Classification Systems has been developed. Thereafter, the Classification System of Wetlands of Bangladesh has been prepared.

The wetlands in Bangladesh encompass a wide verity of dynamic ecosystems including ranging from mangrove forest, natural lakes, man-made reservoir, freshwater marshes (haor), oxbow lakes (baors), freshwater depressions (beels), fish ponds and tank, estuaries, and seasonal inundated extensive floodplains. The clustering of the classified wetland according to their characteristics and functions is crucial. In the active floodplains of Bangladesh, the Surma-Meghna, the Brahmaputra-Jamuna, and the Ganges-Padma river systems, there are several large and small wetlands. The National Water Management Plan, 2004 has delineated the eight Hydrological Regions in Bangladesh, based on the major river system, for planning and development of water resources. The Hydrological Regions are Southwest (SW), Northeast (NE), North Central (NC), Northwest (NW), South Central (SC), Southeast (SE), Eastern Hills (EH), River and Estuary Region (RE). On the other hand the Agro-Ecological zones of Bangladesh have been identified on the basis of four elements such as physiography, soils, land levels in relation to flooding and agro-climatology whereas Bio-ecological zones are more or less similar to the Agro-ecological zones. Initially these three maps have been taken into consideration for clustering of wetlands by superimposing with each other. Finally, for the ease of simplicity, the clustering has been introduced based on hydrological regions as mentioned above.

***Task-12:* Identification of Connectivity of Haor and Wetlands with Adjacent River System to find out the interaction Between Haor and River Ecosystem**

For monsoon wetland delineation, average year (1:2.33 yr) water levels in the major rivers have been considered. About 30 years' time series water level data has been processed for several BWDB gauges in each region to find the closest date of average year flood. The mages of that date or closest to that date has been used to show wetland's connectivity with surrounding river network. Collected high resolution images have been used for delineation of rivers and satellite images from other sources (e.g., Sentinel, Landsat etc.) also used to delineate the wetlands.

Considering the above-mentioned approach, the extent of wetlands has been produced for the driest and wettest periods using collected high resolution images. The Sentinel-1 and Sentinel-2 image have been used in wetland delineation for both wet and dry seasons. These images were duly pre-processed and later were classified in Erdas Imagine environment by using unsupervised classification technique. Finally, connectivity of identified wetlands with their adjacent rivers has been identified to find out the interaction between haor and river ecosystem.

***Task-13:* Development of an Inventory of Wetland Along with Different Categorical Contour Map Through Collection of Data on their Functions, Geo-morphological Data, Physiographic Features, Flora and Fauna Species and Conducting Hydrological Assessment of Different Wetlands Through Physical Surveys**

One the component of this study is to cluster the identified wetland according to their characteristics and functions. In the active floodplains of Bangladesh, the Surma-Meghna, the Brahmaputra-Jamuna, and the Ganges-Padma river systems, there are several large and small wetlands. The National Water Management Plan, 2004 has delineated the eight Hydrological Regions in Bangladesh, based on the major river system, for planning and development of water resources. The Hydrological Regions are Southwest (SW), Northeast (NE), North Central (NC), Northwest (NW), South Central (SC), Southeast (SE), Eastern Hills (EH), River and Estuary Region (RE). On the other hand the Agro-Ecological zones of Bangladesh have been identified on the basis of four elements such as physiography, soils, land levels in relation to flooding and agro-climatology whereas Bio-ecological zones are more or less similar to the Agro-ecological zones. Initially these three maps have been taken into consideration for clustering of wetlands. Finally, for the ease of simplicity, the clustering has been introduced based on hydrological regions as mentioned above.

The wetlands in Bangladesh encompass a wide verity of dynamic ecosystems including ranging from mangrove forest, natural lakes, man-made reservoir, freshwater marshes (haor), oxbow lakes (baors), freshwater depressions (beels), fish ponds and tank, estuaries, and seasonal inundated extensive floodplains. Four major types of wetlands like Haor, Beel, Lake and Baor (Oxbow lake) were investigated under this study. The wetlands were selected for data collection and investigation purposively basing on their characteristics and function, particularly the focus was given to the provisioning (resources for livelihood), regulating (environmental controlling factors), supporting (biodiversity and habitat context) ecosystem services provided by the wetlands. Baikka Beel was selected from North East wetland cluster. Borobila beel was selected from North Central wetland cluster. Beel Halti was selected from North Western wetland cluster. Baluhor Baor and Borni Baor were selected from south western wetland cluster and Kaptai Lake was selected from Eastern hill cluster. These 6 wetlands were selected for detail vegetation, fisheries, biodiversity inventory study in consultation with the client.

Task-14: Evaluation of the Region Wise Clustered Wetland's Value Through Field Survey

A total of four types of values have been considered to assess the evaluation of wetland; these are (i) Ecological value, (ii) Economical value, (iii) Hydrological value and (iv) Social value. The most significant benefits provided by the wetlands are fishing, agricultural product, medicinal herbs, water for livestock, water for general use, transport and tourism, etc.

Ecological Value: Ecological values include the presence of rare or endangered species or habitat (flora, fauna & fish), and biodiversity of wetland. For each of these, the value present at wetland is considered alongside the spatial distribution of the same value in a wider area and these two scores are entered in axes 1 and 2 in the combination matrix.

Economical Value: Economical values of wetlands include tourism, fisheries, agriculture, additional goods & services, and other economic values. Each of these aspects is considered in terms of the proportion of wetland income that the value provides and the percentage of the adult community that are involved in the value. By considering both aspects, the monetary and community importance of the value are represented and the dependency of the community on a wetland value is reflected.

Hydrological Value: Hydrological values include provision of water for irrigation scheme, flood storage, future hydro-electric power (HEP) scheme, maintenance of flows during droughts and provision of drinking water. Each value is considered in terms of the size of the population that benefit from the value and the feasibility of providing the value through another means. As the hydrological value can affect a large area downstream of wetland, the population affected by the value could be much larger than the community living directly around the wetland. The number of people that benefit from a hydrological value may vary greatly. For example, the provision of water for flood storage may affect millions of people, whereas the provision of a potable water supply may only affect several hundred people. However, both are of great importance to the communities that benefit.

Social Value: The social values include the religious importance and cultural importance. By their nature, the assessments are likely to be prone to the greatest subjectivity. Each value is considered in terms of the importance of the site and the uniqueness of the site for the value.

Task-15: Identification of the Most Possible Causes of Wetland Degradation and Sources of Pollution

Wetlands are dynamic areas, open to influence from natural and human factors. Wetlands all around the country are facing degradation due to human intervention such as illegal landfills (reclamation) along riverbanks, construction of embankments, flood control structures and roads, improper sluice gate management, increased irrigation for agriculture and over exploitation of aquatic resources. Wetlands have also been degraded by unsustainable land use practices; vegetation destruction; nutrient and toxin loading, sedimentation, turbidity, and altered flow regimes. Intensive use of agrochemicals and water transport has also affected the natural balance of wetlands. The people of these localities whose livelihood depended on wetland-based earnings suffer due to these interventions which enhanced the loss of fish production and biodiversity in floodplain ecosystems. At the same time, water absorption capacity of floodplain areas during monsoon has reduced, which escalates the risk of floods in the region. Therefore, there is a dire need to manage the wetlands in an integrated approach so that the renewability of the natural resources could be maintained while sustaining social and economic benefits from the wetlands and biodiversity. A comprehensive data collection programs, field campaign and stakeholder’s consultation has been conducted under this study to identify the causes of wetland degradation as well as to find out the possible sources of pollution for the Ramsar sites in Bangladesh.

Pollution in and around the wetland is a growing concern. Water quality samples has been taken from the selected wetlands among the cluster. The in-situ measurement of physical parameter as well as laboratory testing has been conducted under this study.

Task-16: **Assessment of the Vulnerability of Wetland Considering their Importance in Ecosystem and Resource Conservation**

The vulnerability of wetlands has been assessed as per guidelines of Ramsar Convention (1971) & Convention on Biological Diversity (CBD, 2006) as well as Millennium Ecosystem Assessment (MEA, 2005). A total of four major issues have been considered to assess the vulnerability. Details procedure has been presented in Figure 5-12, and descriptions of those issues are given below:

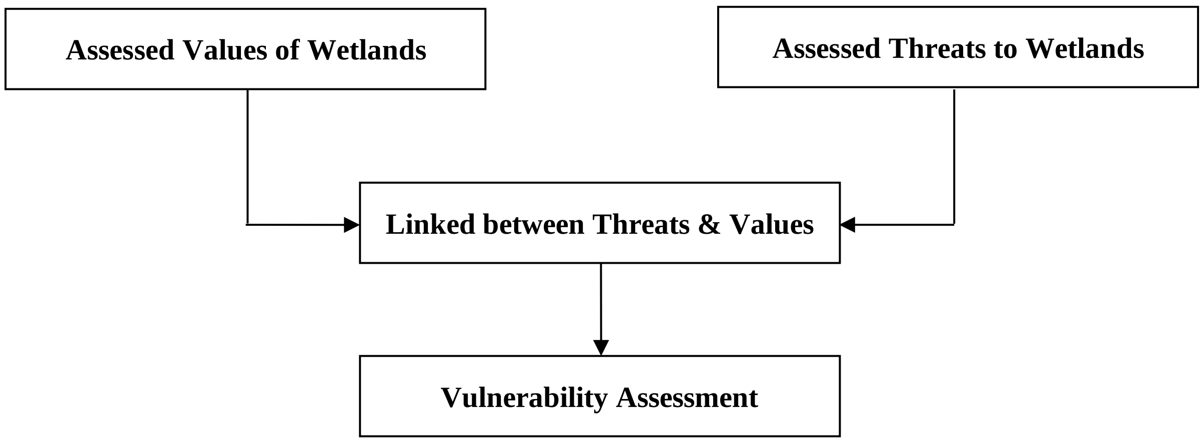


Figure 5-12: Outline of the Vulnerability Assessment Methodology

I. **Values Assessment:** The values are split into four categories viz. ecological, economic, hydrological & social, and within each category, there are pre-defined values. Each value is given two 'scores', the first score relates to the magnitude of the value and the second relates to the reliance on the value. These scores are combined in a simple matrix to give a single score that reflects both the magnitude and reliance of each value.

II. **Threats Assessment:** As with the values, a list of pre-defined threats is given. Two scores, one for severity of threat and one for likelihood of threat, are given to each threat and a simple matrix is used to give a single score.

III. **Links between Values & Threats:** The matrix table determines how the threats are likely to impact on the values.

IV. **Vulnerability Assessment:** Once all of the inputs values are entered in the matrix table, then the vulnerability assessment has been completed.

Each value and threat have been given scores such as High (H), Medium (M), Low (L), and None (N). The two areas then brought together via 'links between threats and values. H, M, L and N scores have entered in the matrix table to determine which threats impact on which values and the magnitude of those impacts. The final stage combines all values in a matrix to give a single value for each value and threat intersect, which have shown in below:

Value Score X *Link* X *Threat Score* = *Final Assessment Value*

where the scores H, M, L and N have numerical values of 3, 2, 1 and 0, respectively. So the final assessment score will be a number between 0 and 27 where values between 0 and 9 are color coded green, values between 10 and 18 are color coded amber and values between 19 and 27 are color coded red as shown in Table 5-2.

Table 5-2: Matrix for Combining Value or Threat Scores

		Axis 1		
		Low	**Medium**	**High**
Axis 2	**Low**	**L**	**L**	**M**
	Medium	**L**	**M**	**H**
	High	**M**	**H**	**H**

***Task-17:* Delineation of Ecosystem Boundary of Clustered Wetlands Based on their Classification Using GIS and RS Technology**

An ecosystem could simply be defined as a collection of communities of organisms (biotic) and the environment (abiotic) in which they live and interact with each other. It is normally an open system with a continuous but variable influx and loss of material and energy. It is a basic, functional unit with no limits of boundaries. It represents the highest level of ecological integration, which is energy based, and this functional unit is capable of energy transformation, accumulation and circulation. In ecological sense, its main function is to emphasize obligatory relationships, inter-dependence & casual relations. On the other hand, ecosystem boundaries are the locations exhibiting gradients of change in environmental conditions and a related shift in the composition of plant and/or animal communities.

Wetland ecosystem in Bangladesh provides supportive habitat for different types of faunal species under four biological classes namely amphibia, reptilia, aves and mammalia. All species under this classification remain in a single ecosystem, commonly known as wetland ecosystem. No specific methods have been identified on this issue through literatures review. Delineation of wetland ecosystem boundary from faunal biodiversity perspective is depends on faunal species home range identification that generally perform through specific study on target faunal species home range analysis via radio-telemetry technique.

The major eco-components of faunal biodiversity are (i) Amphibia, (ii) Reptile, (iii) Aves and (iv) Mammal. Ecosystem boundary of these faunal biodiversity has been described below in brief:

Amphibia: The amphibian species require both water and land for their survival. The travel distance varies among the amphibian species, and in general, maximum travel distances of some amphibian species (terrestrial & aquatic) are in between 300m to 500m from the wetland boundary. So, this distance could be the probable home range / ecosystem boundary for the amphibian species.

Reptile: Reptilian species vary among themselves, and most species require both water and land for their survival. The travel distance varies among the reptilian species, and in general, maximum travel distance of few reptilian species could be in between 0.5km to 1.0km from the wetland boundary. So, this distance could be the probable ecosystem boundary for the reptilian species.

Aves: Avian species are diversified, and some species require both water and land for their survival. The travel distance varies among the avian species, and in general, maximum travel distance of few avian species could be in between 2.0km to 4.0km from the wetland boundary. So, this distance could be the probable home range / ecosystem boundary for the avian species.

Mammal: Mammalian species vary among themselves, and few species require both water and land for their survival. The travel distance varies among the mammalian species, and in general, maximum travel distance of few mammalian species could be in between 2.0km to 5.0km from the wetland boundary. So, this distance could be the probable home range / ecosystem boundary for the mammalian species.

Task-18: Intensive Consultation with Local People and Different Officials of Different Government Organizations to Find out Gaps, and Incorporating Their Suggestions for Successful Completion of the Wetland Inventory

Stakeholder consultation has been conducted at different stages of the study with different users of wetland for gathering qualitative information to develop the Cluster-wise management framework. Stakeholder analysis has been carried out to address pertinent study objectives and to capture the diverse interests of different groups that are involved in these respective wetland management systems. Stakeholder selection criteria included: 1) dependency on wetland and floodplain resources, 2) diversity of the resource users, i.e. fishermen, farmers, small traders, women 3) resource users practicing traditional management approaches, 4) resource users involved in associations and networks, 5) most impacted resource users, 6) policy makers 7) local elites, NGOs and civil society. The study was conducted through applying participatory research methods, specifically Participatory Rural Appraisal (PRA) and also involved Key Informant Interviews (KII), semi structured interviews, Focus Group Discussions (FGD). Key Informant Interview, semi –structure interview, Focus Group Discussion were the chosen methods for stakeholder analysis. Previously mentioned stakeholders from different locations of Hakaluki haor, Tanguar haor, Ratargul Swamp Forest, Baikka beel, Kaptai Lake, Baluhor baor, Borni baor, Borobila beel and Beel Halti has been taken into consideration for stakeholder consultation.

***Task-19:* Finalization of the Inventory of Wetland in Bangladesh**

The inventory of wetlands includes the production of hierarchical and map-based outputs. The level of detail is related to the scale of the maps that are contained within a standardized GIS format with a minimum core data set. The hierarchical approach comprises a progression in scale from river basins to individual sites. The initial analysis (level 1) involves delineation of geographical regions (major river basins) and encompasses a description of the geology, climate and ecology of each based on existing information sources. Level 2 analysis concerns delineation of wetland regions within each geographic region. This is done on the basis of similar climatic, geologic, hydrologic and vegetation features. Several meetings and discussion were held among the different stakeholders to finalize the inventory method. The outcomes from the meetings and discussion is to develop the inventory based on hydrological region of Bangladesh and prepare the map-based outputs in 1:10000 scale. As per the comments and suggestions from the expert, the inventory has been finalized in tabular format including the location (districts, upazila, union and mouza), area and other physical features such as geology, agro- ecological zone and bio-ecological zone and others.

***Task-20:* Selection of Cluster-wise Best Practice of Wetland Management Through Assessing the Existing Management Practices, Reviewing the International Wetland Management Guidelines and Stakeholder Consultation**

To recognize the best practice of managing wetlands, available scientific and technical information, literatures, guidelines relevant to the wetland management has been collected. After categorizing them the international wetlands management guidelines such as the Ramsar guideline has been thoroughly reviewed. Some regional community-based wetland management practices have been developed by the IUCN, MACH, CNRS, CARITAS, CBFM, Department of Fisheries and others, which has also been reviewed and compared with the international practices to primarily select a management practice for the wetlands of Bangladesh. Several consultation meetings with local stakeholders has been arranged to identify the best practices ever established at local level or to find out indigenous knowledge developed by any community to protect the resources of wetlands and manage the sustainable use and equitable share of wetland resources.

Both quantitative and qualitative data and information has been collected and analyzed using the latest analytical tools in respect of the previously developed indicators for the wetlands of Ramsar sites in Bangladesh.

Task-21: **Selection of Pilot Sites and Implementation, Monitoring and Evaluation of Piloting Will Help to Find out Gap in Selected Best Management Practices**

As a part of the study, a pilot site has been selected based on four criterions such as, Physical and Hydrological Criteria, Social Criteria, Biological Criteria, Management/ General Criteria. To select a new site for piloting, it needs a longer period of monitoring as well as investments in the field for maintaining the bio-ecological ecosystem. Considering the limitation of time and financial support, Baikka beel has been selected as a pilot site as because it has been operated by Management of Aquatic Resources through Community Husbandry (MACH) program since 2003. Under this study, the impact of MACH project has been conducted in comparison between the baseline data and data collected under this study. Also, the gaps and limitations of the management approach have been evaluated in this study. For field data a collection a team comprising of fisheries expert, ecologist, forest expert, and sociologist has visited the Baikka beel area for the duration of 10 to 14 December 2019.

Task-22: **Finalization of Wetland Management Framework Based on their Cluster-Wise Best Management Practices and Piloting Results**

Cluster-wise management framework has been finalized through extensive stakeholder consultation. Findings and knowledge gap from stakeholder consultation and piloting results has been compiled using the ecosystem knowledge base to reduce and update lack of the wetland management practices and hence, to develop a cluster-wise wetland management framework. Several consultation meetings with local stakeholders has been arranged to identify the best practices ever established at local level or to find out indigenous knowledge developed by any community to protect the resources of wetlands and manage the sustainable use and equitable share of wetland resources.

Task-23: **Dissemination of the Concept of Wetland Inventory and Cluster-wise Wetland Management Framework through Workshops and Documentation**

Awareness program has been conducted among communities, local wetland users, vulnerable groups, local leaders and stakeholders of different sectors for sustainable use of wetlands. Several stakeholders' consultation and workshops has been organized to disseminate the concept of the wetland inventory and cluster-wise wetland management framework.

Workshops has been arranged at field level to disseminate and share the study results with the beneficiaries of the project. Feedbacks from the stakeholders has been addressed in the Draft Final Report. Another workshop will be arranged at Dhaka after submission of DFR to involve the stakeholders & concerned officials.

Task-24: **Transfer of Technology through Training Program**

Technology transfer is an essential element for successful completion of a project. Training and capacity building ensure the boosting up of the capabilities of the staffs and officials from the concerned agencies/ departments. In this regard since the inception of the project, technology transfer through on-the-job trainings of various activities in the project, interaction meetings and study tour to the concerned officials has been conducted.

According to the ToR the consultants has addressed this very important task through in-formal trainings that has been held on the following issues:

- Application and use of wetland inventory for DBHWD/GoB officials and community peoples.
- Community based livelihoods & value chain training for community peoples.
- Study tour to Asia for DBHWD/GoB officials (DBHWD-5 persons, MoWR-5 persons, PC-2 person, WARPO – 1 person)
- In-country learning visits for DBHWD/GoB officials and community peoples

Task-25**: Reporting**

According to the requirement of the project, several project reporting activities have been done within the study duration. Inception report has been submitted on June 04, 2017 which describes approaches and methodologies to carry out different scope of services. A total 10 nos. of Quarterly Progress Report (QPR) has been submitted at the end of 3rd month for keeping track of the development achieved by the consultants. This report is the Draft Final Report (DFR). A workshop will be arranged at Dhaka on DFR to share the study outputs to the stakeholders and concerned officials. Final report will be submitted after addressing the suggestions to be obtained from the workshop on DFR.

6 DATA COLLECTION AND PROCESSING

6.1 General

The project has been formulated with a view to prepare an inventory of the wetlands of the country through classification of satellite images, delineations of wetlands, study of interaction between haor and river ecosystems and LiDAR survey of Tanguar haor for an area of approximately 120 sq. km. for empirical data collection. To fulfill the study objectives, a comprehensive data collection program has been taken both from the secondary as well as from field survey which is outlined in this chapter. The activities that have been undertaken can be broadly categorized under the following major groups:

- Collection of reports and review of past studies
- Data collection and analysis from the secondary sources
- Data collection and analysis from the field survey

6.2 Review of Past Studies

To acquire preliminary understanding on the previous research and development activities in the project area, available reports and information have been collected and a review has been made. The list of the reports/papers is presented in the Table 6-1 and the findings from the major projects relevant with the study has been reviewed and presented in Chapter 3. However, for the clear understanding on the project, performance of past interventions, its problems and prospects, integrated effort would be continued throughout the study period.

Table 6-1: List of the Reports and Papers

No.	Name of Report/Book	Published By	Year
1.	State and management of wetlands in Bangladesh	International Consortium of Landscape and Ecological Engineering and Springer	2008
2.	Classification of Wetlands of Bangladesh	Prosoil Foundation Consultant, Department of Bangladesh Haor & Wetlands Development, Ministry of Water Resources.	2016
3.	Bio-Ecological Zones of Bangladesh	IUCN, Bangladesh Country Office.	2002
4.	Major Interventions for Sustainable Wetland Resource Management	IUCN: The World Conservation Union, Bangladesh Country Office.	2005
5.	Approaches to Sustainable Wetland Resource Management	IUCN: The World Conservation Union, Bangladesh Country Office.	2005

No.	Name of Report/Book	Published By	Year
6.	A Plan for Ensuring Sustainability of Community Based *Haor* and Floodplain Resource Management Projects	IUCN: The World Conservation Union, Bangladesh Country Office.	2005
7.	Re-excavation: A Major Step in Wetland Restoration in the *Haors*	IUCN: The World Conservation Union, Bangladesh Country Office.	2005
8.	Re-excavation: A Major Step in Wetland Restoration in the Floodplains	IUCN: The World Conservation Union, Bangladesh Country Office.	2005
9.	Hydro-Meteorological Characteristics of Hakaluki *Haor*	IUCN: The World Conservation Union, Bangladesh Country Office.	2005
10.	BIODIVERSITY OF TANGUAR HAOR: A RAMSAR SITE OF BANGLADESH Volume I: Wildlife (Amphibians, Reptiles, Birds and Mammals	IUCN: The World Conservation Union, Bangladesh Country Office.	2012
11.	BIODIVERSITY OF TANGUAR HAOR: A RAMSAR SITE OF BANGLADESH Volume II: Flora	IUCN: The World Conservation Union, Bangladesh Country Office.	2012
12.	IUCN in Bangladesh 2013	IUCN: The World Conservation Union, Bangladesh Country Office	2013
13.	Tanguar Haor Management Plan Framework and Guidelines	IUCN: The World Conservation Union, Bangladesh Country Office	2015
14.	National Framework for Establishing and Managing Marine Protected Areas (MPAs) in Bangladesh	IUCN: The World Conservation Union, Bangladesh Country Office	2015
15.	Transboundary River Basins *Status and Trends*	United Nations Environment Programme (UNEP)	2016
16.	Marine Protected Area Needs in the South Asian Seas Region Volume 1: Bangladesh	IUCN: The World Conservation Union, Bangladesh Country Office	1993
17.	*Wetland conservation and sustainable use in Romania*	11th Meeting of the Conference of the Parties to the Convention on Wetlands, Bucharest, Romania	2012
18.	Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance of the Convention on Wetlands (Ramsar, Iran, 1971) – 2012 revision	11th Meeting of the Conference of the Parties to the Convention on Wetlands, Bucharest, Romania	2012

No.	Name of Report/Book	Published By	Year
19.	Guidelines for developing and implementing National Wetland Policies	Resolution VII.6 (1999) of the Ramsar Convention on Wetlands	1999
20.	A Conceptual Framework for the wise use of wetlands and the maintenance of their ecological character	9th Meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971)	2005
21.	Handbook 2 National Wetland Policies, *4th edition*	Ramsar Convention Secretariat	2010
22.	Handbook 8 Water -related guidance, *4th edition*	Ramsar Convention Secretariat	2010
23.	Handbook 11 Managing groundwater, *4th edition*	Ramsar Convention Secretariat	2010
24.	Handbook 13 Inventory, assessment, and Monitoring, *4th edition*	Ramsar Convention Secretariat	2010
25.	Handbook 15 Wetland inventory, *4th edition*	Ramsar Convention Secretariat	2010
26.	Handbook 16 Impact assessment, *4th edition*	Ramsar Convention Secretariat	2010
27.	Handbook 18 Managing wetlands, *4th edition*	Ramsar Convention Secretariat	2010
28.	Principles and guidelines for wetland restoration	8th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands (Ramsar, Iran, 1971)	2002
29.	A Framework for a Wetland Inventory Metadatabase	Ramsar Convention Secretariat	2010
30.	A Framework for assessing the vulnerability of wetlands to climate change	Ramsar Convention Secretariat	2011
31.	The Ramsar Convention Manual, 6th edition	Ramsar Convention Secretariat	2013

6.3 Secondary Data Collection, Review and Analysis

A comprehensive data collection program from the secondary sources has been taken which include the following:

- Topographic Data/ Digital Elevation Model
- Landuse type
- Soil profile
- River alignment, cross section data etc.
- Surface water level and discharge data

Secondary Data have been collected from the following organizations:

- Survey of Bangladesh (SoB)

- Soil Resource Development Institute (SRDI)
- Bangladesh Water Development Board (BWDB)
- Water Resources Planning Organization (WARPO)
- Department of Bangladesh Haor and Wetlands Development (DBHWD)
- Bangladesh Meteorological Department (BMD)
- Bangladesh Agricultural Development Corporation (BADC)
- Others

It has been observed that, some of the data are not sufficient while some are not available from secondary sources. All secondary and primary data has been checked for quality and consistency using standard procedure. The details of data collection are described in the following sections.

6.3.1 Digital Elevation Model (DEM) Data

The topographic data available in IWM and Survey of Bangladesh (SoB) has been used to produce the DEM of Bangladesh as shown in Figure 6-1. SoB is now implementing a project to produce 1:25,000 scale digital topographic maps and data covering whole Bangladesh territory using digital aerial photos and satellite images. In this connection, 980 sheets in total for open series map of 1: 25,000 scale in digital Form of Geo-database format (*.gdb) has been purchased from SoB. Digital terrain model (DTM), which is a digital representation of the terrain surface, given by

a. Gridded data points, where a uniform grid is established in the horizontal (XY) plane, and the elevation at each grid intersection is given, or

b. Random data points, at locations where significant elevation changes occur.

The specifications of data available in SoB are as follows whereas the details are given in Table 6-2.

DTM points interval = 20 meter
Accuracy of DTM points = +/- 50cm

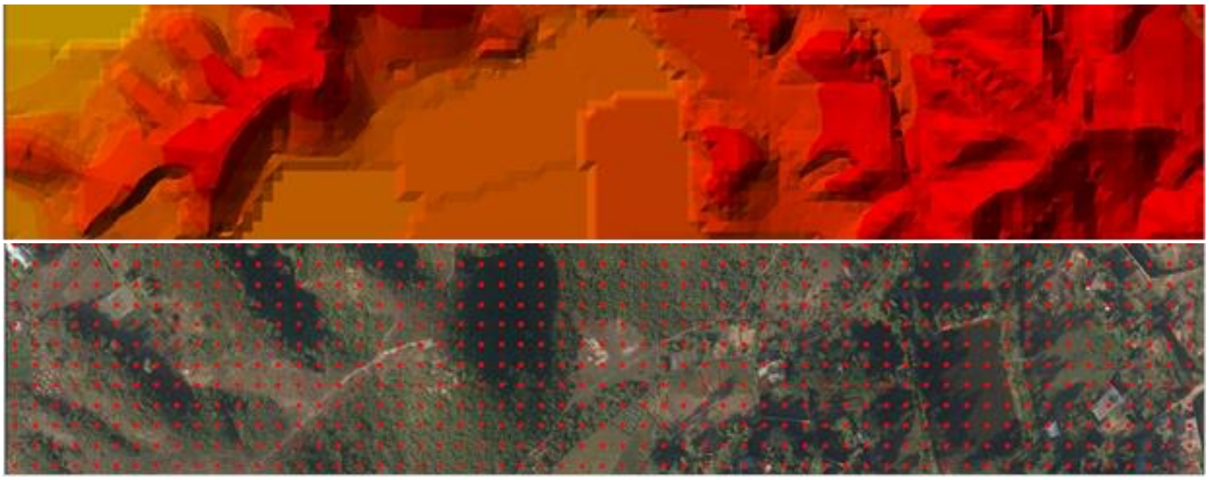


Figure 6-1: Sample Data of DEM in 20m interval and Digital Elevation Model

Table 6-2: Specifications of Data Available in SoB

Sl. No.	Features/Items	Remarks
1	Administrative Boundary	Ward, Union, Mouza, Thana, District and Division Boundaries
2	Building and Structure	Important Building and KPIs
3	Facilities	Utility Service Lines
4	Forest	Different Types of Forests
5	Geodetic Control Point	Bench Marks with XYZ values
6	Hydrographic Feature	River, Khal and other water bodies
7	Industrial	Different Types of Industries
8	Relief	Land levels for DEM generation and Contour lines
9	Transportation	Road and Railways including bus and rail Stations
10	Vegetation	Agricultural and other landuse
12	Layer Files	Layer Files for the Symbology to be used in Map generation
13	Any other Relevant GIS data	

6.3.2 Landuse Data

The landuse data has been collected from secondary sources and has been used to validate the imagery collected under this study.

6.3.3 Soil Data

During the period from 1963 to 1975 Reconnaissance Soil Survey (RSS) of almost the entire country was completed except mangrove forest of the south-west (the Sundarban) and reserve forest of the Chittagong Hill Tracts by Soil Research Development Institute (SRDI). The Primary purpose of the survey was to provide a basic guide on the soil resources of the study area to those responsible agricultural planning and economic development. For this purpose, the major kinds of the survey area have been identified and described, maps have been prepared showing their geographical occurrence, and estimates have been made of their potential for improvement.

6.3.4 Hydrological Data

BWDB has maintained a good hydrological data collection network for the whole country. A total of 364 Nos. of surface water level and 154 Nos. of discharge measuring stations are available all around the country. All the data has been collected and processed. A sample plot of surface water level for Sunamganj stations are given in Figure 6-2.

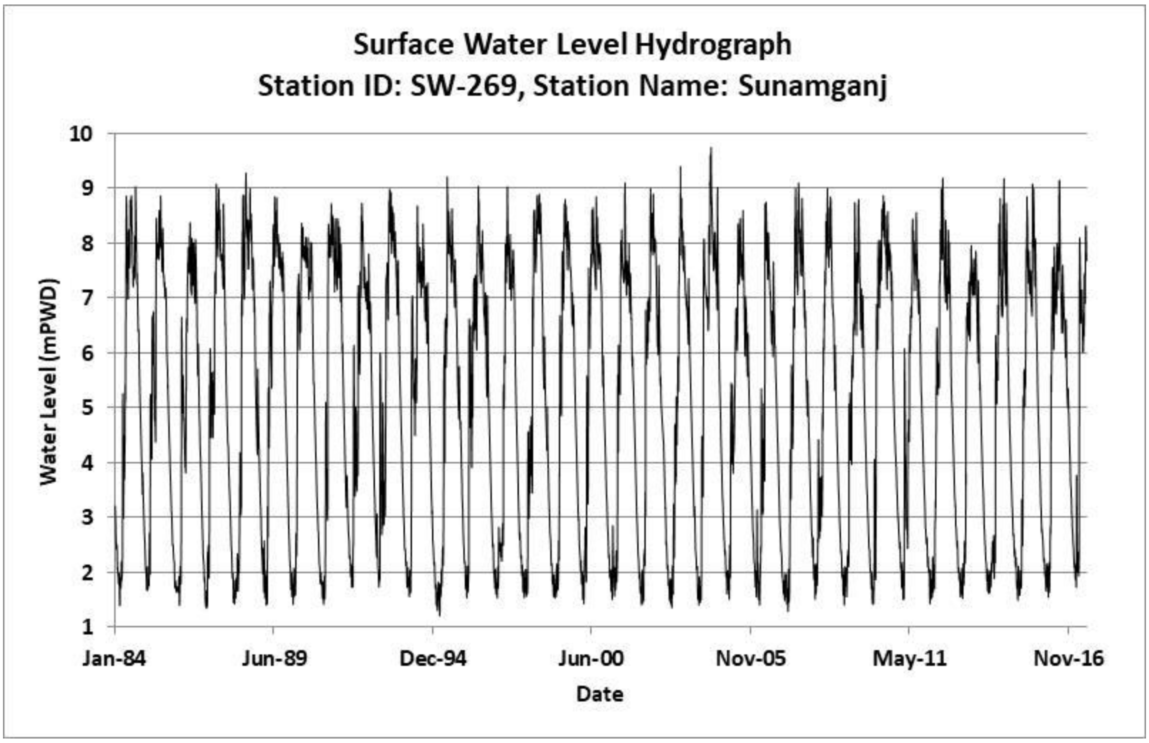


Figure 6-2: Sample Plot of Surface Water Level at Sunamganj

6.3.5 Collection of Satellite Images from Secondary Sources

Based on hydrological analysis for the optimum water levels for dry and wet seasons, the required satellite images have been downloaded from respective sites.

The Sentinel-1 and Sentinel-2 image have been used in wetland delineation for both wet and dry seasons. The image specification is presented in the following Table 6-3.

Table 6-3: Image Specification for Wetland Delineation

Period	Date Time	Satellite Image	Sensor Type	Spatial Resolution (meter)	Bit
Dry Season	18/03/2016 04:34:01	Sentinel-2	MSI	10	16
Wet Season	18/08/2015 23:47:15	Sentinel-1	SAR	10	16

The band specifications of the above two selected images are described below:

a) Sentinel-1 Satellite Image

The Sentinel-1 Satellite Image comes from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument. The specification of Sentinel-1 image has been presented in Table 6-4. This collection includes the S1 Ground Range Detected (GRD) scenes which contains all the GRD scenes. Each scene has one of 3 resolutions (10, 25 or 40 meters), 4 band combinations (corresponding to scene polarization) and 3 instrument modes. The possible combinations are single band VV or HH, and dual band VV+VH and HH+HV. The final terrain corrected values are converted to decibels via log scaling (10*log10(x)) and quantized to 16-bits.

Table 6-4: Band Specification of Sentine-1 C-Band Synthetic Aperture Radar (SAR)

Band	X Resolution	Y Resolution	Wave Length	Description
HH	10 metes	10 metes	5.405GHz	Single co-polarization, horizontal
HV	10 metes	10 metes	5.405GHz	Dual-band cross-polarization, horizontal transmit/vertical receive
VV	10 metes	10 metes	5.405GHz	Single co-polarization, vertical transmit/vertical receive
VH	10 metes	10 metes	5.405GHz	Dual-band cross-polarization, vertical transmit/horizontal receive
Angle	-1 meter	0 PIXEL_UNIT_UNSPECIFIED		Approximate viewing incidence angle

For water extent classification, VH band was selected as it provides the better results for identifying water features from the image.

b) Sentinel-2 Satellite Image

Sentinel-2 is a wide-swath, high-resolution, multi-spectral imaging mission supporting Copernicus Land Monitoring studies, including the monitoring of vegetation, soil and water cover, as well as observation of inland waterways and coastal areas. The specification of Sentinel-2 image has been presented in Table 6-5. The Sentinel-2 data contain 13 units of 16 spectral bands.

Table 6-5: Band Specification of Sentinel-2 Multi Spectral Instrument, Level-1C

Band	Resolution (Meters)	Wave Length (Micrometers)	Description
B1	60	0.443	Aerosols
B2	10	0.490	Blue
B3	10	0.560	Green
B4	10	0.665	Red
B5	20	0.705	Red Edge-1
B6	20	0.740	Red Edge-2
B7	20	0.783	Red Edge-3
B8	10	0.842	NIR

Band	Resolution (Meters)	Wave Length (Micrometers)	Description
B8a	20	0.865	Red Edge-4
B9	60	0.940	Water vapor
B10	60	1.375	Cirrus
B11	20	1.610	SWIR 1
B12	20	2.190	SWIR 2
QA10	10	-	Always empty
QA20	20	-	Always Empty
QA60	60	-	Cloud mask

6.4 Primary Data Collection, Quality Checking and Processing

The primary data that has been collected under this study is mentioned below:

- Image collection
- LiDAR survey
- Batheymetric survey & Discharge measurement
- Collection of Water Quality Data
- Data collection on Biodiversity
- Data collection for Fisheries Resources
- Data collection on Forest
- Data collection for Agricultural Development
- Socio – economic Data collection

6.4.1 Image Collection and Analysis

Satellite image is an important component of the project, high resolution image of recently captured has been purchased to identify the locations and boundaries of wetlands, calculate their area and to determine their types, status incorporating their underlying characteristics.

In order to meet with the study objectives, a total of 339 Nos. of high resolution satellite imagery has been procured from DigitalGlobe covering the whole country. The specifications of satellite image have been presented in Table 6-6.

Table 6-6: Specifications of Satellite Image

Item	Specification
Total Image scene	339 Nos.
Number of Blocks	18 Nos.
Type	Optical
Bands	Red, Green, Blue, Infra-red

Item	Specification
Cell Size	0.5 m
Processing level	Orthorectified
Cloud cover	<= 15%, calculated over the whole country
Imagery date	January 1, 2009 to 18 May 20 2017
Coordinate System	BUTM
File Format	GeoTIFF

Analysis of Satellite Images: The satellite images purchased from DigitalGlobe are "Pan Sharpened (4-band)". The multi-spectral band designations are Blue-Green-Red-Near Infra-red. To cover the whole country, it has been divided into 18 numbers of blocks as shown in Figure 6-3 which included a total of 339 Nos. of images as shown in index map as Figure 6-4. A sample image scene is shown in Figure 6-5.

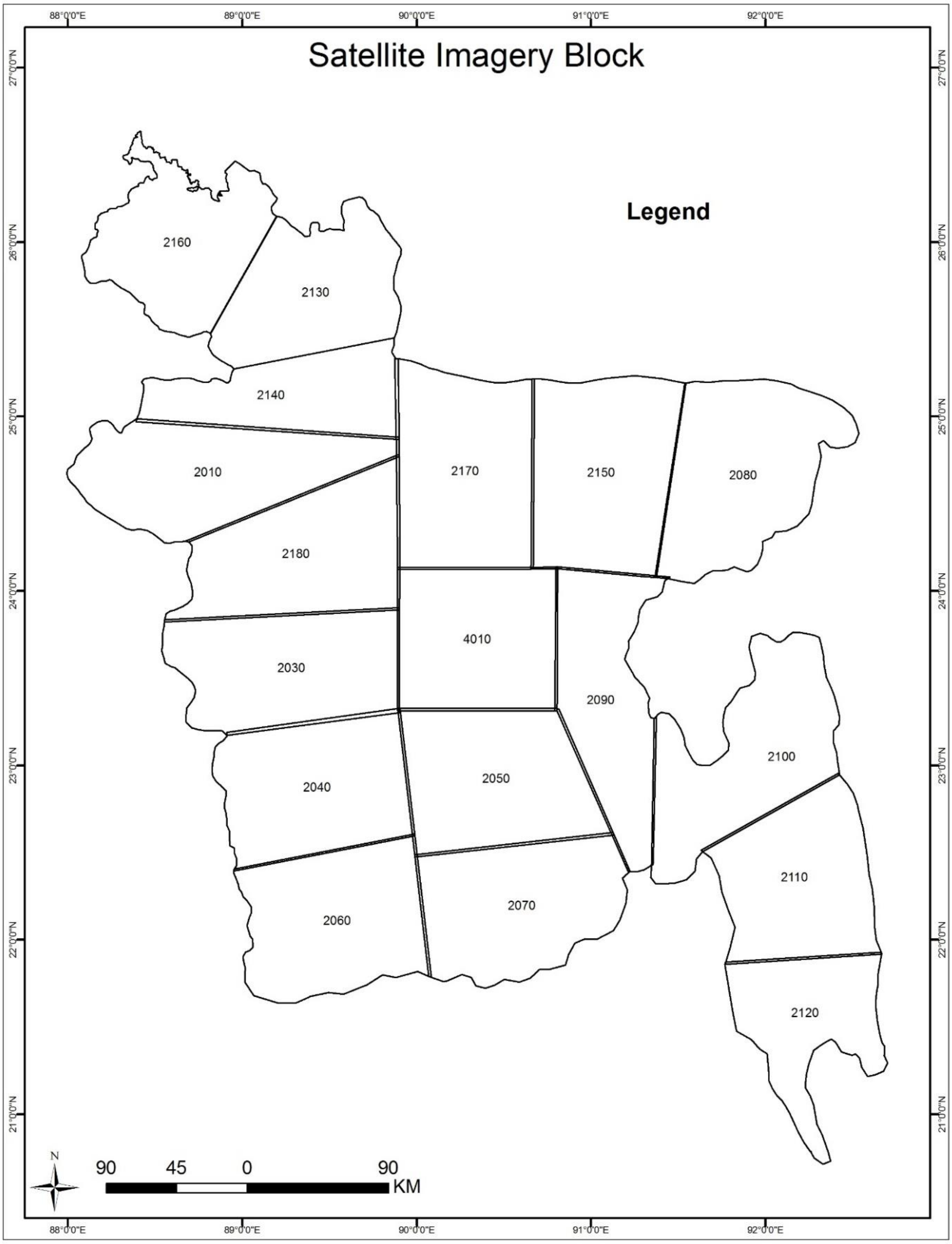


Figure 6-3: Map Showing Block Locations

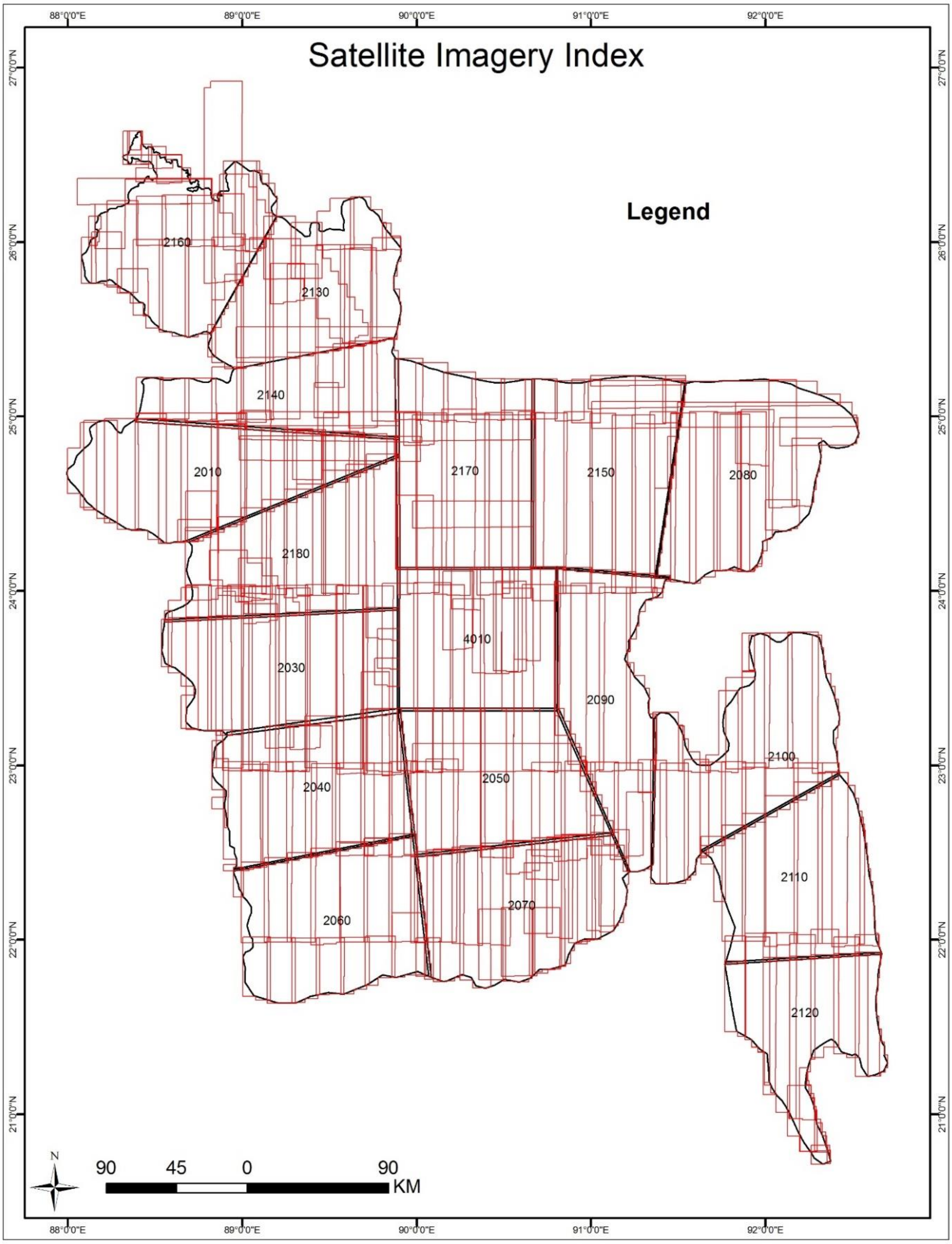


Figure 6-4: Location of Image Scene

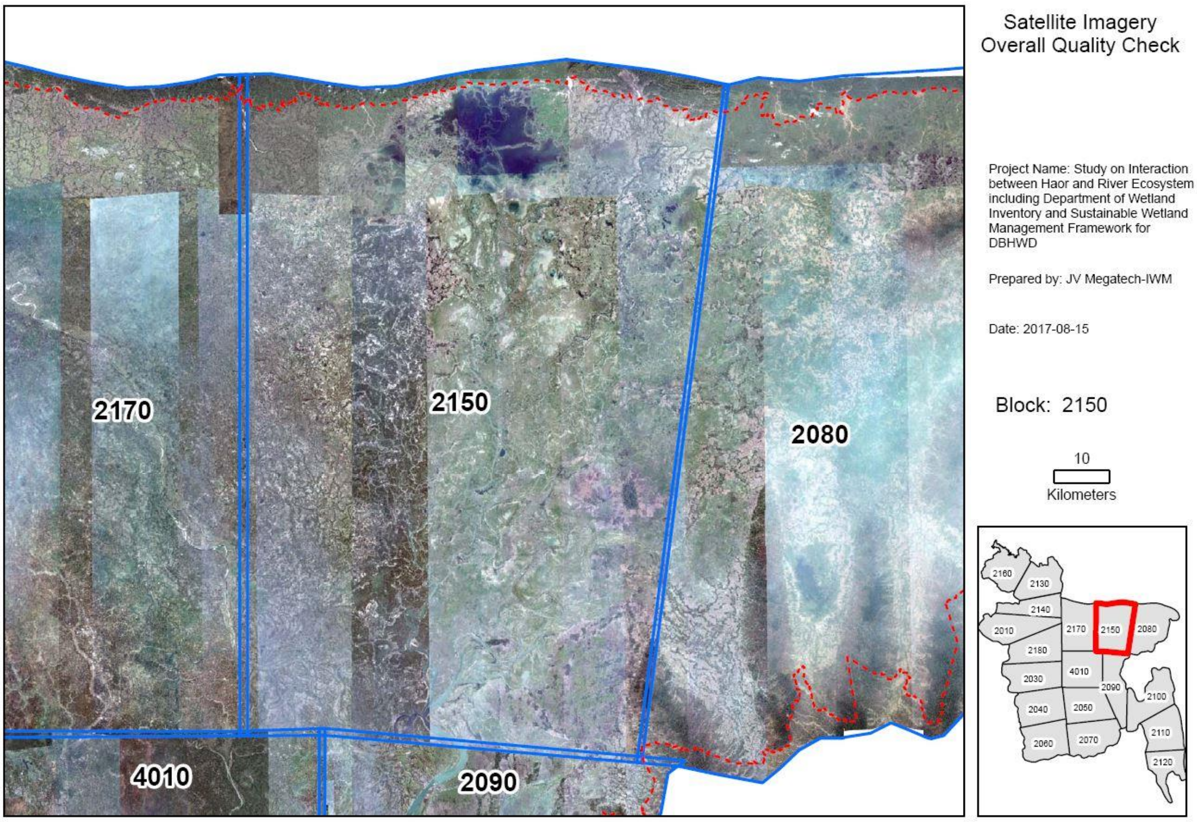


Figure 6-5: Sample Image Scene in a Block

6.4.2 LiDAR Survey

The LiDAR & photo survey has been conducted with a Riegl Q680i lidar equipment and Hasselblad H60 medium format aerial camera as shown in Figure 6-6. The project was surveyed with a Cessna 208 - Grand Caravan aircraft as shown in Figure 6-6.

Figure 6-6: LiDAR (left), Camera (Middle) and AVION (Right)

A quality control has been made after the flight in which photo coverage is checked with the software QuickMap. No picture is missing. Total area covered by photos is 157 sq. km in mono coverage and 136 sq. km in stereo coverage. The survey details are illustrated in Table 6-7 whereas the survey routes are shown in Figure 6-7.

Table 6-7: The Flight Details

Date	Actions	Flight Hours	Hours On Line
March 20th 2019	Flight of runs 1 to 26 (All Area completed - No refly)	5:05	3:20

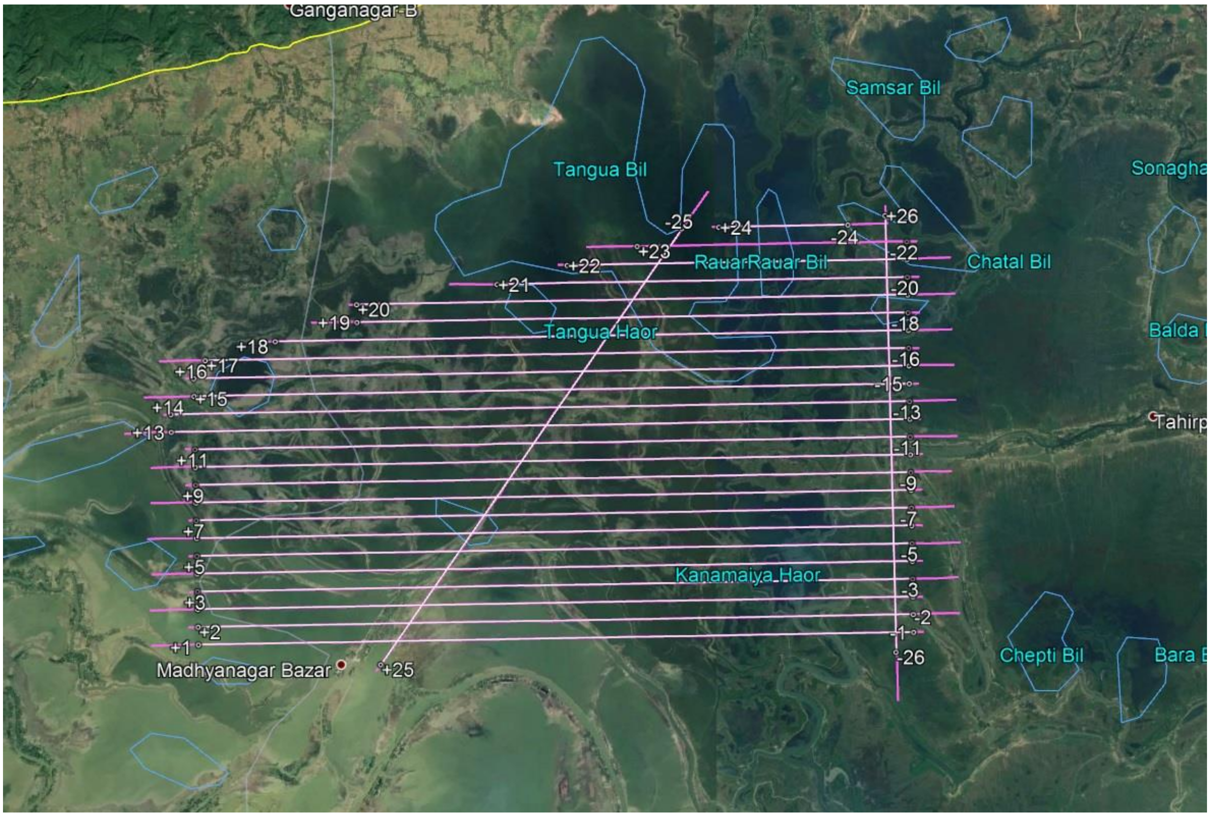


Figure 6-7: Survey Flight Routes

TerraSolid 2019 package has been used for processing the LiDAR data. Map sheets in 1x1 km named using left upper corner coordinates. Format is LAS 1.2. Projection is BUTM and height system is MSL, same as control points. Transformation has been done from UTM46N to BUTM and height is adjusted using geoid model created from GCP list. The accuracy of the data has been checked as presented below:

Below is a list GCP's compared to triangulated ground model

Easting	Northing	Known Z	Laser Z	Dz
610808.562	2774929.539	4.819	4.823	+0.004
611106.699	2774923.194	4.043	4.036	-0.007
608554.040	2777001.441	3.236	3.250	+0.014
608550.366	2777005.621	3.378	3.316	-0.062
606113.304	2780270.986	3.488	3.467	-0.021
606108.888	2780262.217	3.613	3.619	+0.006
610428.202	2779242.598	4.319	4.251	-0.068
612088.501	2780297.431	3.039	3.085	+0.046
612121.119	2780291.329	3.135	3.153	+0.018
612072.920	2780304.648	3.721	3.649	-0.072
612452.791	2777478.000	3.058	3.110	+0.052
612387.046	2777465.651	6.811	6.795	-0.016
612964.192	2775822.407	3.440	3.427	-0.013
612960.971	2775828.773	3.357	3.316	-0.041
612594.734	2775296.995	4.328	4.351	+0.023
612851.727	2771859.974	3.424	3.404	-0.020
611045.871	2771513.051	2.245	2.299	+0.054
611043.408	2771565.470	6.016	6.054	+0.038
611015.363	2773079.206	0.992	1.020	+0.028
611057.745	2773090.763	5.869	5.892	+0.023
602971.942	2776799.863	4.899	4.913	+0.014
602978.778	2776823.769	5.642	5.692	+0.050
601510.214	2778631.292	5.222	5.260	+0.038
601515.624	2778636.576	5.274	5.298	+0.024
601546.343	2778688.980	5.186	5.189	+0.003
600772.021	2777166.540	5.044	5.050	+0.006
600765.200	2777165.625	5.054	5.103	+0.049
599013.679	2777844.226	8.071	8.004	-0.067
596354.545	2777299.493	6.566	6.555	-0.011
596315.539	2777337.194	5.687	5.652	-0.035
596500.152	2775525.599	6.503	6.460	-0.043
596854.694	2776218.554	5.426	5.426	+0.000
597657.050	2775880.887	5.384	5.384	+0.000
608480.138	2773556.986	4.375	4.448	+0.073
608591.188	2773526.931	6.516	6.525	+0.009
606151.739	2771183.260	3.661	3.664	+0.003
606157.862	2771183.881	3.741	3.763	+0.022
605783.207	2774269.830	6.215	6.152	-0.063
604261.253	2775623.228	5.181	5.206	+0.025
603378.899	2774178.035	5.151	5.133	-0.018
603428.721	2774344.968	5.216	5.164	-0.052
602209.661	2773293.061	4.922	4.927	+0.005
600094.330	2774618.188	5.116	5.090	-0.026
596687.715	2772496.467	4.063	4.067	+0.004
596712.618	2772485.249	3.905	3.922	+0.017

Average dz	+0.000
Minimum dz	-0.072
Maximum dz	+0.073
Average magnitude	0.029
Root mean square	0.036
Std deviation	0.036

The details of the LiDAR survey have been presented in Volume-II: Appendix-B.

6.4.3 Bathymetric Survey and Discharge Measurement

Survey team has been mobilized on August 2019 to conduct BM fly, Bathymetric survey and Discharge measurement. List of the equipment used for the survey works is given Table 6-8.

Table 6-8: List of the Equipment used for the Survey Works

Sl. No.	Equipment Type	Name of Equipment	No. of Equipment
1	Positioning	Trimble 4400	1 set
		Garmin Handheld GPS	2 nos
2	Topographic Survey	SOKKIA Auto Level (B20/B21)	1 Set
3	Depth Measurement	Teledyne ODOM Hydrotrac II Ecosounder	1 set
4	Discharge measurement	Teledyne RDI River Ray (600 KHz) ADCP	1 set

Survey Methodology

Benchmark Fly: National Benchmarks; established and maintained by Survey of Bangladesh (SoB), available in the vicinity of Tanguar haor and Hakaluki haor area have been collected by and used as the vertical reference for the survey work. A sample benchmark has been presented in Figure 6-8.

Figure 6-8: BM 7412 Situated at Jame Mosque Field, Komolakanda, Netrokona

The SoB BMs along the route of survey have been inter-connected by direct leveling to check the consistency. BM Fly has been made to facilitate the bathymetric survey and water level connection. Closing error has been checked to maintain the survey accuracy.

TBMs have been kept by engraving on permanent structures like bridges, culverts and other available infrastructure during the level survey. Benchmarks used for the work are given Table 6-9.

Table 6-9: List of the Benchmarks used for Survey Work

Sl. No.	BM-ID	Description	Easting	Northing	RL (mMSL)
1	BM-7412	The pillar is situated in north-east corner of Jame Mosque field at Gilachowkha Beshorpasa. Vill: Gilachowkha, District:Netrokona	294502	2777501	7.7378
2	BM-7414	The pillar is situated at south-west corner of Tahirpur upazilla play ground and south-east corner of Upazilla boundary wall, east side of rest house. Vill: Tagirpur, District: Sunamgonj	316161	2776974	7.7078
3	BM-7509	South side Fenchudanj Kushiara bridge at Moulavibazar High school	392064	2731773	11.1882
4	GPS-4334	The pillar is situated in the south-east corner of Zangirai Primary School play ground and 500m south from Juri railway station. Vill: Zangirai, Dist: Moulavibazar	410402	2720424	10.7277

Co-ordinates System: Universal Transverse Mercator (UTM) projection system was being used for data collection as well as projection of Maps. This is to mention here that entire survey area is under UTM 46N zone.

Bathymetry Survey: Bathymetric survey has been carried out for both Tanguar haor and Hakaluki haor. For Tanguar haor the maximum length of x-section survey is 12km and the spacing between transect lines is 1200m and for Hakaluki haor maximum length of x-section survey is 14km, the spacing between transect lines is 2000m. The bathymetric survey was done using single frequency digital Echo-sounder (Odom Hydrotrac II) and Trimble 4400 GPS. Calibration of the Echo-sounder was done every day before and after measurements with the help of bar checks. A Laptop computer with Trimble HydroPRO software was used to interface the instruments. HydroPRO Navigation software guided the survey boat on the desired transects. The survey data were stored in tabular format MS Access database during the survey works. The NavEdit module of the software compiles depth of water column and position of sounding with time. Erroneous data were removed by checking the sections during processing. Figure 6-9 and Figure 6-10is shown the transect line of bathymetric survey in Hakaluki haor and Tanguar haor area respectively. A sample plot of cross-section at Tanguar haor area has been presented in Figure 6-11 whereas the remaining is presented in Volume-II: Appendix-C.

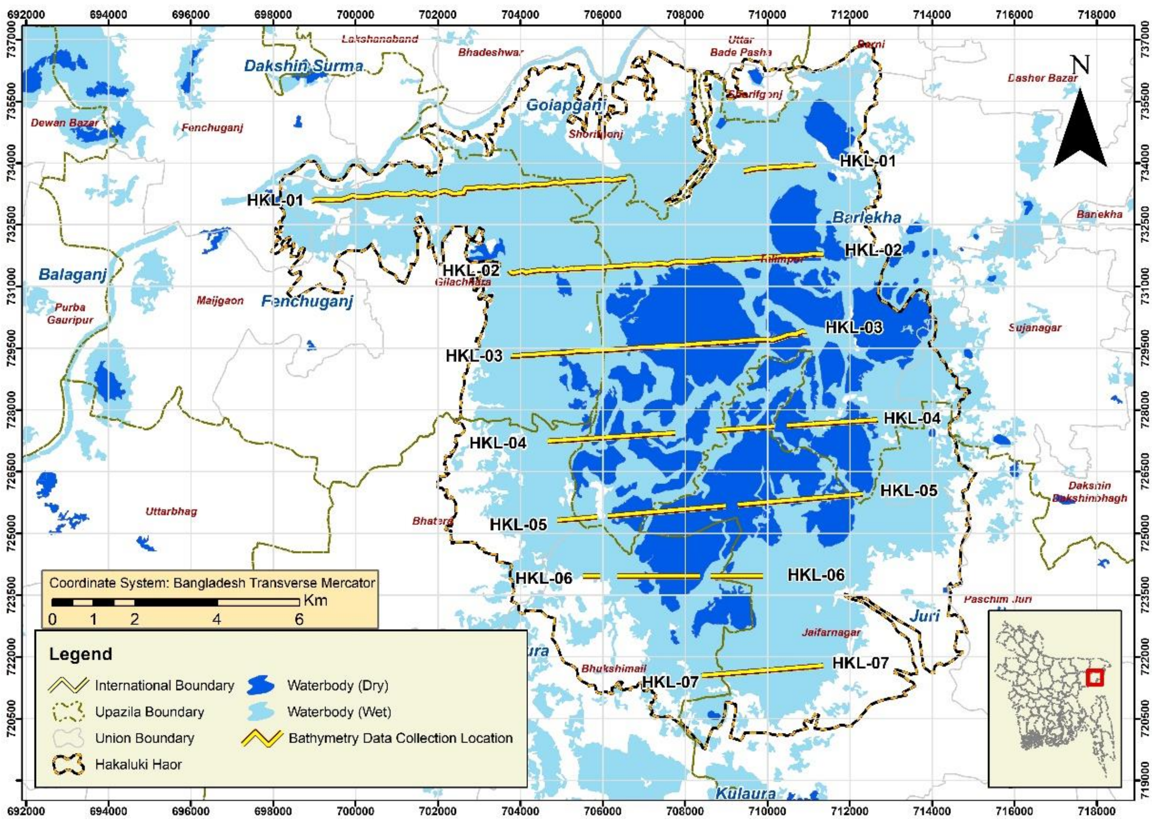


Figure 6-9: Bathymetric Transect Line at Hakaluki Haor

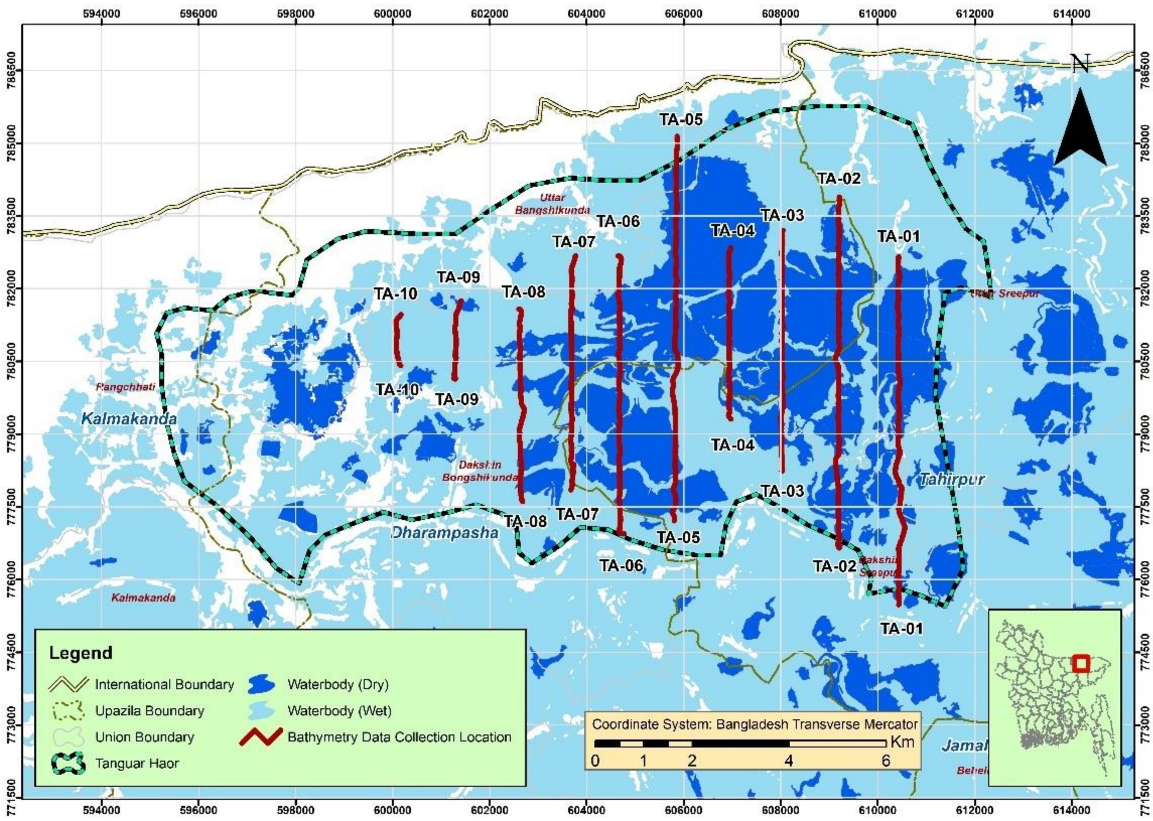


Figure 6-10: Bathymetric Transect Line at Tanguar Haor

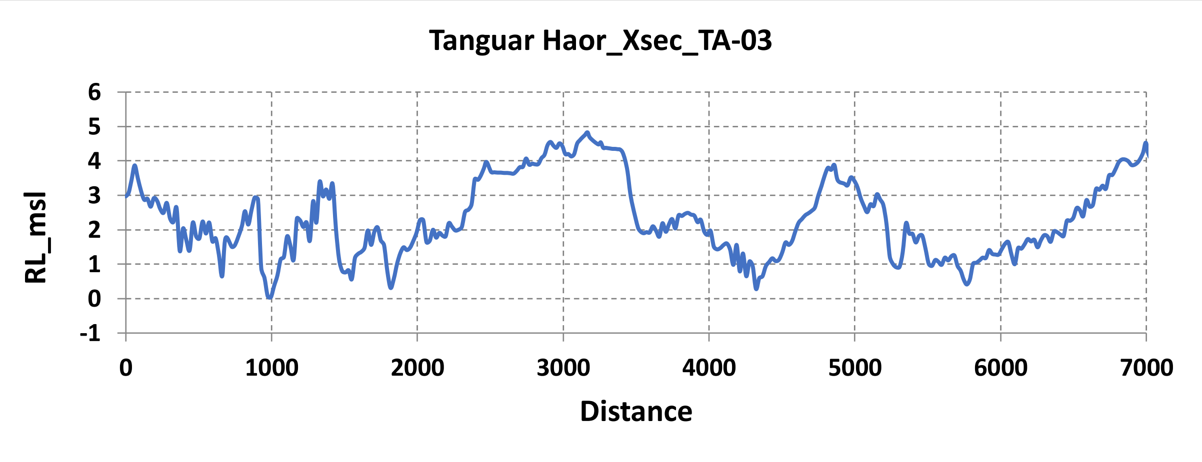


Figure 6-11: A Sample Plot of Cross-section for Tanguar Haor

Water level was connected by Level machine daily before & after Bathymetric survey as shown in Figure 6-12. Water Level correction was made to the soundings using the NavEdit module of the HydroPRO. The edited data were then exported into ASCII format from the NavEdit module of HydroPRO software.

Figure 6-12: Water Level Observation at Tahirpur

<u>Discharge Measurement</u>

Discharge measurements were conducted at 4 locations on each of Tanguar and Hakaluki haor as shown in Figure 6-13 and Figure 6-14 respectively. A total of 16 measurements were conducted during August to September 2019 @ of 2 spells on each location. Teledyne RD Instruments (TRDI) River Ray 600 KHz ADCP was used for the measurements. The velocity profiling range of the ADCP is from 0.40 meter depth up to 45 meter depth.

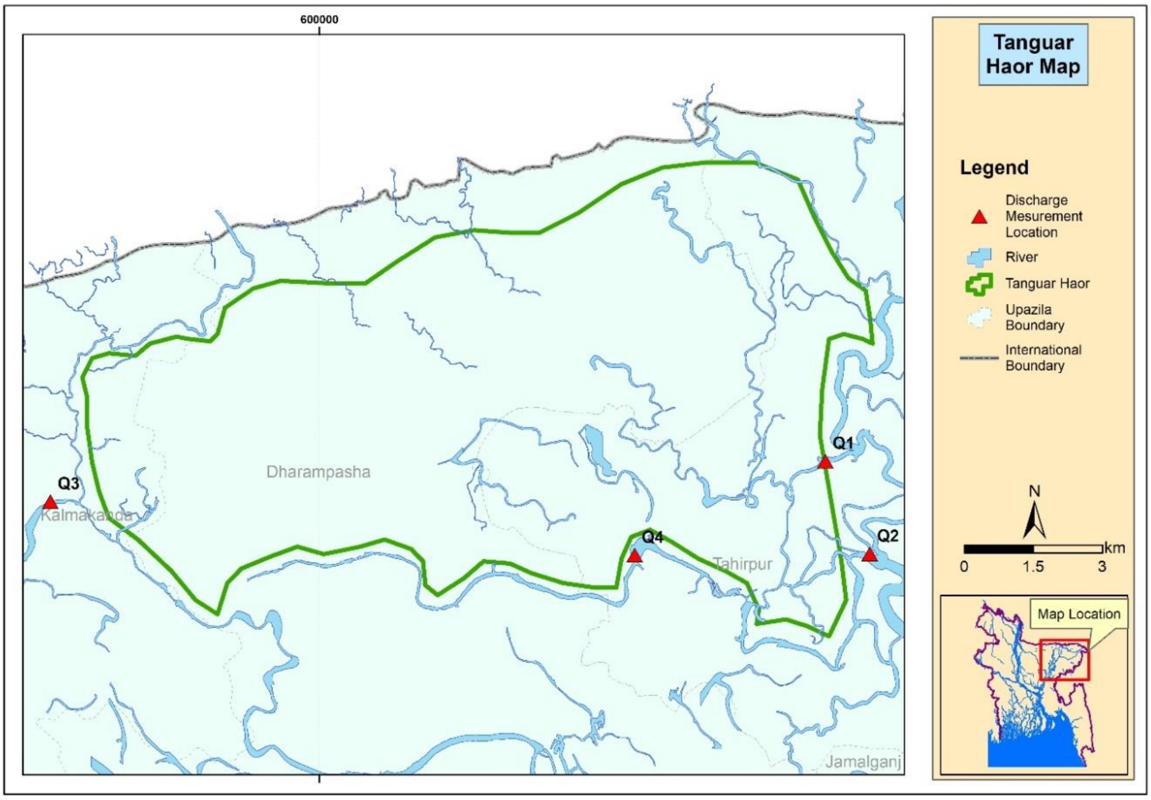


Figure 6-13: Discharge Measurement Location at Tanguar Haor

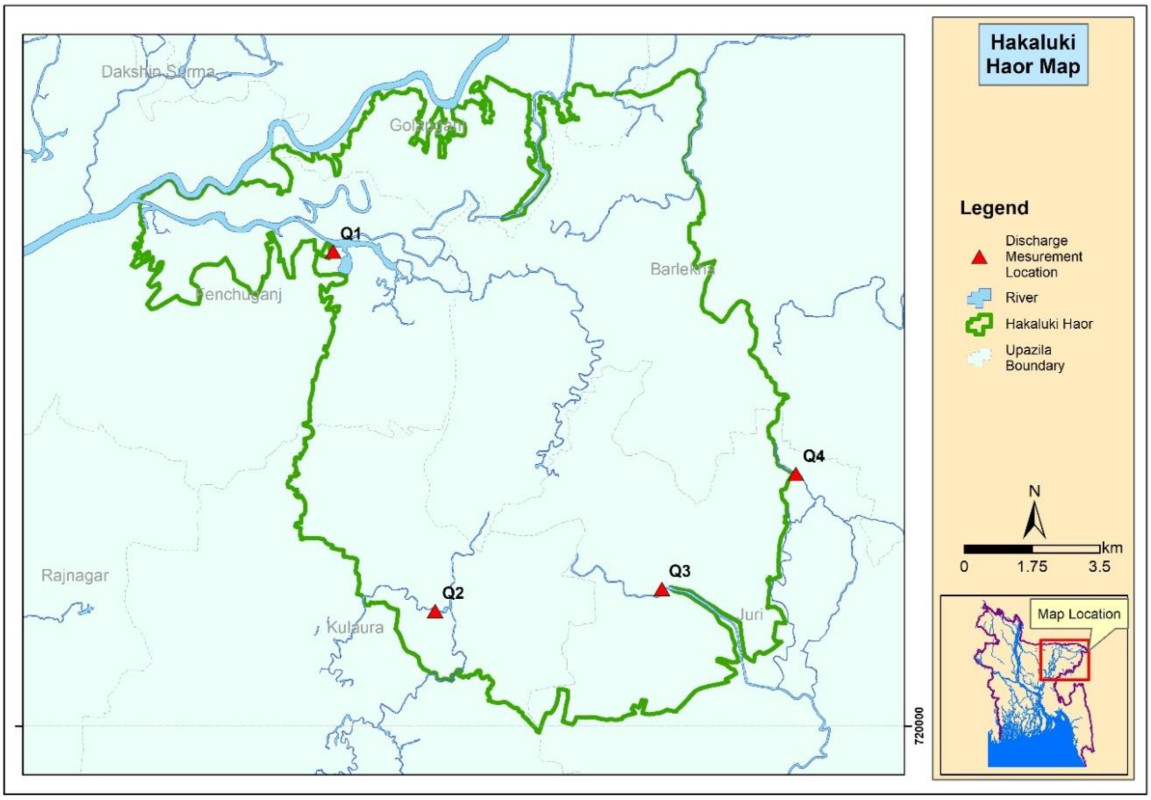


Figure 6-14: Discharge Measurement Location at Hakaluki Haor

The measurements are done following User Guide supplied by the manufacturer of the instrument. The instrument is capable of measuring velocity without anchoring at measurement locations (moving boat condition). It measures flow velocity at each ensemble across the whole river. At each ensemble, velocity is measured at 50 cm interval along the water column depending on the total depth. Thus, a series of velocity data is recorded along the transect line. The interval between ensembles varies from 1 to 3 seconds depending on the configuration and depth of the river. The software estimates the discharge of unmeasured areas (the top of the river flow, instrument face, near bottom part and edges) is calculated by WinRiver II Software. The discharge of Tanguar haor and Hakaluki haor has been presented in Table 6-10.

Table 6-10: Discharge at Tanguar Haor and Hakaluki Haor Area

Location	X_UTM	Y_UTM	Date	Discharge (m^3/S)	Velocity (m/s)
Tanguar Haor					
Q1	308584	2780441	23/8/2019	4.80	0.0100
Q2	309504	2778402	23/8/2019	21.701	0.0400
Q3	291690	2779939	23/8/2019	3.02	0.0250
Q4	304386	2778490	23/8/2019	4.894	0.0050
Q1	308584	2780441	29/9/2019	20.556	0.0470
Q2	309504	2778402	29/9/2019	33.91	0.0310
Q3	291690	2779939	29/9/2019	5.11	0.0570
Q4	304386	2778490	29/9/2019	7.73	0.0170
Hakaluki Haor					
Q1	399369	2731378	24/8/2019	261.22	0.0920
Q2	401801	2722030	24/8/2019	23.621	0.0620
Q3	407669	2722471	25/8/2019	78.38	0.6710
Q4	411196	2725374	25/8/2019	6.71	0.0580
Q1	399369	2731378	30/9/2019	93.328	0.0540
Q2	401801	2722030	30/9/2019	4.12	0.0280
Q3	407669	2722471	1/10/2019	42.85	0.5940
Q4	411196	2725374	1/10/2019	2.049	0.0410

6.4.4 Collection of Water Quality Data for Tanguar Haor and Hakaluki Haor

Water Sampling: A total of 20 sets of surface water samples have been collected from Tanguar haor and Hakaluki haor area. Table 6-11 shows location details of the sampling points at Tanguar and Hakaluki haor. The sampling location for Hakaluki and Tanguar haor area has been presented in Figure 6-15 and Figure 6-16 respectively.

Table 6-11: Details of Sampling Campaigns

Sl. No.	ID	Sampling Location	Sampling Date & Time	Latitude	Longitude	Weather Condition
1	H-1	Hakaluki Haor	28.08.19, 2:00 PM	24.60009	93.0541131	Sunny
2	H-2		28.08.19, 2:48 PM	24.61573	92.0897513	
3	H-3		28.08.19, 1:00 PM	24.63464	92.024523	
4	H-4		28.08.19, 3:18 PM	24.63699	92.10547	
5	H-5		28.08.19, 12:43 PM	24.65396	92.023323	
6	H-6		28.08.19, 12:25 PM	24.67265	92.0297506	
7	H-7		28.08.19, 4:29 PM	24.69077	92.1042329	
8	H-8		28.08.19, 5:30 PM	24.70141	92.0456336	
9	H-9		28.08.19, 11:45 AM	24.69145	92.0194456	
10	H-10		28.08.19, 6:00 PM	24.6994	92.0054837	
11	T-1	Tanguar Haor	26.08.19, 11:05 AM	25.15108	91.094447	Sunny
12	T-2		26.08.19, 11:18 AM	25.14735	91.07499	
13	T-3		26.08.19, 11:29 AM	25.15765	91.063095	
14	T-4		26.08.19, 11:35 AM	25.15569	91.048513	
15	T-5		26.08.19, 11:45 AM	25.15124	91.032542	
16	T-6		26.08.19, 12:00 PM	25.13973	91.020154	
17	T-7		26.08.19, 12:16 PM	25.1379	91.004207	
18	T-8		26.08.19, 12:31 PM	25.14058	90.987078	
19	T-9		26.08.19, 1:11 PM	25.13693	91.044896	
20	T-10		26.08.19, 1:30 PM	25.12355	91.070222	

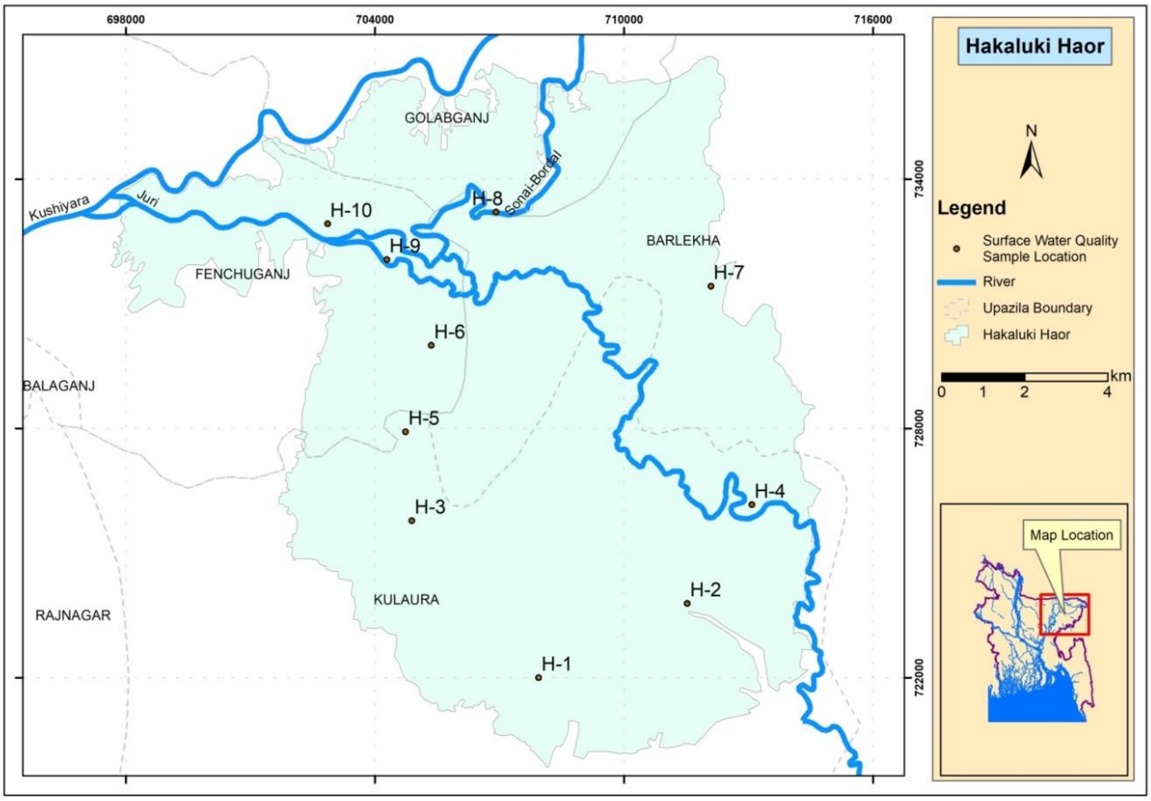


Figure 6-15: Water Sampling Location at Hakaluki Haor area

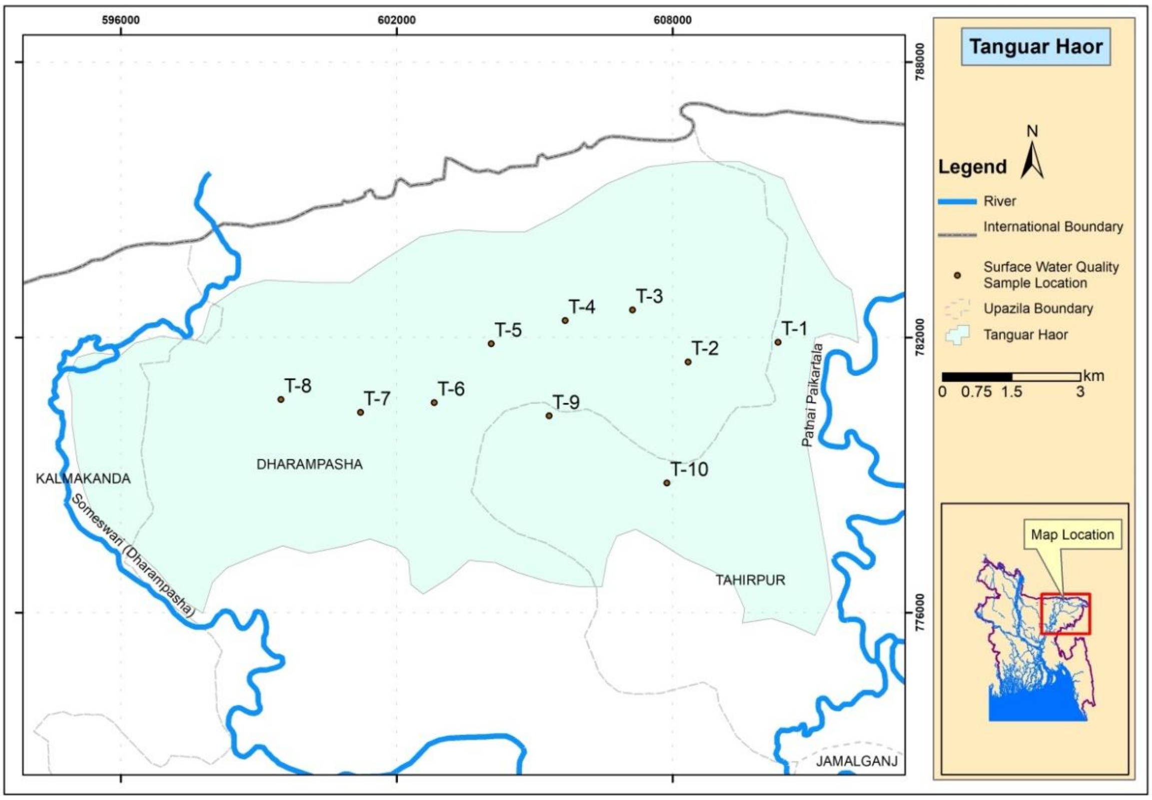


Figure 6-16: Water Sampling Location at Tanguar Haor area

A water vessel has been used for sample collection. Water samples have been collected manually. Separate sampling bottles have been used for collecting water samples for physical, chemical bacteriological water quality analysis. During sampling campaign, in-situ measurements have been done for several water quality parameters (pH, Temperature and DO). All collected water samples have been put into ice box and all the samples has been transported to the Environmental Engineering Laboratory of the Department of Civil Engineering, BUET and Laboratory of ICDDRB, Bangladesh quickly for testing.

Testing of Raw Water Samples: Both in-situ testing and laboratory analysis of the raw water samples has been done. A few water quality parameters have been tested at the sampling site just after sample collection, because of possible changes of their values with passage of time. These parameters included pH, dissolved oxygen (DO) and temperature. A pH meter and a DO meter (fitted with a temperature probe) have been used for these in-situ measurements. A sample photo for in-situ measurement has been presented in Figure 6-17.

Figure 6-17: A Sample Photo for in-situ Measurement of Water Sample in Hakaluki Haor Area

Characteristics of Raw Water of Tanguar Haor: The results of the in-situ testing and laboratory analysis of water samples collected from the Tanguar haor area has been presented in Table 6-12 whereas analysis of water samples collected from the Hakaluki haor area has been presented in Table 6-13 respectively. The tables also show Bangladesh Drinking Water Standards (DoE, 1997) for the parameters listed.

Temperature of collected surface water samples ranges between 33 and 35^{0}C in the Tanguar haor area. In Hakaluki haor, temperature ranges from 31.5 to 33.6^{0}C. All the sample results exceeded the Bangladesh drinking water standard.

p^H value of collected surface water samples varies from 6.4 to 8.62 in the Tanguar haor area where as for Hakaluki haor area it ranges from 6.63 to 7.4. In most of the cases the values are within the range of Bangladesh drinking water standard.

The Dissolved Oxygen (DO) content value of the collected samples ranges from 7.68 to 8.8 mg/l for Tanguar haor whereas it varies from 5.27 to 8.28 mg/l for Hakaluki haor areas. In context of Bangladesh drinking water standard, the DO value of Tanguar haor and Hakaluki haor is out of range except in 1 location of Hakaluki haor area.

The laboratory analysis of collected water sample reveals that Total Hardness as $CaCO_3$ varies from 27 to 48 mg/l for Tanguar haor and 14.9 to 19 mg/l for Hakaluki haor and all the values are below Bangladesh drinking water standard.

Biochemical Oxygen Demand (BOD_5) ranges between 2.8 to 6 mg/l for Tanguar haor and 3 to 4.2 mg/l for Hakaluki haor whereas Chemical Oxygen Demand (COD) varies from 6 to 20 mg/l for Tanguar haor and 5 to 8 mg/l for Hakaluki haor. The turbidity values range from 1.43 to 5.25 NTU for Tanguar haor and 1.54 to 59.4 NTU for Hakaluki haor area.

Table 6-12: Characteristics of Raw Water Collected from Tanguar Haor Area

Water Quality Parameter	Sampling ID										Statistics			Bangladesh Drinking Water Standard
	T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	Maximum	Minimum	Standard Deviation	
Temp (°C)	33.2	33.2	33.7	33.4	33.2	33.7	35	33.9	33.4	33	35.00	33.00	0.58	20-30
pH	6.4	6.91	8.13	8.62	8.2	8.09	7.59	7.95	7.03	7.39	8.62	6.40	0.69	6.5-8.5
DO (mg/l)	8.04	8.55	8.8	8.75	7.68	7.59	7.93	7.85	7.94	8.05	8.80	7.59	0.43	6
Total hardness as $CaCO_3$ (mg/l)	48	39	28	27	30	30	36	42	31	34	48.00	27.00	6.77	200-500
Free carbon dioxide (mg/l)	3.58	3.67	3.29	3.38	3.48	3.48	3.48	3.58	3.38	3.58	3.67	3.29	0.12	--
Chemical Oxygen Demand (mg/l)	<3	<3	<3	<3	<3	6	<3	20	6	<3	20.00	6.00	--	4
Biochemical Oxygen Demand (BOD5; 20°C) (mg/l)	<2	<2	<2	<2	<2	3	<2	6	2.8	<2	6.00	2.80	--	0.2
Turbidity (NTU)	1.43	1.98	2.59	1.51	2.49	3.56	5.25	2.2	1.8	2.12	5.25	1.43	1.15	10
Phosphate (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--	--	--	6
Ammonia as Nitrogen (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--	--	--	--
Total Suspended Solids (TSS) (mg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	--	--	--	10
Nitrate-Nitrogen (NO_3-N) (mg/l)	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.30	0.20	0.05	10
Color (Pt. Co. Unit)	3	5	5	6	5	5	9	8	6	5	9.00	3.00	1.70	15

Table 6-13: Characteristics of Raw Water Collected from Hakaluki Haor Area

Water Quality Parameter	Sampling ID										Statistics			Bangladesh Drinking Water Standard
	H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	H-9	H-10	Maximum	Minimum	Standard Deviation	
Temp (^oC)	33	32.2	33.6	32	32.2	32.9	32.3	31.5	32	31.5	33.60	31.50	0.67	20-30
pH	7.36	6.79	7.3	6.96	7.06	6.91	7.4	6.94	6.63	7.17	7.40	6.63	0.25	6.5-8.5
DO (mg/l)	7.57	6.2	8.28	8.24	7.59	7.07	8.81	5.27	6.89	7.98	8.81	5.27	1.07	6
Total hardness as $CaCO_3$ (mg/l)	16.5	18.5	14.9	15	16.5	18	15	19	18.5	18.8	19.00	14.90	1.69	200-500
Free carbon dioxide (mg/l)	3.09	3.19	3.09	3.38	3.09	2.8	3.58	3.38	3.29	3.09	3.58	2.80	0.22	--
Chemical Oxygen Demand (mg/l)	<3	7	<3	<3	<3	5	<3	8	<3	<3	8.00	5.00	--	4
Biochemical Oxygen Demand (BOD5; 20°C) (mg/l)	<2	4	<2	<2	<2	3	<2	4.2	<2	<2	4.20	3.00	--	0.2
Turbidity (NTU)	6.52	59.4	1.54	14.57	1.82	5.22	2.2	38.4	9.65	10.85	59.40	1.54	19.01	10
Phosphate (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--	--	--	6
Ammonia as Nitrogen (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--	--	--	--
Total Suspended Solids (TSS) (mg/l)	<10	46	<10	14	<10	<10	<10	36	<10	12	46.00	12.00	16.69	10
Nitrate-Nitrogen (NO_3-N) (mg/l)	0.3	0.4	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.40	0.20	0.06	10
Color (Pt. Co. Unit)	10	95	9	20	9	12	8	33	16	15	95.00	8.00	26.48	15

6.4.5 Collection of Water Quality Data for Clustered Wetland

The identified wetland has been clustered according to their characteristics and functions. Clustering has been introduced based on hydrological regions of the Bangladesh. Baikka beel was selected from North East wetland cluster. Borobila beel was selected from North Central wetland cluster. Beel Halti was selected from North Western wetland cluster. Baluhor Baor and Borni Baor were selected from south western wetland cluster. In-situ water quality parameters have been tested at the sampling site for these clustered wetlands as shown in Figure 6-18. Water quality sampling location has been presented from Figure 6-19 to Figure 6-23. The in-situ water quality data has been presented in Table 6-14 to Table 6-18.

Figure 6-18: In-situ Water Quality Measurement at Borobila Beel Area

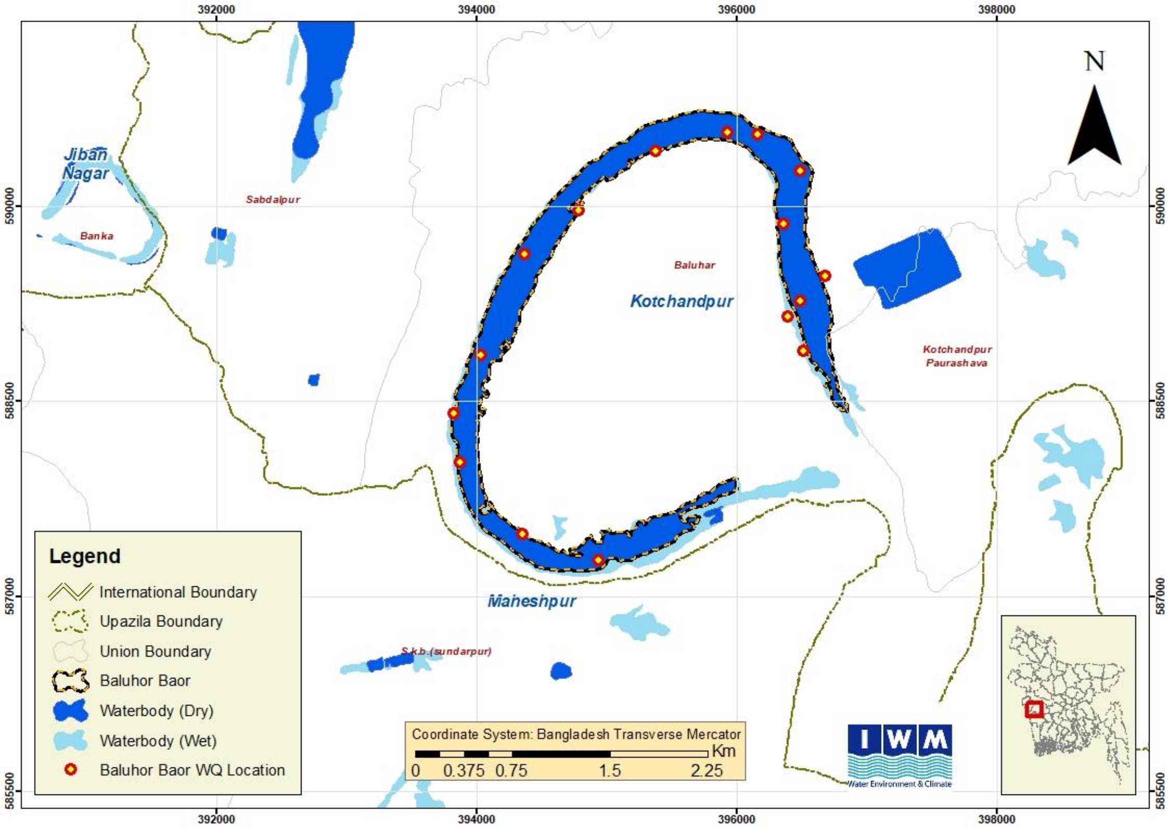


Figure 6-19: Water Sampling Location at Baluhor Baor Area

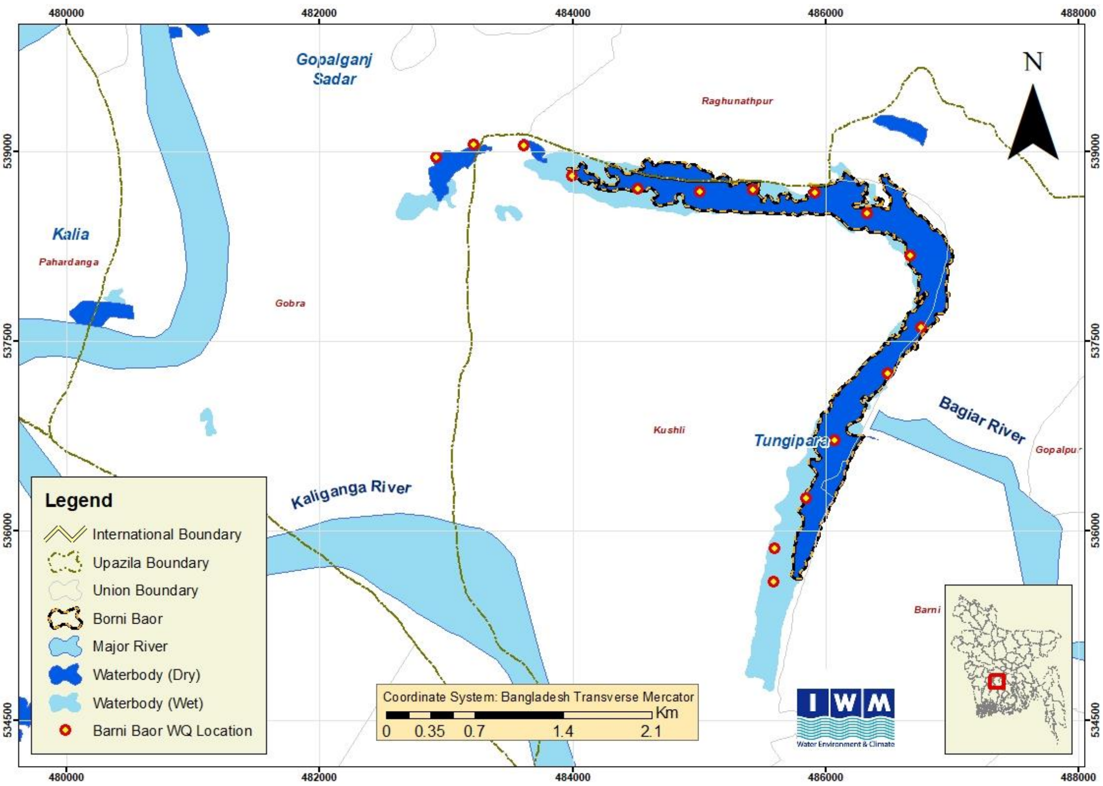


Figure 6-20: Water Sampling Location at Borni Baor Area

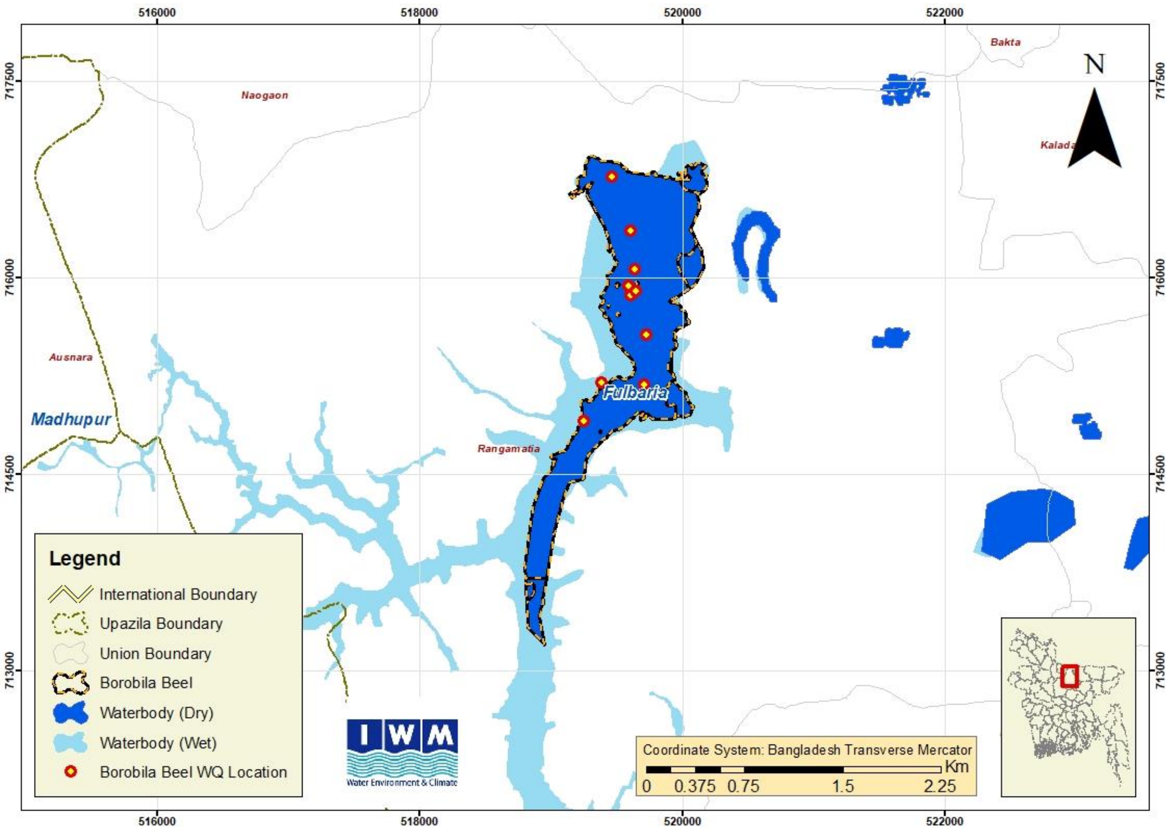


Figure 6-21: Water Sampling Location at Borobila beel Area

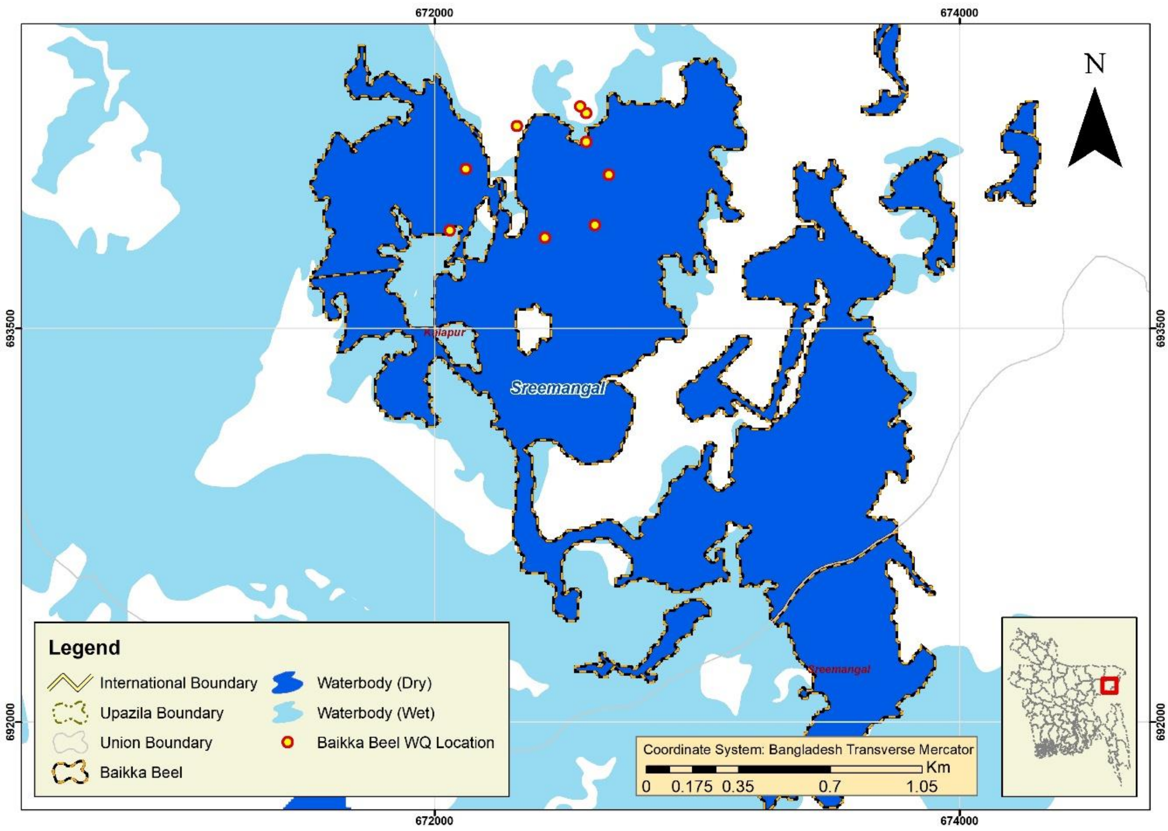


Figure 6-22: Water Sampling Location at Baikka Beel Area

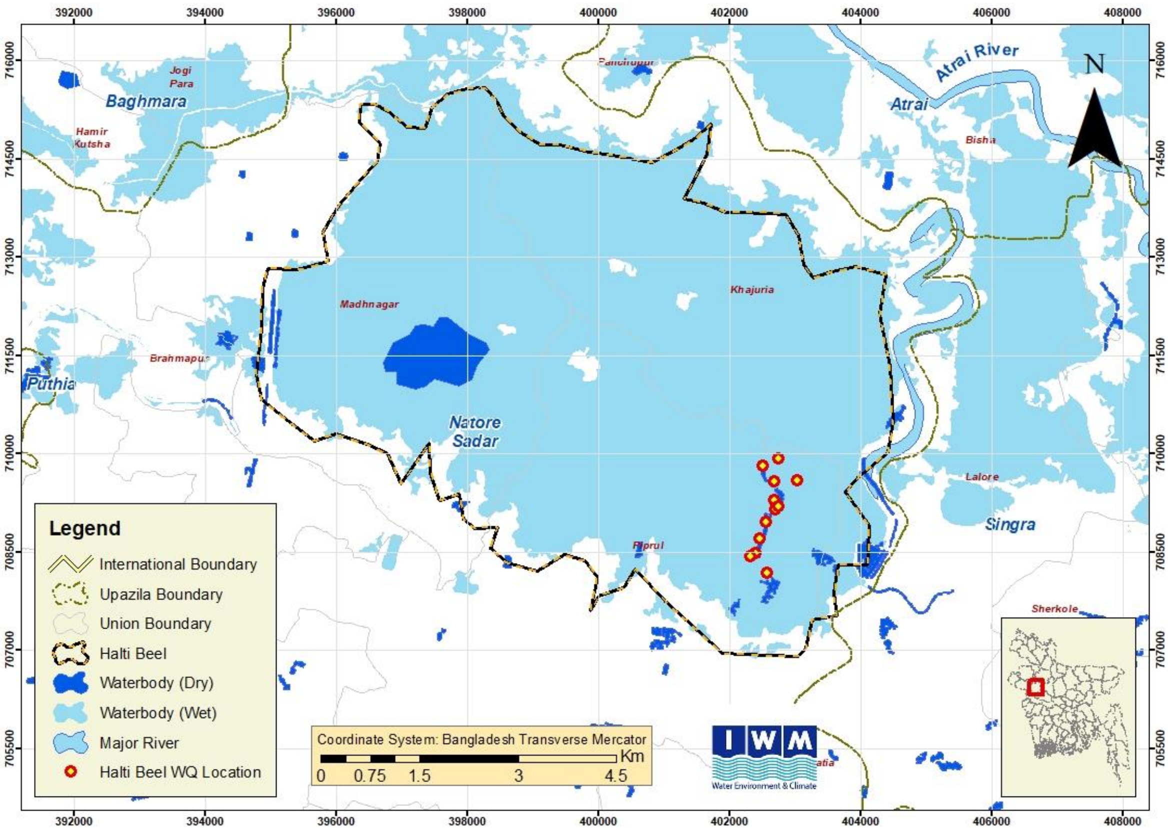


Figure 6-23: Water Sampling Location at Beel Halti Area

Table 6-14: In-Situ Water Quality Parameter at Baluhor Baor on November 29, 2019

ID	Longitude	Latitude	Temp (°C)	pH	DO (mg/l)	TDS (mg/l)	Turbidity (NTU)	Salinity (%)	Conductivity (µS/cm)
Bangladesh Drinking Water Standard			**20-30**	**6.5-8.5**	**6**	**1000**	**10**		**600-1000**
1	88.9843469	23.4091823	26.8	7.6	5.36	174.5	4.96	0.17	363
2	88.9841402	23.4126243	27.5	7.72	4.87	172.7	2.29	0.17	359
3	88.9828081	23.4179235	28.4	7.79	5.72	172.4	2.08	0.17	359
4	88.9840396	23.42164	26.9	7.74	5.62	174.1	1.89	0.17	362
5	88.9808189	23.4241513	27	7.78	5.92	174.3	2.05	0.17	363
6	88.9690896	23.394564	27.8	7.51	3.64	176.3	0.87	0.17	367
7	88.9633336	23.3962964	27.2	7.29	4.41	175.5	1.59	0.17	381
8	88.9586203	23.4012421	26.7	7.7	6.78	173.6	1.84	0.17	361
9	88.9601351	23.4087024	26.5	7.64	6.87	176.6	2.23	0.17	367
10	88.9633675	23.4156896	26.9	7.85	9.25	167.4	1.01	0.17	349
11	88.9674022	23.4188087	27.2	7.8	8.31	178.3	2.7	0.18	371
12	88.97313	23.4229251	26.9	7.69	8.17	175.7	2.28	0.17	366
13	88.98322715	23.411505	22.5	7.39	4.67	162.7	4.97	0.16	339
14	88.9581207	23.4046523	28	7.9	7.63	173.6	1.65	0.17	361
15	88.9785467	23.4242655	28	7.97	8.35	173.8	1.88	0.17	362
16	88.9860137	23.4143682	25.9	7.64	6.45	175.8	5.12	0.17	366
Maximum			28.40	7.97	9.25	178.30	5.12	0.18	381.00
Minimum			22.50	7.29	3.64	162.70	0.87	0.16	339.00
Standard Deviation			1.33	0.18	1.63	3.76	1.35	0.00	9.10

Table 6-15: In-Situ Water Quality Parameter at Borni Baor on December 03, 2019

ID	Longitude	Latitude	Temp (°C)	pH	DO (mg/l)	TDS (mg/l)	Turbidity (NTU)	Salinity (%)	Conductivity (μS/cm)
Bangladesh Drinking Water Standard			**20-30**	**6.5-8.5**	**6**	**1000**	**10**		**600-1000**
1	89.8680075	22.9492046	25.4	7.2	2.82	318	7.48	0.32	652
2	89.8671877	22.9543642	25.8	7.28	2.52	306	4.81	0.3	632
3	89.8638789	22.9573356	26.1	7.25	2.43	301	2.76	0.3	619
4	89.8598076	22.9588002	26	7.27	2.99	299	2.07	0.3	615
5	89.8550846	22.9590546	26.4	7.24	2.66	302	2.41	0.3	622
6	89.850959	22.9589067	26.3	7.26	2.85	311	2.2	0.31	639
7	89.8462062	22.9590645	26.3	7.29	3.79	323	1.99	0.32	663
8	89.8411073	22.9599635	26.6	7.32	3.72	337	2.28	0.34	691
9	89.8374092	22.9621667	26.8	7.36	4.26	341	1.89	0.34	699
10	89.8335243	22.9622377	25.8	7.31	3.3	383	3.56	0.38	783
11	89.8306497	22.9612801	26	7.8	6.71	381	5.36	0.38	780
12	89.8654567	22.9458847	25.3	7.25	3.02	321	7.57	0.32	660
13	89.8613968	22.9411259	25.5	7.23	2.57	308	3.47	0.31	633
14	89.8592172	22.9369592	25.4	7.2	2.44	302	2.47	0.3	622
15	89.8567885	22.9334311	25.6	7.14	2.06	297	1.38	0.3	611
16	89.8566564	22.9310483	25.7	7.14	2.43	296	1.05	0.29	609
Maximum			26.8	7.8	6.71	383	7.57	0.38	783
Minimum			25.3	7.14	2.06	296	1.05	0.29	609
Standard Deviation			0.453	0.150	1.114	27.577	2.005	0.028	55.123

Table 6-16: In-Situ Water Quality Parameter at Borobila Beel on November 14, 2019

ID	Longitude	Latitude	Temp (°C)	pH	DO (mg/l)	TDS (mg/l)	Turbidity (NTU)	Salinity (%)	Conductivity (µS/cm)
Bangladesh Drinking Water Standard			**20-30**	**6.5-8.5**	**6**	**1000**	**10**		**600-1000**
1	90.18727	24.550624	29.5	6.97	5.62	46.5	7.99	0.05	98.5
2	90.19186427	24.5530909	29	6.96	6.38	43.4	4.83	0.04	91.4
3	90.19204273	24.5565530	28.3	7.33	9.28	36.1	2.93	0.03	70.6
4	90.190827	24.559255	28.1	7	7.12	33.5	2.88	0.03	71.2
5	90.19112	24.561066	27.6	6.46	5.65	40.5	4.27	0.04	86.1
6	90.190815	24.563732	28.2	6.82	6.87	46.9	4.91	0.05	99.5
7	90.189406	24.567396	27.5	6.65	7.23	50.4	3.89	0.05	106.7
8	90.188642	24.553226	27.8	6.83	5.88	40.1	20.3	0.04	85.2
9	90.190691	24.559892	29.9	7.02	6.18	33.6	3.06	0.03	71.5
10	90.191248	24.559513	29.4	6.85	5.08	35.4	5.34	0.03	75.3
Maximum			29.90	7.33	9.28	50.40	20.30	0.05	106.70
Minimum			27.50	6.46	5.08	33.50	2.88	0.03	70.60
Standard Deviation			0.86	0.23	1.19	6.01	5.24	0.01	13.23

Table 6-17: In-Situ Water Quality Parameter at Baikka Beel December 12, 2019

ID	Longitude	Latitude	Temp (°C)	pH	DO (mg/l)	TDS (mg/l)	Turbidity (NTU)	Salinity (%)	Conductivity (µS/cm)
Bangladesh Drinking Water Standard			**20-30**	**6.5-8.5**	**6**	**1000**	**10**		**600-1000**
1	91.7023307	24.3524796	23.7	7.62	9.15	24.9	1.27	0.02	53
2	91.7014968	24.3536293	23.7	7.3	8.35	24.7	1.3	0.02	52.6
3	91.7015015	24.3546082	23.9	6.49	5.27	22.6	3.89	0.02	48.1
4	91.7012836	24.3548498	23.2	6.32	2.72	22.4	4.02	0.02	47.8
5	91.7002771	24.3648712	23.7	8.04	9.75	21.81	4.52	0.02	46.5
6	91.6988968	24.3542002	23.9	6.47	5.56	24.1	3.24	0.02	51.3
7	91.6969646	24.3527359	23.9	7.01	7.43	24.9	1.56	0.02	53.1
8	91.6963353	24.3506378	23.9	7.68	9.25	26.1	1.96	0.02	55.6
9	91.6998935	24.3503418	23.2	8.16	9.48	31.3	1.57	0.03	66.7
10	91.7017755	24.3507624	24.5	7.08	8.17	28	1.67	0.03	59.7
Maximum			24.50	8.16	9.75	31.30	4.52	0.03	66.70
Minimum			23.20	6.32	2.72	21.81	1.27	0.02	46.50
Standard Deviation			0.37	0.66	2.30	2.86	1.27	0.00	6.09

Table 6-18: In-Situ Water Quality Parameter at Beel Halti on December 26, 2019

ID	Longitude	Latitude	Temp (°C)	pH	DO (mg/l)	TDS (mg/l)	Turbidity (NTU)	Salinity (%)	Conductivity (µS/cm)
Bangladesh Drinking Water Standard			**20-30**	**6.5-8.5**	**6**	**1000**	**10**		**600-1000**
1	89.033933	24.489661	19.2	8.13	10.27	216.5	8.66	0.21	446
2	89.034555	24.491622	18.7	8.28	10.08	99.5	7.76	0.1	208.3
3	89.035502	24.493951	18.2	7.89	8.96	98.7	7.1	0.11	206.8
4	89.036825	24.495627	18.5	7.54	8.92	98.2	7.06	0.1	206.6
5	89.036698	24.497009	18.4	7.66	10.03	102.8	18.6	0.1	215.3
6	89.036665	24.499528	19.2	8.08	9.41	106.3	12.3	0.1	220
7	89.035027	24.501607	19.4	8.11	9.98	107.6	10.2	0.11	226
8	89.037268	24.502642	19.4	7.91	9.44	105.6	30.7	0.1	222
9	89.040169	24.499676	19.4	8.08	10.14	104.8	12.8	0.1	220
10	89.037427	24.496149	18.5	7.95	9.67	100	10.6	0.1	210.2
11	89.033154	24.489189	18.8	8.07	10.03	101.7	15	0.1	213.1
12	89.035699	24.486868	19.1	7.93	10	105.6	33.5	0.1	222
Maximum			19.40	8.28	10.27	216.50	33.50	0.21	446.00
Minimum			18.20	7.54	8.92	98.20	7.06	0.10	206.60
Standard Deviation			0.43	0.21	0.46	32.98	8.90	0.03	66.87

The temperature, pH, TDS and conductivity of the all water samples of clustered wetlands are within the limit of Bangladesh drinking water standard. The maximum and minimum DO value of Beel Halti water samples was 8.92mg/l and 10.27mg/l. All the water sample of Beel Halti area the DO value exceeds the Bangladesh drinking water standard. The minimum and maximum DO value of Baluhor Baor, Borni Baor, Borobila Beel and Baikka Beel was 3.64mg/l and 9.25mg/l, 2.06mg/l and 6.17mg/l, 5.08mg/l and 9.28mg/l, 2.72mg/l and 9.75mg/l respectively. Only 1 sample of DO value of Borni Baor area exceed Bangladesh standard whereas 8 sample DO value of Borni Baor area exceed Bangladesh standard. 6 sample of DO value of Borobila Beel area exceed Bangladesh standard whereas 7 sample DO value of Baikka Beel area exceed Bangladesh standard. The turbidity value of all water samples of Baluhor Baor, Borni Baor and Baikka Beel were within the limit of Bangladesh drinking water standard. The maximum and minimum value of turbidity of Borobila Beel and Beel Halti area was 20.30NTU and 2.88NTU and 33.50NTU and 7.06NTU respectively.

6.5 Data Collection on Biodiversity, Fisheries Resources, Forest, Agricultural Development and Socio – economic data for Tanguar and Hakaluki Haor

Tanguar haor also called Tangua haor is located at 250009’ N latitude and 910004’ E longitude in the floodplain of the Surma river in Sunamganj District extending over 10 mauzas of Dharmapasha and Tahirpur Upazilas. The mauzas covering the Tanguar haor are (1) Jagadishpur, (2) Bhabanipur, (3) Lamagaon, (4) Ramsinhapur, (5) Mahajampur, (6) Maindag, (7) Mayajuri, (8) Bhangachara Purba, (9) Noagaon and (10) Tanguar Haor. The haor consists of 120 beels of various sizes. The area of Tanguar haor including 46 villages within the haor is about 100 km^2 of which 2802.36 ha is wetland (Alam and Hosain, 2015). It is the source of livelihood for more than 40,000 people. It is Bangladesh's most important freshwater wetland, one of the main tributaries of the Brahmaputra at the base of the Meghalaya Hills in adjacent India. Tanguar haor provides habitat for at least 135 fish and 208 bird species, including 92 water birds and 98 migratory bird species. Tanguar haor also supports a rich fishery and is regarded as one of the country's richest breeding grounds for freshwater fish. In 2000, the hoar basin was declared a Ramsar site number 1031 - wetland of international importance.

Hakaluki haor is a marsh wetland ecological system of north-eastern Bangladesh. It is the largest marsh wetland resources in Bangladesh and is bounded by the Kushiyara River as well as a part of the Sonai Bardal River to the north, by the Fenchuganj-Kulaura railway to the west and to the south, and by the Kulaura-Beanibazar road to the east. It lies between $24^{0}35^{/}$ to $24^{0}44^{/}$ N latitude and $92^{0}00^{/}$ E to $92^{0}08^{/}$ E longitude. The haor is mainly fed by the Juri, Sonai, Damai, Fanai and Kuiachara rivers. Sonai and Juri rivers are trans-boundary rivers originated in India. Hakaluki haor covers a large surface area of about 181.15 km^2. Around 40% of this land falls in the territory of Baralekha Upazila. This huge land coverage makes it Bangladesh's largest haor and one of Asia's larger wetlands. There are more than 238 small, medium and large interconnecting beels, some of which are perennial. During the dry season, approximately 4,400 ha is covered by the beel, but with the onset of monsoon, the entire area floods to about four and half times of this size (18,383 ha) and remains under water for up to five-six months. During this period, all the beels unite together to form one large lake (haor). The Hakaluki wetland ecosystem is the home of 558 species of animals and birds including some very rare and endangered species It supports numerous wetland species of plants including a significant number of medicinal plants. It provides sanctuary to many species of animals and birds. The map of Tanguar haor and Hakaluki haor area is shown in Figure 6-24 and Figure 6-25 respectively.

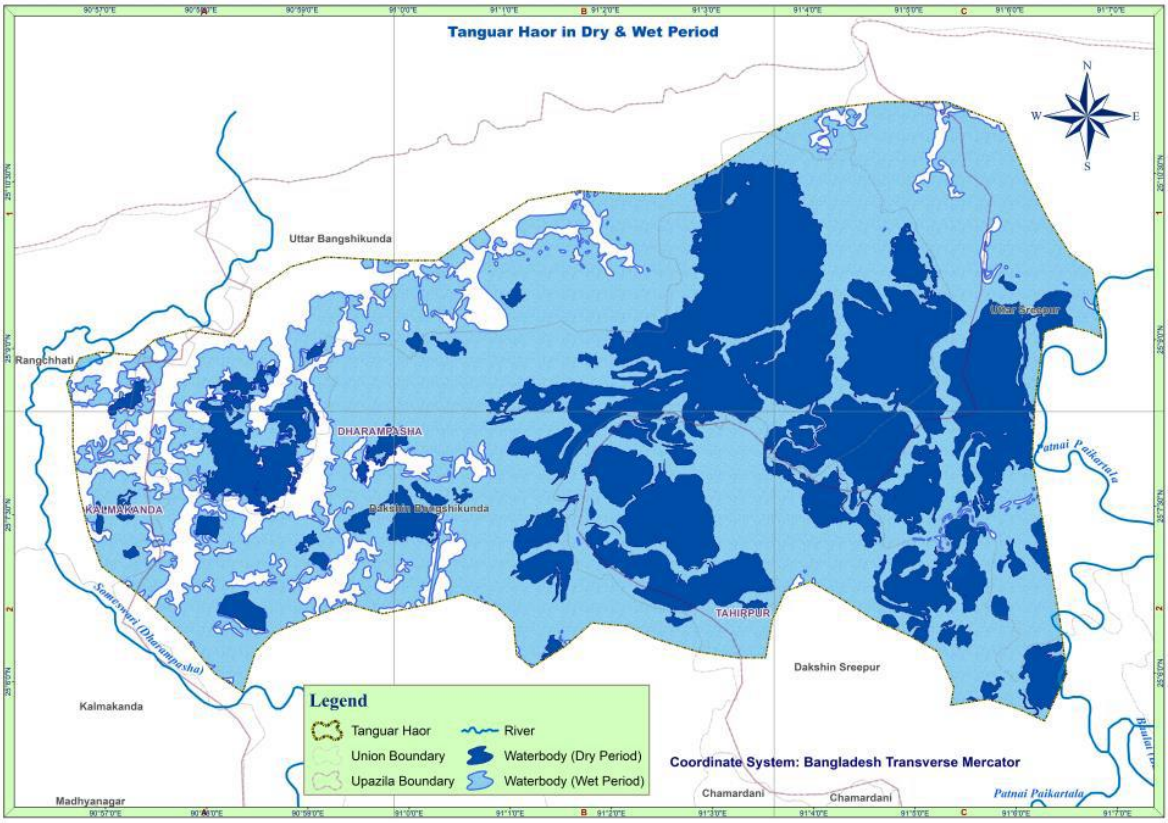


Figure 6-24: Map of Tanguar Haor

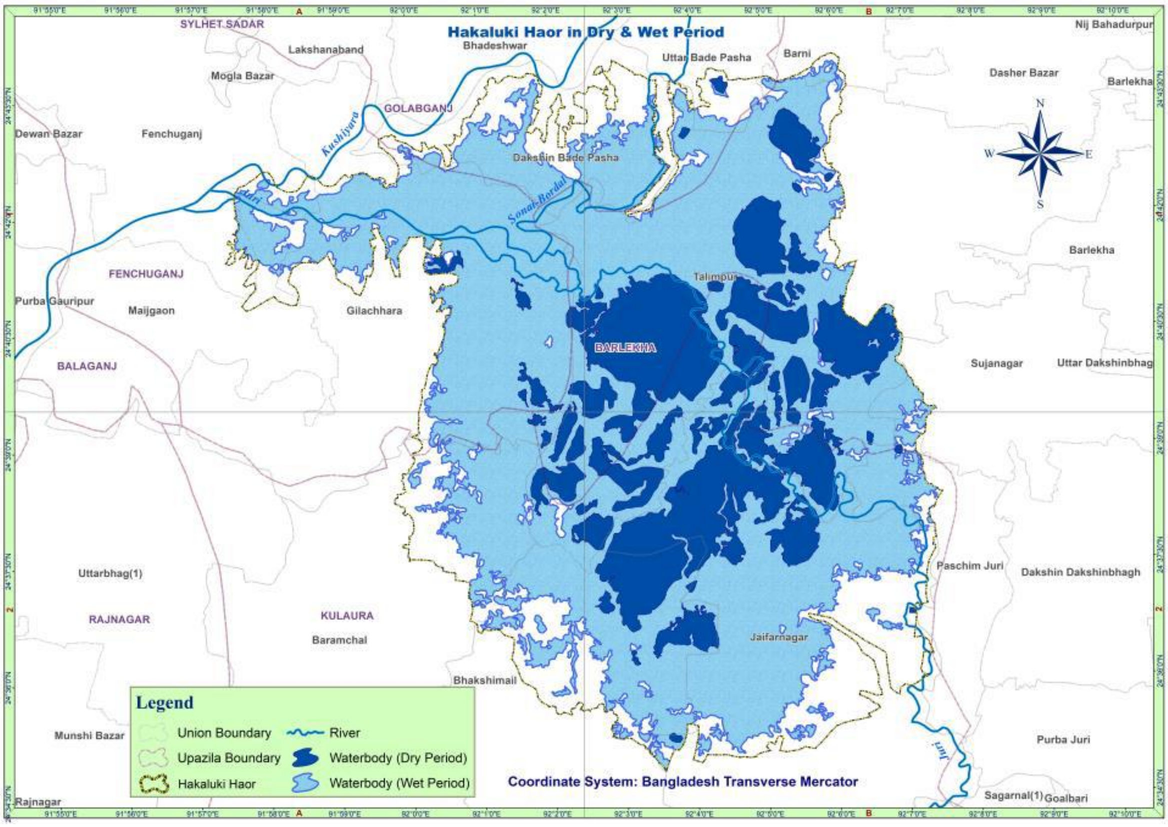


Figure 6-25: Map of Hakaluki Haor

In view of addressing the national goal for protecting wetland resources, the Project Implementation Committee (PIC) and Project Steering Committee (PSC) have asked the consultant to collect the detail data on biodiversity, fisheries, vegetation cover, agricultural and socio –economic condition of Tanguar and Hakaluki haor area. Accordingly, the above-mentioned data has been collected for two season’s namely dry and wet seasons of Tanguar and Hakaluki haor.

The broad objectives of the study related to Tanguar haor and Hakaluki haor and adjacent River Ecosystem interaction for development of wetland biodiversity and sustainable wetland management framework and identification of measures for conservation of natural resources. As such, the present survey and study of Tanguar haor and Hakaluki haor is conducted to cover the following issues:

- A quantitative- qualitative approach is applied to obtain data to analyze the vegetation status along with peoples’ attitude, perception & historical information for making a complete inventory in regard to propose a comprehensive management framework.
- Collection of data for fisheries resources and status of fish biodiversity in haor wetland ecosystems to identify the present fishing practices and fishing crafts and gear used and identify the potential causes of fish biodiversity and habitat degradation.
- Collection of information on existing socio-economic and cultural conditions in the project area and develop baseline primary information gathered through reconnaissance and household survey, community consultations and Focus Group Discussions (FGDs).
- Baseline study on macro-faunal wetland biodiversity of Tanguar haor and Hakaluki haor to identify the interaction between Haor and River ecosystem of Bangladesh with respect to macro-faunal biodiversity.
- Collection of data on crop agricultural component of Hakaluki and Tanguar haor wetland ecosystem to identify the existing crop production, constraints and potentials of agricultural production and productivity.

6.5.1 Data Collection on Biodiversity

A baseline biodiversity study has been carried out within and periphery of Tanguar haor and Hakaluki haor. The baseline biodiversity study primarily focused on identifying the faunal diversity with their abundance and distribution within and periphery of Tanguar haor and Hakaluki haor as well as their biological status in Bangladesh. The survey has been conducted in December 2018 and July 2019. The field survey was also enriched by the presence of Project Director (PD) of this project as shown in Figure 6-26. The study was conducted primarily in daytime, but few studies also conducted at night due to the non-favorable condition of the study areas. Aural and visual search was the main survey method for ornithological study. Herpeto-faunal and mammalian study was done through visual search and through discussion with local people and literature review. All collected information has been recorded through pre-develop data sheet for faunal inventory. Both formal and informal interviews as well as public consultation, in the form of focus group discussion (FGD) sessions as shown in Figure 6-26, and some institutional consultations with the relevant institutions, have also been conducted as a part of this baseline study to learn about the seasonal variation of faunal biodiversity. The details of the Bio-diversity data collection have been presented in Volume-II: Appendix-E.

Figure 6-26: Bio-diversity Survey at Tanguar Haor Area (Left) and Stakeholder Consultation at Hakaluki Haor Area (Right)

6.5.2 Data Collection for Fisheries Resources

Stakeholder consultation as well as survey of fish market and landing center has been conducted at different stages of the study with different users of wetland for gathering qualitative information. Stakeholder analysis has been carried out to address pertinent study objectives and to capture the diverse interests of different groups that are involved in these respective wetland management systems. Stakeholder selection criteria included: 1) dependency on wetland and floodplain resources, 2) diversity of the resource users, i.e. fishermen, farmers, small traders, women 3) resource users practicing traditional management approaches, 4) resource users involved in associations and networks, 5) most impacted resource users, 6) policy makers 7) local elites, NGOs and civil society. The study was conducted through applying participatory research methods, specifically Focus Group Discussions (FGD), Key Informant Interviews (KII), Personal Interview (PI), Household Survey (HS) and semi structured interviews. Consultation at different locations of Hakaluki haor and Tanguar haor area has been conducted during dry season and wet season for detail fisheries survey. The duration of the field survey has been presented Table 6-19. The list of Focus Group Discussion (FGD), Personal Interview (PI), Key Informant Interviews (KII) and Household Survey (HS) for different wetlands are illustrated in Table 6-20 to

Table 6-21. The details of the fisheries resources survey have been presented in Volume-II: Appendix-F.

Table 6-19: Duration of Filed Survey

Sl. No.	Name of Wetland	Duration of Survey
1.	Tanguar Haor	01 to 14 December 2018 for Dry Season Survey
		01 to 06 September 2019 for Wet Season Survey
2.	Hakaluki Haor	07 to 12 December 2018 for Dry Season Survey
		27 to 30 August 2019 for Wet Season Survey

Table 6-20: List of Survey and Study Sites of Tanguar Haor and Hakaluki Haor Areas during Dry Season

Location			FGD		PI		HS		KII	
District	Upazila	Union	No.	Nos. of Person	No.	Nos. of Person	No.	Nos. of Person	No.	Nos. of Person
Tanguar Haor (Dry Season)										
Sunamganj	Tahirpur	Watch Tower, Joypur	1	10	2	2				
		Indropur	1	12	3	3				
		Bangal Vita	1	12	1	1				
		Lamagaon	1	13	4	4				
		Solaimanpur	1	8	1	1				
		Tahirpur Sadar							1	UFO
	Dharmapasha	Rongchi	1	12	3	3				
		Amtorpur	1	12	1	1	2	2		
		Dharmapasha	1	10	5	5			1	UFO
Hakaluki Haor (Dry Season)										
Moulvibazar	Kulaura	Gourkoran Bazar	1	14	3	3				
		Kulaura Sadar							1	UFO
		Howaboni Footbeel Landing center			3	3				

Location			FGD		PI		HS		KII	
District	**Upazila**	**Union**	**No.**	**Nos. of Person**	**No.**	**Nos. of Person**	**No.**	**Nos. of Person**	**No.**	**Nos. of Person**
		Jalalpur	1	13	1	1				
	Barlekha	Barlekha Sadar, Kanaga Bazar	1	12	1	1			1	UFO
Sylhet	Sylhet	DOF Office, Sylhet							1	DD, Fisheries, Sylhet Division

Table 6-21: List of Survey and Study Sites of Tanguar Haor and Hakaluki Haor Areas during Wet Season

Location			FGD		PI		KII	
District	**Upazilla**	**Union**	**No.**	**Nos. of Person**	**No.**	**Nos. of Person**	**No.**	**Nos. of Person**
Tanguar Haor (Wet Season)								
Sunamganj	Tahirpur	Lamagaon	1	15	5	5		
		Upazilla Fishery Office, Tahirpur Sadar					1	Assistant Fishery officer
		Tahirpur Lalabazar Landing Center			1	1		
		Indropur	1	12	4	4		
		Bangal Vita	1	12	6	6		
		Gulabari	1	13	6	6		
		Solaimanpur Landing Center			1	1		
	Dharmapasha	Rongchi	1	12	4	4		
		Amtorpur	1	17	4	4		
		Rupnagar	1	13	4	4		
Hakaluki Haor (Wet Season)								
Moulvib azar	Kulaura	Noagaon, Kulaura					1	SUFO
		Kulaura Sadar Landing Centre	1	40	6	6		

Location			FGD		PI		KII	
District	Upazilla	Union	No.	Nos. of Person	No.	Nos. of Person	No.	Nos. of Person
	Barlekha	Halla, Barlekha Sadar	1	12	2	2		
Sylhet	Fenchuganj	Vitatjkor, Fenchuganj, Lamabazar Landing Centre	1	14	5	5		
		Badeoduy, Fenchuganj	1	12	4	4		

6.5.3 Data Collection on Vegetation Survey

For vegetation/forest study, vegetation sample plots were taken either from within the wetland boundary or at the boundary of the delineated wetland. The sample plots lie within the 30meter linier distance from the water body. The vegetation study focused on studying biodiversity status along with finding out the total carbon stock in tree corps per hector, vegetation structure along with biodiversity indexing and above ground biomass and carbon estimation.

Quantitative Empirical Vegetation Inventory: A nested plot designed was followed to collect inventory data. The plot size was 20m by 20m for tree measurement, 10m by 10m for pole measure measurement and 5m by 5m for regeneration (seedling) measurement. For tree and pole diameter at breast height and total height were recorded for number of individual. For trees sectional diameter were also recorded for each species found to fit in the allometric equation to finding the total above ground biomass for carbon measurement. A schematic nested plot designed is shown in Figure 6-27.

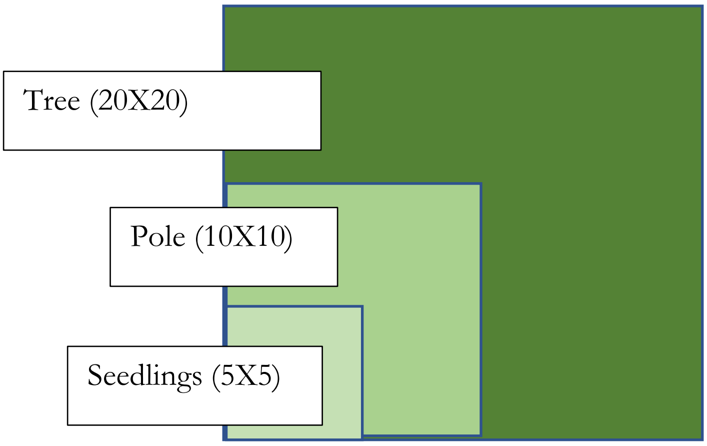


Figure 6-27: Nested Plot Design

A total of 104 nos. of nested plots were measured during wet season whereas 111 nos. of nested plots were measured in dry season. Plots layout was done based on prevailing literature and documents indicating the vegetation density of the respective wetlands and along with a reconnaissance field observation. Cluster wise nested plots numbers are given in and plot locations are shown in the Figure 6-28 to Figure 6-31.

Table 6-22: Sample Plots for Tanguar and Hakaluki Haor

Wetland	Location			Plot No. (Wet)	Plot No. (Dry)
	District	Upazila	Union		
Hakaluki Haor	Molvi Bazar	Kulaura, Juri, Baralekha Golapganj	Bhatera, Baramchal, Bahakshimail, jaifarnagar, Paschim juri, Talimpur, Sujanagar Talimpur	53	50
	Sylhet	Fenchugang	Gila chara		
Tanguar Haor	Sunamganj	Tahirpur Dharmapasha	Uttar sripur Dakshin sripur Dakshin Bongshi Kunda Uttar Bongshi Kunda	51	61

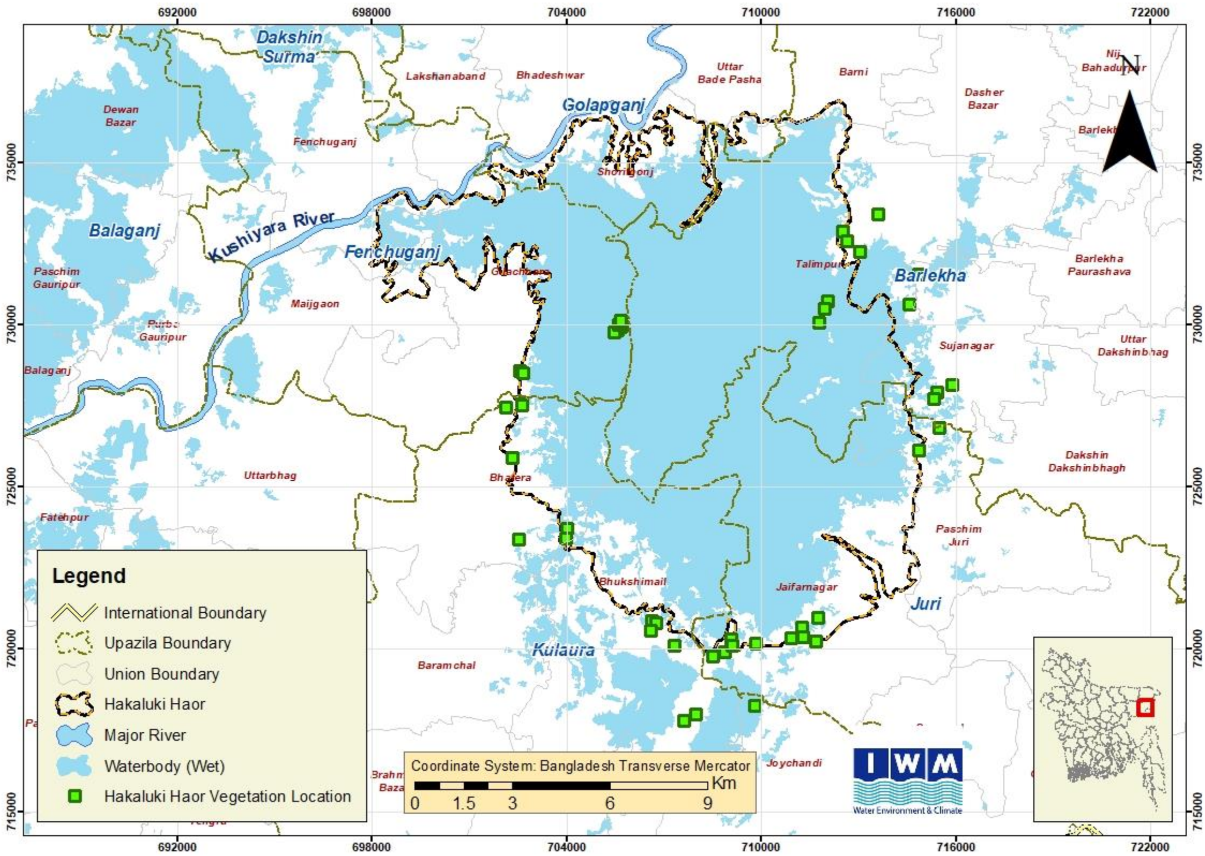


Figure 6-28: Vegetation Inventory Plots in Hakaluki Haor (Wet Season)

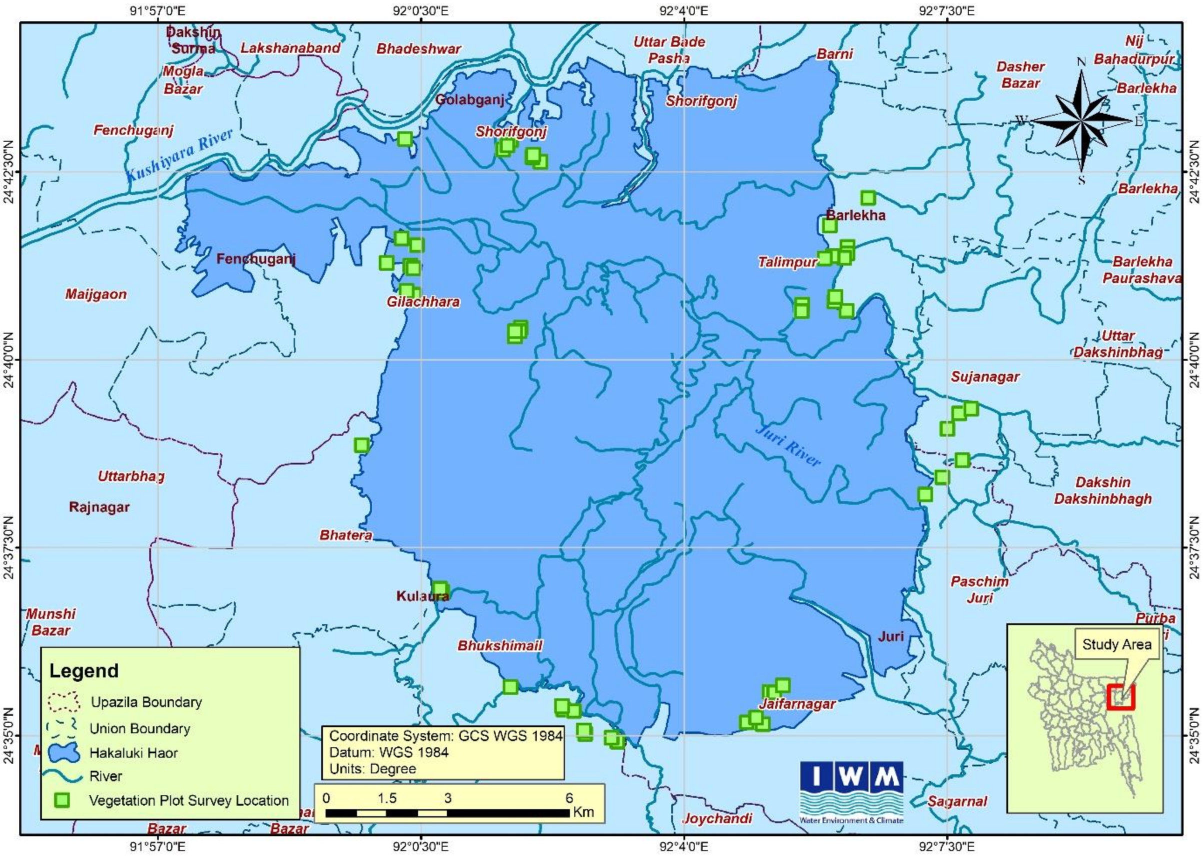


Figure 6-29: Vegetation Inventory Plots in Hakaluki Haor (Dry Season)

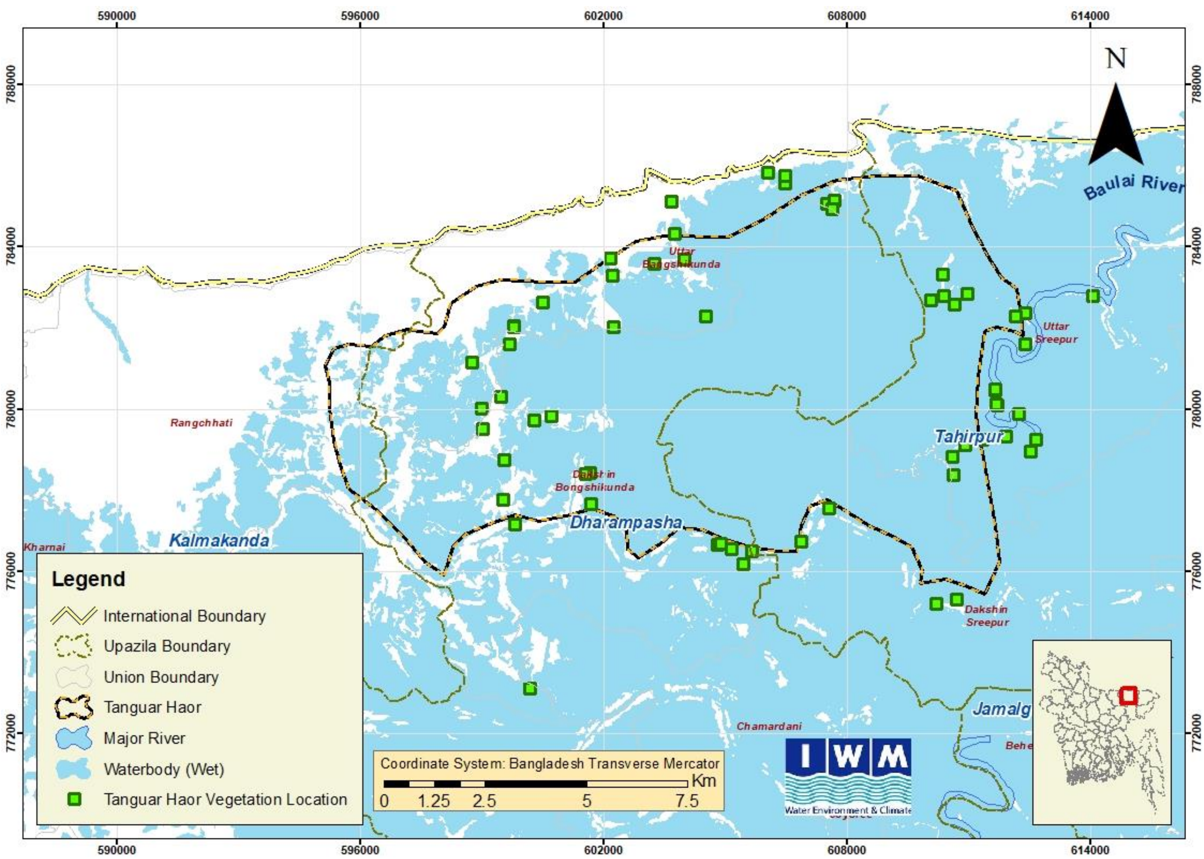


Figure 6-30: Vegetation Inventory Plots in Tanguar Haor (Wet Season)

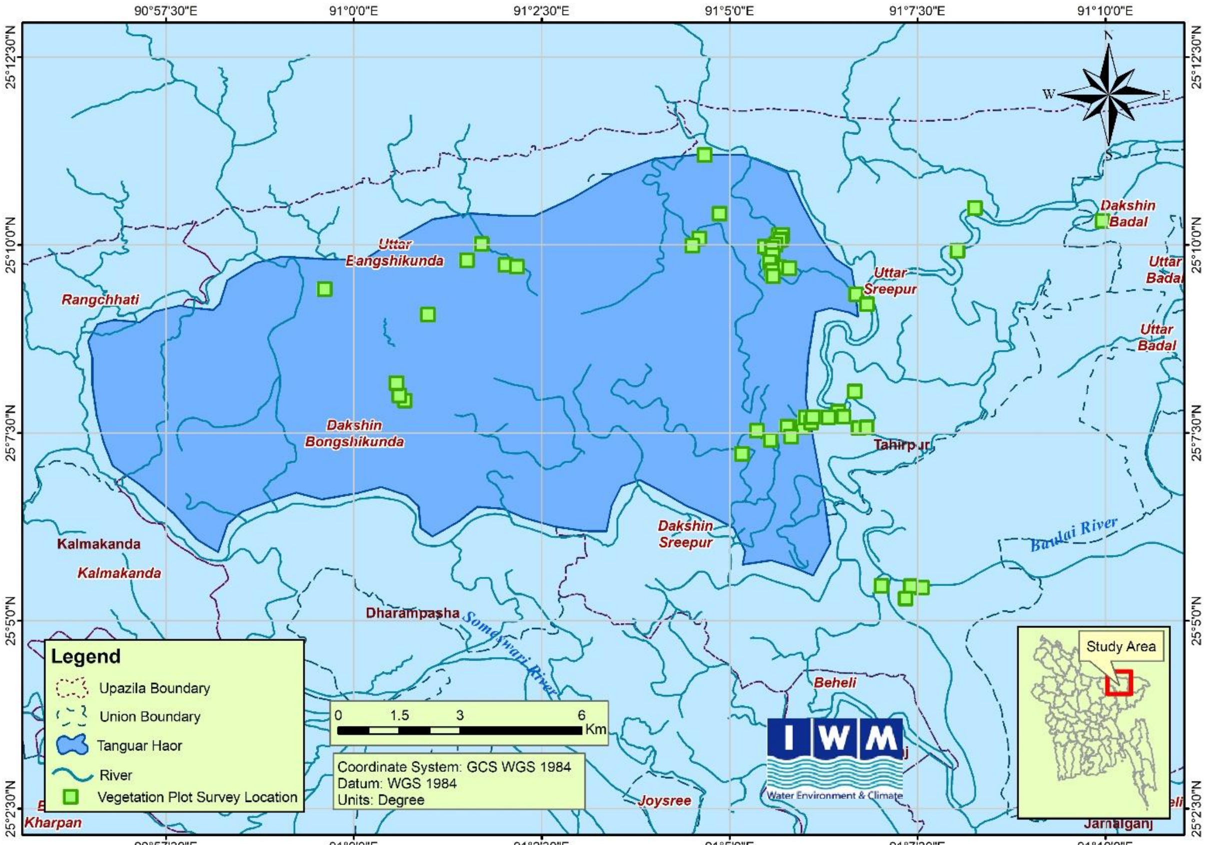


Figure 6-31: Vegetation Inventory Plots in Tanguar Haor (Dry Season)

Data Analysis for Tanguar Haor:

Species Composition: A total of 52 species under 30 families were found in the study sites from 61 plots and of total 24400 m^2 area during the first survey period (dry season) and 54 secrecies were found from 51 plots of wet season. Amid of them, Moraceae switched 4 species, Fabaceae clicked 10 species and Meliaceae family carried out 3 species respectively, rest of the species had gone to several families which was shown in Table 6-23. Pongamia pinnata and Barringtonia acutangula were frequently observed throughout the study sites. These mentioned species also used for plantation in the Tanguar Haor. Principle wetland habitats of Tanguar Haor include open water with submerged and floating aquatic vegetation, seasonally inundated mixed herbaceous vegetation, reed beds and rice fields. Hijol (*Barringtonia racemose*) and Koroch (*Milletia pinnata*; old name: *Pongamia pinnata*) were dominant species in swamp forests, but these have now disappeared except for an occasional isolated tree and nearly a pure formation in the Rongchi 'forest', which is an 8-hectare stand of 800+ severely-lopped and old trees (Gieson and Rashid, 1997). During last couple of years again Barringtonia racemose species were replanted on Kandas. *Barringtonia acuatangula, Bambusa arundinacea, Dendrocalamus strictus, Musa paradisiaca, Areca cathecu, Calamus tenuis, Caryota urens and Cocos nucifera, Albizzia procera* etc., have been found in Tanguar haor with rich species diversity. Many species of terrestrial birds take shelter in such vegetation and build nest or roost on the trees and bamboos. List of floral species and their status for the Tanguar haor area is illustrated in Table 6-23.

The diversity index is a well-known method of showing that diversity is not only numbers of different species, but also how well each of these species is represented in different areas. The tree vegetation diversity of the study site was analyzed using the quantitative indexing approaches, the Shannon- Wiener index indicate the diversity status of the site where as Magalef index is showing the richness and Simpson is showing the dominance. The study found the tree vegetation diversity is in the mid-range as the Shannon index is around 0.54 in range of (0 to 1). The tree vegetation diversity of Tanguar haor has been given in the Table 6-24.

Table 6-23: List of Floral Species at the Tanguar Haor area

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Acacia auriculiformis (Akashmoni)	*Anthocephalus indicus* (Kadam)	*Streblus asper* (sheora)
Albizia lebbeck (Koroi)	*Barringtonia acutangula* (Hijol)	
Anthocephalus indicus (Kadam)	*Bombax ceiba* (Shimul)	
Artocarpus heterophyllus (Kanthal)	*Crataeva magna* (Barun)	
Barringtonia acutangula (Hijol)	*Ficus bengalensis* (Bot)	
Bombax ceiba (Shimul)	*Lagerstroemia speciosa* (Jarul)	
Crataeva magna (Barun)	*Millettia pinnata* (Koroch)	
Dillenia indica (Chalta)	*Terminalia arjuna* (Arjun)	
Diospyros malabarica (Gaab)	*Trewia polycarpa* (Pitali)	
Erythrina variegata (Mandar)	*Albizia procera (Shil Kori)*	
Eucalyptus globulus (Eucalyptus)	*Azadirachta indica* (Neem)	
Ficus bengalensis (Bot)	*Averrhoa carambola (Kamranga)*	
Ficus hispida (Dumur)	*Cassia fistula (Shonalu)*	
Lagerstroemia speciosa (Jarul)	*Streblus asper* (sheora)	
Litchi chinensis (Litchi)	*Tamarindus indica (Tetul)*	
Mangifera indica (Aam)		
Millettia pinnata (Koroch)		
Psidium guajava (Peyara)		
Samanea saman (Raintree)		
Spondias mombin (Amra)		
Swietenia mahagoni (Mahogany)		
Syzygium cerasoides (Kalo Jam)		

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Syzygium cumini (Jam)		
Terminalia arjuna (Arjun)		
Trewia polycarpa (Pitali)		
Zizyphus mauritiana (Boroi)		
Acacia mangium (M angium)		
Areca cathecu (shupari)		
Rongi		
Bilash Khea		
Ficus racemosa (Dumur)		

Table 6-24: Total Species Recorded and Studied with Values of Shannon-Wiener Index (diversity), Margalef Index (Richness) and Simpson Index (Dominance) in Tanguar Haor Area

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	52	0.54	0.81	0.73
Wet	54	0.51	0.56	0.28

Tree Biomass and Carbon Accumulation in both Above and Below Ground: Mean above-ground, below-ground, and Total Biomass Carbon (TBC) of the studied areas were 21.38Ton per ha, 4.55Ton per ha and 25.93Ton per ha respectively as given in Table 6-25.

Table 6-25: Carbon Accumulation (Ton per ha) in the Tanguar Haor Area

Name of the wetland	Maximum Total Carbon (ton/ha) in a plot	Minimum Total Carbon (ton/ha) in a plot	Average Total tree Carbon stock per unit area (ton/ha)
Tanguar haor	115.65	3.33	25.93

Data Analysis for Hakaluki Haor:

Species Composition: A total of 28 species were found in the study sites from 50 plots and of total 20000 m^2 area during dry season and 34 species were found in wet season from 53 plots. Amid of them, Moraceae switched 4 species, Fabaceae clicked 5 species and Meliaceae family carried out 2 species respectively, rest of the species had gone to several families which was shown in Table 6-26. *Pongamia pinnata and Barringtonia acutangula* were frequently observed throughout the study sites. These mentioned species also used for planation in the Hakaluki haor. List of floral species and their status for the Hakaluki haor area is illustrated in Table 6-26.

The tree vegetation diversity of the study site was analysed using the quantitative indexing approaches, the Shannon- Wiener index indicate the diversity status of the site where as Magalef index is showing the richness and Simpson is showing the dominance. The study found the tree vegetation diversity is in the mid-range as the Shannon index is around 0.54 in range of (0 to 1). The tree vegetation diversity of Hakaluki haor has been given in the Table 6-27.

Table 6-26: List of Floral Species and their Status in the Hakaluki Haor Area

Abundantly Found Trees	Trees Sparsely Found (becoming rare)	Trees Lost from Ecosystem
Acacia auriculiformis (Akashmoni)	*Anthocephalus indicus* (Kadam)	*Phragmites kakra*
Acacia catechu (Khoi Babla)	*Barringtonia acutangula* (Hijol)	
Acacia mangium (Mangium)	*Bombax ceiba* (Shimul)	
Albizia lebbeck (Koroi)	*Crataeva magna* (Barun)	
Anthocephalus indicus (Kadam)	*Ficus bengalensis* (Bot)	
Artocarpus heterophyllus (Kanthal)	*Lagerstroemia speciosa* (Jarul)	
Barringtonia acutangula (Hijol)	*Millettia pinnata* (Koroch)	
Bombax ceiba (Shimul)	*Trewia polycarpa* (Pitali)	
Crataeva magna (Barun)		
Dillenia indica (Chalta)		
Diospyros malabarica (Gaab)		
Eucalyptus globulus (Eucalyptus)		
Ficus bengalensis (Bot)		
Lagerstroemia speciosa (Jarul)		
Litchi chinensis (Litchi)		
Local tree (undefined)		
Mangifera indica (Aam)		
Millettia pinnata (Koroch)		
Samanea saman (Raintree)		
Spondias mombin (Amra)		
Streblus asper (Sheora)		
Swietenia mahagoni (Mahogany)		
Syzygium cumini (Jam)		
Trewia polycarpa (Pitali)		

Table 6-27: Total Species Recorded and Studied with Values of Shannon-Wiener Index (diversity), Margalef Index (Richness) and Simpson Index (Dominance) in Hakaluki Haor Area

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	28	0.54	0.81	0.73
Wet	34	0.82	0.87	0.42

Tree Biomass and Carbon Accumulation in both Above and Below Ground: Mean above-ground, below-ground, and Total Biomass Carbon (TBC) of the studied areas were 28.02Ton per ha, 5.57Ton per ha and 33.59Ton per ha respectively as given in Table 6-28.

Table 6-28: Carbon Accumulation (Ton per ha) in the Hakaluki Haor Area

Name of the wetland	Maximum Total Carbon (ton/ha) in a plot	Minimum Total Carbon (ton/ha) in a plot	Average Total tree Carbon stock per unit area (ton/ha)
Hakaluki haor	107.48	5.62	33.59

The details analysis of vegetation survey has been presented in Volume-II: Appendix-G.

6.5.4 Data collection for Agricultural Development

The data collection covers the crop agricultural component of Hakaluki and Tanguar haor wetland ecosystem to identify existing crop production, constraints and potentials of agricultural production and productivity. The data has been collected through the RRA-cum-FGD exercises in different Upazilas around Hakaluki Haor and Tanguar haor basin as well as review of secondary information available at different sources pertinent to the study. The details of the agricultural study have been given in Volume-II: Appendix-H.

Soil Association Data of Hakaluki and Tanguar Haor: The soil association data for Hakaluki and Tanguar haor has been collected from SRDI. The haor basin area is predominantly represented by Shurma-Kushiara Floodplain (AEZ 20), Sylhet Basin AEZ 21), North-Eastern Piedmont Plains (AEZ 22) and a minor portion of North-Eastern Hills (AEZ 29). However, Hakaluki and Tanguar haor basin area is mostly represented by AEZ 20 and AEZ 21. As reported by SRDI, there several Soil Associations and Soil Series in each Upazila. Upazila-wise occurrence of Physiographic Units and Soil Series of Hakaluki and Tanguar haor is presented in Table 6-29.

Table 6-29: Upazila-wise Soil Associations and Soil Type Distribution Soil Association and area distribution of Hakaluki and Tanguar Haor Area

Upazila	Physiographic Unit	Soil Association	Land area (Ha)
Goainghat	Shurma-Kushiara Floodplain (AEZ 20)	Monu, Goainghat, Fagu, Hakaluki	14138
Baralekha	North-Eastern Piedmont Plains (AEZ 22)	Pritompasha, Monu	5865
	AEZ 29: North-Eastern Hills	Boralekha, Binaibazaar	19289
	Homestead and Others		40
Kulaura	Shurma-Kushiara Floodplain (AEZ 20)	Balaganj, Goainghat, Fagu, Terchibari, Hakaluki	15753
	North-Eastern Piedmont Plains (AEZ 22)	Jaflong, Bijipur, Monu Pritompasha,	11805
	North-Eastern Hills (AEZ 29)	Boralekha, Khadimnagr, Srimangal, Jaflong, Monu, Bijipur, Pritompasha, Juri	29215
	Homestead and Others		645
Fenchuganj	Surma-Kushiara Floodplain (AEZ 20)	Balaganj, Goainghat, Fagu, Terchibari	3823
	N&E Piedmont Plains (AEZ 22)	Pritompasha, Monu	2645
	North-Eastern Hills (AEZ 29)	Boralekha, khadimnagar, Bijipur, Pritompasha	2076
	Homestead and Others		64
Golapganj	Surma-Kushiara Floodplain (AEZ 20)	Balaganj, Goainghat, Fagu, Terchibari, Hakaluki	13813
	N&E Piedmont Plains (AEZ 22)	Bijipur, Pritompasha, Monu, Juri	3069
	North-Eastern Hills (AEZ 29)	Khadimnagar, Ramgar, Bijipur, Pritompasha	645
	Homestead and Others		363
Kamlakanda	Sylhet Basin (AEZ 21)	Goainghat, Fgua, Sulla	6764
	North-Eastern Piedmont Plains (AEZ 22)	Kulaura, Borolekha, Bijipur, Pritimpasha, Ramnagar, Kongsho, Nalitabari, Susong Nunni	27382
	Old Brahmaputra Floodplain (AEZ 9)	Lokdeo, Ghatail	468
	Homestead and Others		128
Dharmapasha	AEZ 21: Sylhet Basin	Balaganj, Goainghat, Fagu, Terchibari, Shalla, Dhirai	28141
	AEZ 22: North-Eastern Piedmont Plains	Jaligang, Pahartali, Bijipur Pritompasha, Nalitabari Monu, Chinakuri	8405
	Homestead and Others		101

Land Resources Data of Hakaluki and Tanguar haor: Total land area of five Upazilas (accommodating Hakaluki haor) is 157360 ha, of which 28672 ha represent the haor land as shown in Table 6-30. Of this, 21544 ha is cultivable, and rest 7128 ha is permanent water body and not available for crop cultivation. However, analysis of satellite imagery shows that the present area of Hakaluki haor is 17302 ha of which 6082, 4068, 2771, 2905 and 1476 ha falls under Baralekha, Juri, Kulaura, Fenchuganj and Golapganj Upazilas, respectively (IWM, 2019).

Table 6-30: Land Resources of Different Upazilas in Hakaluki Haor Region

Parameter	Area (ha)					
	Baralekha	Juri	Kulaura	Fenchuganj	Golapganj	Total
1. Highland	18792	3724	15640	745	5205	44106
2. Medium Highland	9914	6430	15470	2178	8499	42491
3. Medium Lowland	6725	3080	15460	3225	8543	37033
4. Lowland	2976	426	7930	1810	4735	17877
5. Haor (cultivable)	4550	4900	8620	3212	262	21544
6. Haor (water body)	1948	70	4200	310	600	7128
7. Total Haor Area	6498	4970	12820	3522	862	28672
8. Total land Area	44905	18630	54500	11480	27845	157360

Source: Department of Agriculture Extension (DAE)

Similarly, the total land area of the Upazilas accommodating Tanguar haor is 84525 ha out of which 48815 ha is occupied by haor in Dharmapasha and Tahirpur Upazilas as presented in Table 6-31. It is noteworthy that in both Hakaluki and Tanguar haor basin, there is no flood free land and all area including the haor ridges (Kanda) is deeply flooded during the rainy season.

Table 6-31: Land Resources of Different Upazilas in Tanguar Haor Region

Parameter	Area (ha)		
	Dharmapasha	Tahirpur	Total
1. Highland	2110	1450	3560
2. Medium Highland	4490	3370	7860
3. Medium Lowland	7969	4195	12164
4. Lowland	11078	5790	16868
5. Haor land (cultivable)	25000	9790	34790
6. Haor Area (water body)	10625	3400	14025
7. Total Haor Area	35625	13190	48815
8. Total land Area	53100	31425	84525

Source: Department of Agriculture Extension (DAE)

Land Utilization Pattern Data for Hakaluki and Tanguar Haor Area: The land use data pertaining to the concerned Upazilas is presented in Table 6-32. It was observed that altogether, the area under annual crops was 0.42% and that of single, double and triple crops is 41.77%, 23.79% and 3.41%, respectively. While the extent of area in other type of land use was 0.48%.

Table 6-32: Land Utilization Pattern of Different Upazilas in Hakaluki and Tanguar Haor Region

Upazila	Total Area (ha)	Land Use Pattern						Cropping Intensity (%)
		Ann. Crop	SCA	DCA	TCA	Others	NCA	
Baralekha	44905	450	5215	5225	655	105	11650	157
Juri	18630	70	3550	5695	1140	115	10570	176
Kulaura	54500	70	12000	7030	3220	100	22420	160
Dharmapasha	53123	100	30910	3750	550	190	35500	114
Tahirpur	31425	70	14710	7720	300	120	22920	136
Fenchuganj	11480	0	5400	2750	200	150	8500	138
Golapganj	27355	10	4900	11500	200	100	16710	172
Total	241418	770	76685	43670	6265	880	128270	150.43
% of Total Cropped Area		**0.42**	**41.77**	**23.79**	**3.41**	**0.48**	**-**	**-**

Major Crops and Cropping Patterns in Hakaluki and Tanguar Haor Area: The only crop grown in haor basin is boro rice in Boro-Fallow-Fallow cropping pattern. In fact, the fallow period of Kharif-I and Kharif-II season's remains inundated in haor basin, hence other crops cannot be grown during this period. However, in highland and medium highland situation beyond haor areas, diversified cropping is practiced, especially in the *Rabi* and *Kharif-I* seasons including mustard, lentil, winter vegetable and jute. The existing cropping patterns in Upazilas around Hakaluki and Tanguar haor is given in Table 6-33.

Table 6-33: Upazila Wise Existing Cropping Patterns in Hakaluki and Tanguar haor Area

Name of Upazila	Major Cropping Patterns	Area (ha)	% NCA of Upazila	% NCA of the Region
Dharmapasha	Boro−Fallow−Fallow	29500	83.10	9.68
	Boro−Fallow−T.Aman	2500	7.04	2.07
	Fallow−Fallow−T.Aman	1100	5.52	0.94
Borolekha	Boro−Fallow−Fallow	2100	18.03	0.69
	Fallow−Aus−T.Aman	2100	18.03	2.16
	Boro−Fallow−T.Aman	2000	17.17	1.65
	Fallow−Fallow−T.Aman	2000	17.17	1.65

Name of Upazila	Major Cropping Patterns	Area (ha)	% NCA of Upazila	% NCA of the Region
Golapganj	Boro−Fallow−T.Aman	4500	26.93	3.72
	Fallow−Aus−T.Aman	4200	25.13	4.33
	Fallow−Fallow−T.Aman	2400	14.36	2.04
	Boro−Fallow−Fallow	2300	13.76	0.75
Juri	Boro−Fallow−T.Aman	3000	28.38	2.48
	Boro−Fallow−Fallow	1700	16.08	0.56
	Fallow−Fallow−T.Aman	1650	15.61	1.40
	Fallow−Aus−T.Aman	1300	12.30	1.34
	Boro−Aus−T.Aman	500	4.73	2.80
Fenchuganj	Boro−Fallow−Fallow	3600	42.35	1.18
	Fallow−Aus−T.Aman	2100	24.71	2.16
	Fallow−Fallow−T.Aman	1800	21.18	1.53
	Boro−Fallow−T.Aman	100	1.18	0.08
Kulaura	Fallow−Fallow−T.Aman	8400	37.47	7.15
	Fallow−Aus−T.Aman	5600	24.98	5.77
	Boro−Fallow−Fallow	3600	16.06	1.18
	Boro−Fallow−T.Aman	1150	5.13	0.95
	Boro−Aus−T.Aman	1600	7.14	8.97
Tahirpur	Boro−Fallow−Fallow	14000	61.08	4.59
	Boro−Fallow−T.Aman	6000	26.18	4.96
	Fallow−Fallow−T.Aman	6000	26.18	4.96

6.5.5 Socio – Economic Data Collection

The social assessment has been conducted based on primary and secondary data. The primary data has been collected through field survey to follow purposive random sampling technique using semi-structured questionnaire. A total of 10 unions have been selected from 5 upazilas (two unions from each upazila) of Moulvibazar and Sylhet district for Hakaluki haor. Similarly, 6 unions from 3 upazilas (two unions from each upazila) of Sunamganj and Netrokona district have been selected for Tanguar haor. A total of 650 sample households (333 for Hakaluki haor and 317 for Tanguar haor) have been taken for conducting survey. The appraisal has been accomplished through inter-personal face to face interview with the head of the households. Moreover, the assessment involves a qualitative investigation using checklist for Key Informant Interview (KII) and guideline for Focus Group Discussion (FGD). The KII has been carried out with UP representatives, and NGO workers & CBO, etc. and FGD has been facilitated with various occupational groups like wage labor, farmer, fishermen, businessmen, service holders, etc.

From general theory, the minimum required sample size is determined by the usual sample size determination formula for estimating proportion, which is used by (BBS, 2016).

$$n = \frac{n_o}{1 + \frac{n_o}{N}} \times deff \qquad \text{where, } n_0 = \frac{p(1-p)}{d^2} \times Z^2_{\alpha/2}$$

Where, *'p'* is a proportion of the required characteristics in the population, $Z^2_{\alpha/2}$, the value of the standard normal variant allowing (1-∝) % confidence interval, d the allowing margin of error, N is the population size.

The conventional value ∝= *0.05* has been considered which has given $Z_{\alpha/2}$= *1.96* for most socio-economic surveys in Bangladesh. Theoretically, when *'p'* is unknown, *p=0.5* gives the safest sample size since *p (1-p)* takes the highest value for p=0.5. The allowable margin of error is *d =0.055* will be used. For safer sample size design effect has been chosen as *deff* =2.

$$\text{So, } n_0 = \frac{(0.5)(0.5)(1.96)^2}{(0.055)^2} = 317$$

$$\text{Then, } n = \frac{317}{1 + \frac{317}{286067}} \times 2 = 635$$

However, to make the figure round the ultimate sample size will be 650.

The distribution of sample within the Hakaluki and Tanguar Haor for conducting social survey has been presented in Table 6-34.

Table 6-34: Distribution of Sample for Conducting Social Survey at Hakaluki and Tanguar Haor

District	Upazila	Union	Population (HHs)	Sample Weight (HHs)	Sample Size
A	**B**	**C**	**D**	**E= (D/ΣD) ×100**	**F=E (n)**
Hakaluki Haor					
Sylhet	Golapganj	Dakshin Bade Pasha	3453	1.2	8
	Fenchuganj	Gilachhara	5798	2.0	13
Maulvibazar	Barlekha	Sujanagar	22279	7.8	51
		Talimpur	21707	7.6	49
	Kulaura	Bhukshimail	24892	8.7	57
		Baramchal	19191	6.7	44
	Juri	Paschim Juri	22914	8.0	52
		Jaifarnagar	26182	9.2	59
		Sub-Total	***146416***	***51.2***	***333***

Tanguar Haor					
Sunamganj	Tahirpur	Dakshin Bongshikunda	28689	10.0	65
		Uttar Bangshikunda	20900	7.3	47
	Dharampasha	Uttar Sreepur	50061	17.5	114
		DashinSreepur	20738	7.2	47
Netrokona	Kalmakanda	Rangchhati	9223	3.2	21
		Kalmakanda	10040	3.5	23
		Sub-Total	***139651***	***48.7***	***317***
		Total	**286067**	**100.0**	**650**

So, for this social impact study a total of 650 household's survey, 4 FGDs, and 8 KIIs have been conducted. A semi-structured both open and close ended questionnaires has been used for conducting survey, and checklist and guideline for KII, and FGD has been used at field level. The sample selection for conducting Household Survey, KII, FGD and PRA has been shown in Table 6-35.

Table 6-35: Sample Selection for Conducting Household Survey, KII, FGD and PRA

Stakeholders type	**Methods to be used**				**Tools used**
	Household Survey	**FGD**	**KII**	**PRA**	
Project adjacent HHs	650	18	6	24	Questionnaire
Various occupational groups					Guideline
Teacher, UP chairmen/member, young leader, NGO representative, Imam, Member of civil society					Checklist
Total:	**650**	**18**	**6**	**24**	

The details of data collection, analysis and findings are presented in Volume-II: Appendix-J.

6.6 Data Collection on Biodiversity, Fisheries Resources, Forest, Agricultural Development and Socio – economic Data for Clustered Wetlands

One the component of this study is to cluster the identified wetland according to their characteristics and functions. In the active floodplains of Bangladesh, the Surma-Meghna, the Brahmaputra-Jamuna, and the Ganges-Padma river systems, there are several large and small wetlands. The National Water Management Plan, 2004 has delineated the eight Hydrological Regions in Bangladesh, based on the major river system, for planning and development of water resources. The Hydrological Regions are Southwest (SW), Northeast (NE), North Central (NC), Northwest (NW), South Central (SC), Southeast (SE), Eastern Hills (EH), River and Estuary Region (RE). On the other hand the Agro-Ecological zones of Bangladesh have been identified on the basis of four elements such as physiography, soils, land levels in relation to flooding and agro-climatology whereas Bio-ecological zones are more or less similar to the Agro-ecological zones. Initially these three maps have been taken into consideration for clustering of wetlands. Finally, for the ease of simplicity, the clustering has been introduced based on hydrological regions as mentioned above.

The wetlands in Bangladesh encompass a wide verity of dynamic ecosystems including ranging from mangrove forest, natural lakes, man-made reservoir, freshwater marshes (haor), oxbow lakes (baors), fresh water depressions (beels), fish ponds and tank, estuaries, and seasonal inundated extensive floodplains. Four major types of wetlands like Haor, Beel, Lake and Baor (Oxbow lake) were investigated under this study. The wetlands were selected for data collection and investigation purposively basing on their characteristics and function, particularly the focus was given to the provisioning (resources for livelihood), regulating (environmental controlling factors), supporting (biodiversity and habitat context) ecosystem services provided by the wetlands. Baikka Beel was selected from North East wetland cluster. Borobila beel was selected from North Central wetland cluster. Beel Halti was selected from North Western wetland cluster. Baluhor Baor and Borni Baor were selected from south western wetland cluster and Kaptai Lake was selected from Eastern hill cluster. These 6 wetlands were selected for detail vegetation, fisheries, biodiversity inventory study in consultation with the client.

6.6.1 Data Collection on Biodiversity

A baseline biodiversity study has been carried out within and periphery of several clustered wetlands. The baseline biodiversity study was conducted within and periphery wetlands

- To enlist the faunal species with their national or international status,
- To enlist keystone, rare and threatened faunal species, and
- To investigate the distribution & abundance of faunal species

Both formal and informal interviews as well as public consultation, in the form of Focus Group Discussion (FGD) sessions as shown in Figure 6-32, and some institutional consultations with the relevant institutions, have also been conducted as a part of this baseline study to learn about the seasonal variation of faunal biodiversity. The details of the Bio-diversity data collection have been presented in Volume-II: Appendix-E.

Figure 6-32: Bio-diversity Survey at Kaptai Lake Area (Left) and Stakeholder Consultation at Borobila Beel, Mymensingh

6.6.2 Data Collection on Fisheries Resources

The duration of the field survey has been presented Table 6-36. The list of Focus Group Discussion (FGD), Personal Interview (PI), Key Informant Interviews (KII) and Household Survey (HS) for different wetlands is illustrated in Table 6-37. The details of the fisheries resources survey have been presented in Volume-II: Appendix-F.

Table 6-36: Duration of Filed Survey for Fisheries Resources for Clustered Wetlands

Sl. No.	Name of Wetland	Duration of Survey
1.	Kaptai Lake	04 November to 08 November 2019
2.	Baluhor Baor	28 November to 01 December 2019
3.	Borni Baor	02 December to 04 December 2019
4.	Borobila Beel	13 November to 15 November 2019
5.	Baikka Beel	11 December to 13 December 2019
6.	Beel Halti	24 December to 28 December 2019

Table 6-37: List of Survey and Study Sites for Kaptai Lake, Baluhor Baor, Borni Baor, Borobila Beel, Baikka Beel and Beel Halti

Location			FGD		PI		KII	
District	Upazilla	Location Spot	No.	Nos. of Person	No.	Nos. of Person	No.	Nos. of Person
Kaptai Lake								
Rangamati	Kaptai	Jale Para, Kaptai Zeti Ghat landing Centre,	1	24	4	4	1	BFDC Marketing Officer
		Chowdhary chora	1	18	3	3		

Location			FGD		PI		KII	
District	**Upazilla**	**Location Spot**	**No.**	**Nos. of Person**	**No.**	**Nos. of Person**	**No.**	**Nos. of Person**
		Kolabunia para, Karnafuli River Side	1	13	3	3		
		Natun mash bazar			1	1		
	Langadu	Hedmentila	1	18	1	1		
	Rangamati Sadar	Rangamati fish landing & trading center			5	5	1	SSO, BFRI
Baluhar Baor								
Jhenaidah	Kotchandpur	Kagmari	1	30	6	6		
		Ramchandrapur	1	40	5	5	1	Baluhar Baor Manager
Borni Baor								
Gopalgonj	Tungipara	Borni & Borni Bazar Fish Market	1	24	6	6		
	Gopalganj sadar	Nuklirchar & UFO Office, Gopalganj Sadar	1	35	5	5	1	Assistant Fishery Officer
Borobila Beel								
Mymensingh	Mymensingh sadar	District fisheries officer Office					1	DFO/SUFU
	Fulbaria	Anuhadi	1	32	12	12		

<table>
<tr><th colspan="3">Location</th><th colspan="2">FGD</th><th colspan="2">PI</th><th colspan="2">KII</th></tr>
<tr><th>District</th><th>Upazilla</th><th>Location Spot</th><th>No.</th><th>Nos. of Person</th><th>No.</th><th>Nos. of Person</th><th>No.</th><th>Nos. of Person</th></tr>
<tr><td colspan="9">Baikka Beel</td></tr>
<tr><td rowspan="2">Moulvibazar</td><td rowspan="2">Sreemangal</td><td>Hajipur, Kalapur union</td><td>1</td><td>12</td><td>6</td><td>6</td><td>1</td><td>UFO, Sreemangal Upazila</td></tr>
<tr><td>Boruna, Kalapur union</td><td></td><td></td><td>6</td><td>6</td><td></td><td></td></tr>
<tr><td colspan="9">Beel Halti</td></tr>
<tr><td rowspan="3">Natore</td><td rowspan="3">Naldanga</td><td>Khajura</td><td>1</td><td>19</td><td>1</td><td>1</td><td></td><td></td></tr>
<tr><td>Patul</td><td>1</td><td>27</td><td>4</td><td>4</td><td></td><td></td></tr>
<tr><td>Madhnagar</td><td>1</td><td>36</td><td>3</td><td>3</td><td></td><td></td></tr>
</table>

6.6.3 Data Collection on Forest for Clustered Wetlands

In total 178 numbers of nested plots were measured during this study. Plots layouts were done based on prevailing literature and documents indicating the vegetation density of the respective wetlands and along with a reconnaissance field observation. Cluster wise nested plots numbers are given in the Table 6-38 and plot locations are shown in the Figure 6-33 to Figure 6-38.

Table 6-38: Cluster Wise Sample Plots

<table>
<tr><th rowspan="2">Cluster Name</th><th rowspan="2">Wetland</th><th colspan="3">Location</th><th rowspan="2">Plot nos.</th></tr>
<tr><th>District</th><th>Upazilla</th><th>Union</th></tr>
<tr><td rowspan="2">North East</td><td>Ratargul Swamp Forest</td><td>Sylhet</td><td>Gowainghat</td><td>Fatepur</td><td>27</td></tr>
<tr><td>Baikka Beel</td><td>Molvi Bazar</td><td>Sreemangal</td><td>Sreemangal</td><td>15</td></tr>
<tr><td>North Central</td><td>Borobila Beel</td><td>Mymensingh</td><td>Fulbaria</td><td>Fulbaria, Rangamatia</td><td>20</td></tr>
<tr><td>North Western</td><td>Beel Halti</td><td>Natore</td><td>Natore Sadar</td><td>Khajura, Piprul, Lalore</td><td>25</td></tr>
<tr><td rowspan="2">South Western</td><td>Baluhor Baor</td><td>Jhenaidah</td><td>Kotchadpur</td><td>Baluhor</td><td>21</td></tr>
<tr><td>Borni Baor</td><td>Gopalganj</td><td>Gopalganj Shadar, Tungipara</td><td>Borni, Gobra, Kushli, Raghunathpur</td><td>20</td></tr>
</table>

Cluster Name	Wetland	Location			Plot nos.
		District	Upazilla	Union	
Eastern Hill	Kaptai Lake	Rangamati	Kaptai, borkol, Langadu, Bilaichari	Jibtoli, Shuvolong, Mainimukh, Aymachara, Faroa, Kaptai, Kalmichara	50

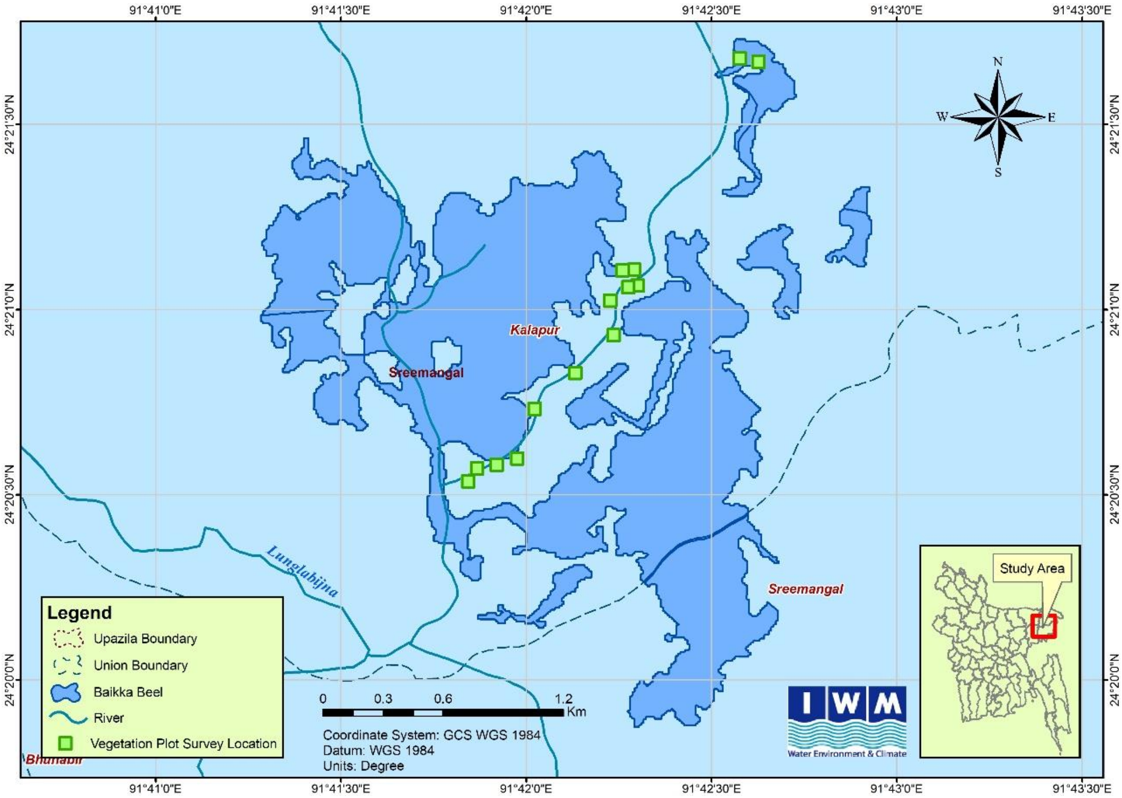


Figure 6-33: Vegetation Inventory Plots in Baikka Beel (Dry Season)

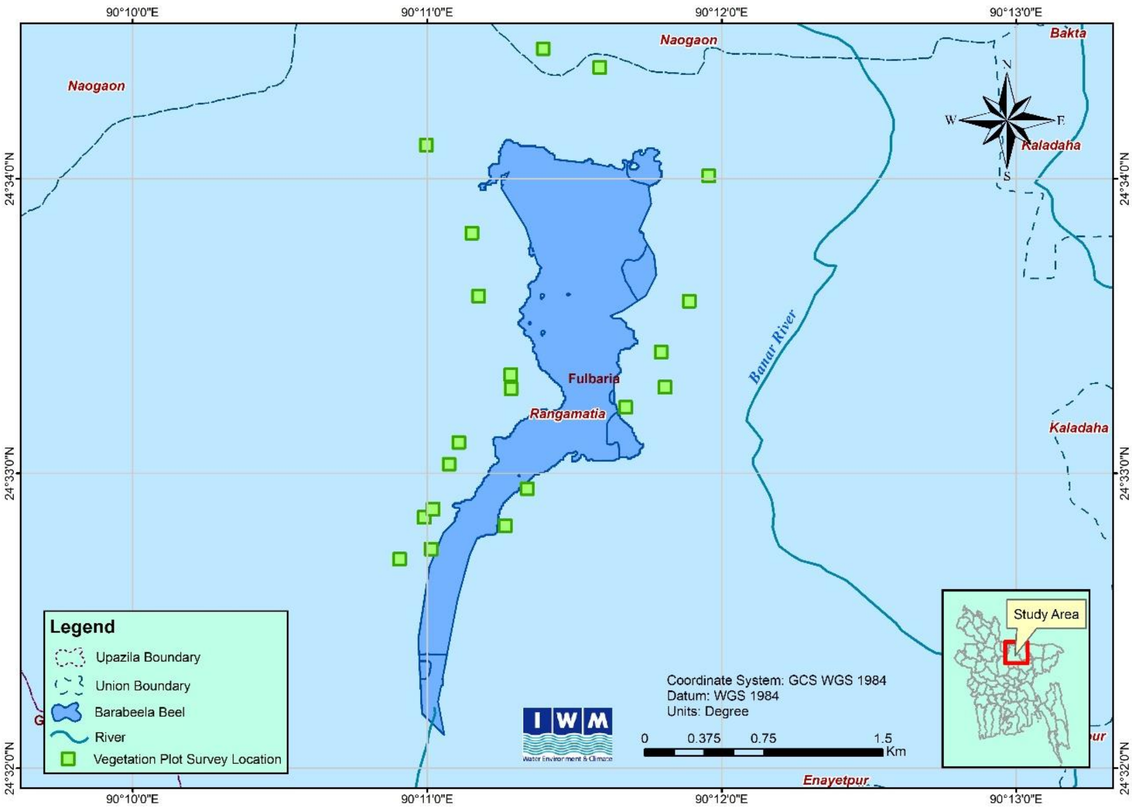


Figure 6-34: Vegetation Inventory Plots in Borobila Beel (Dry Season)

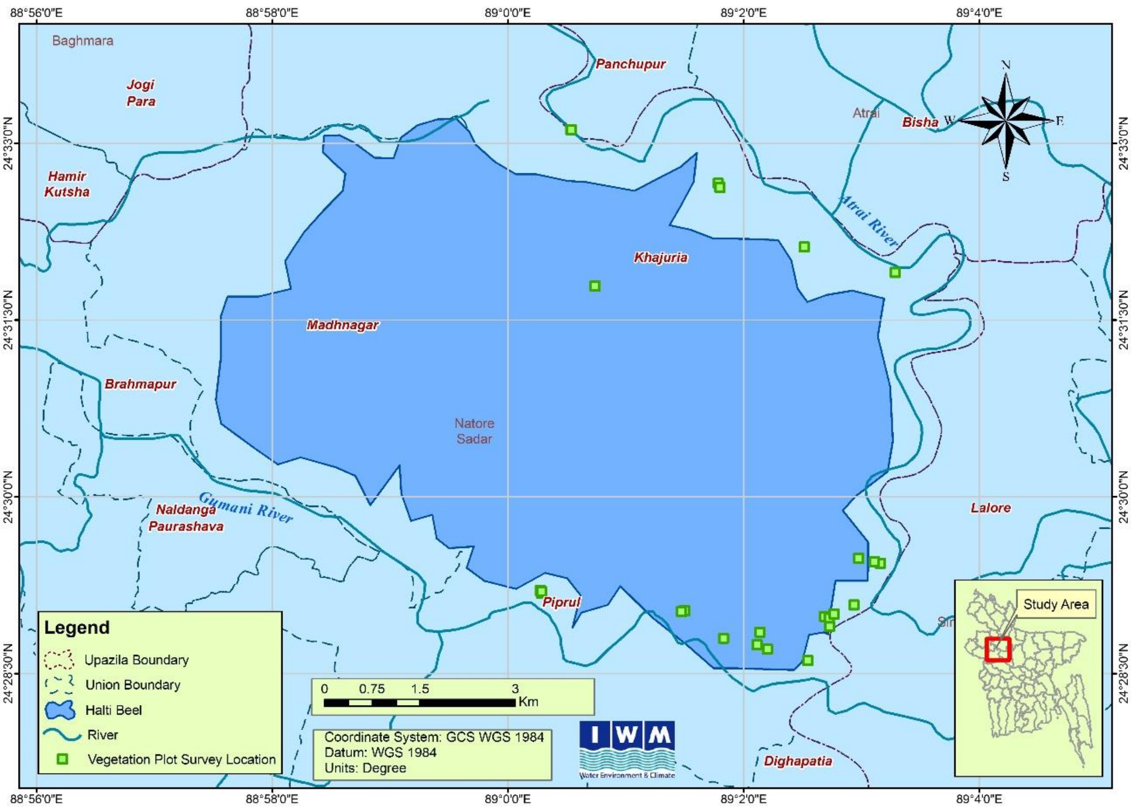


Figure 6-35: Vegetation Inventory Plots in Beel Halti (Dry Season)

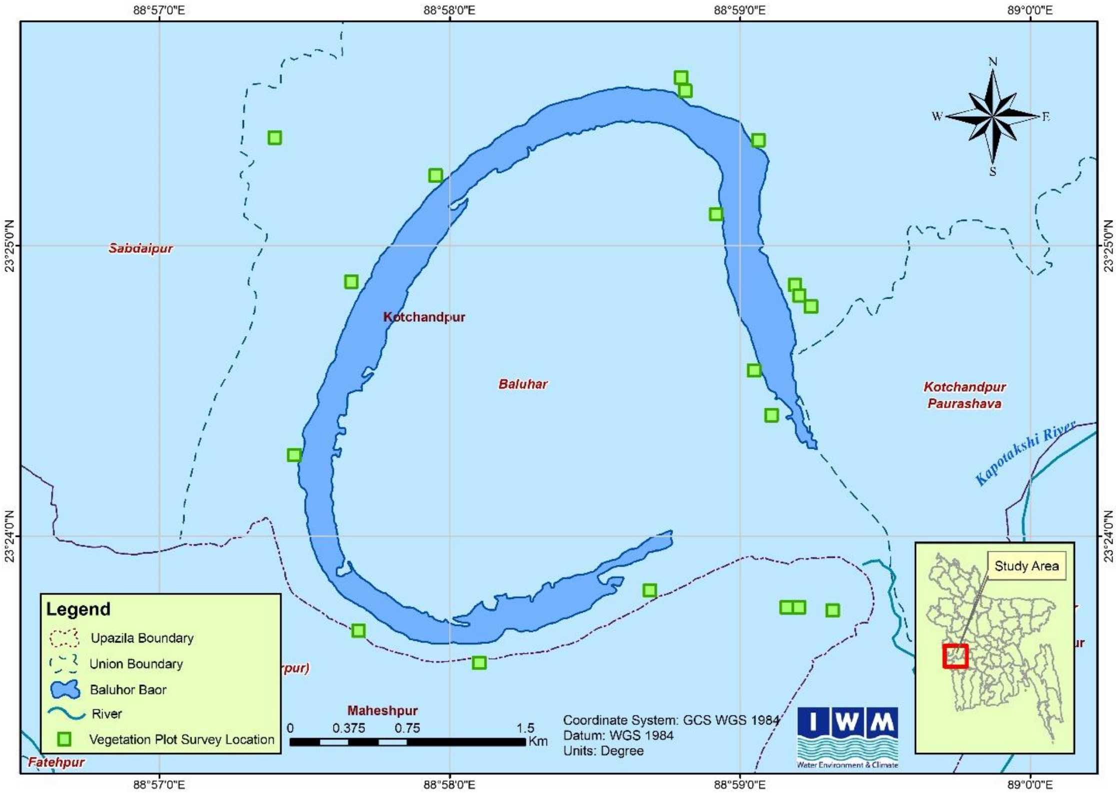


Figure 6-36: Vegetation Inventory Plots in Baluhor Baor (Dry Season)

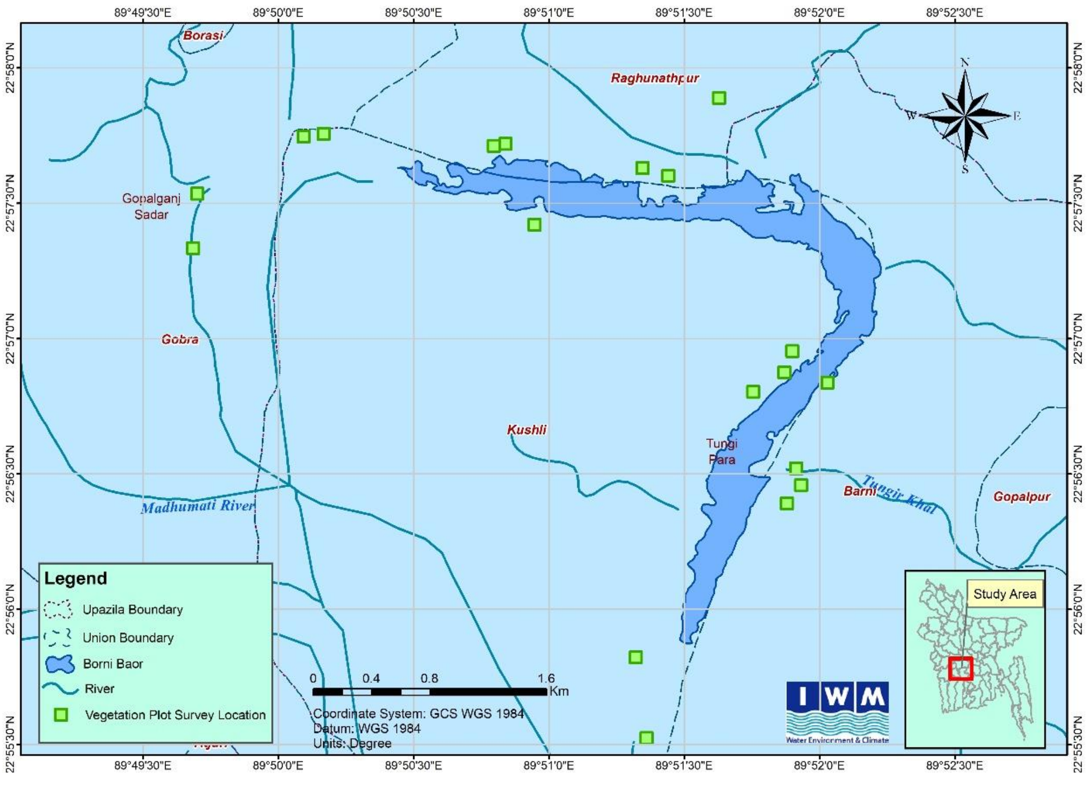


Figure 6-37: Vegetation Inventory Plots in Borni Baor (Dry Season)

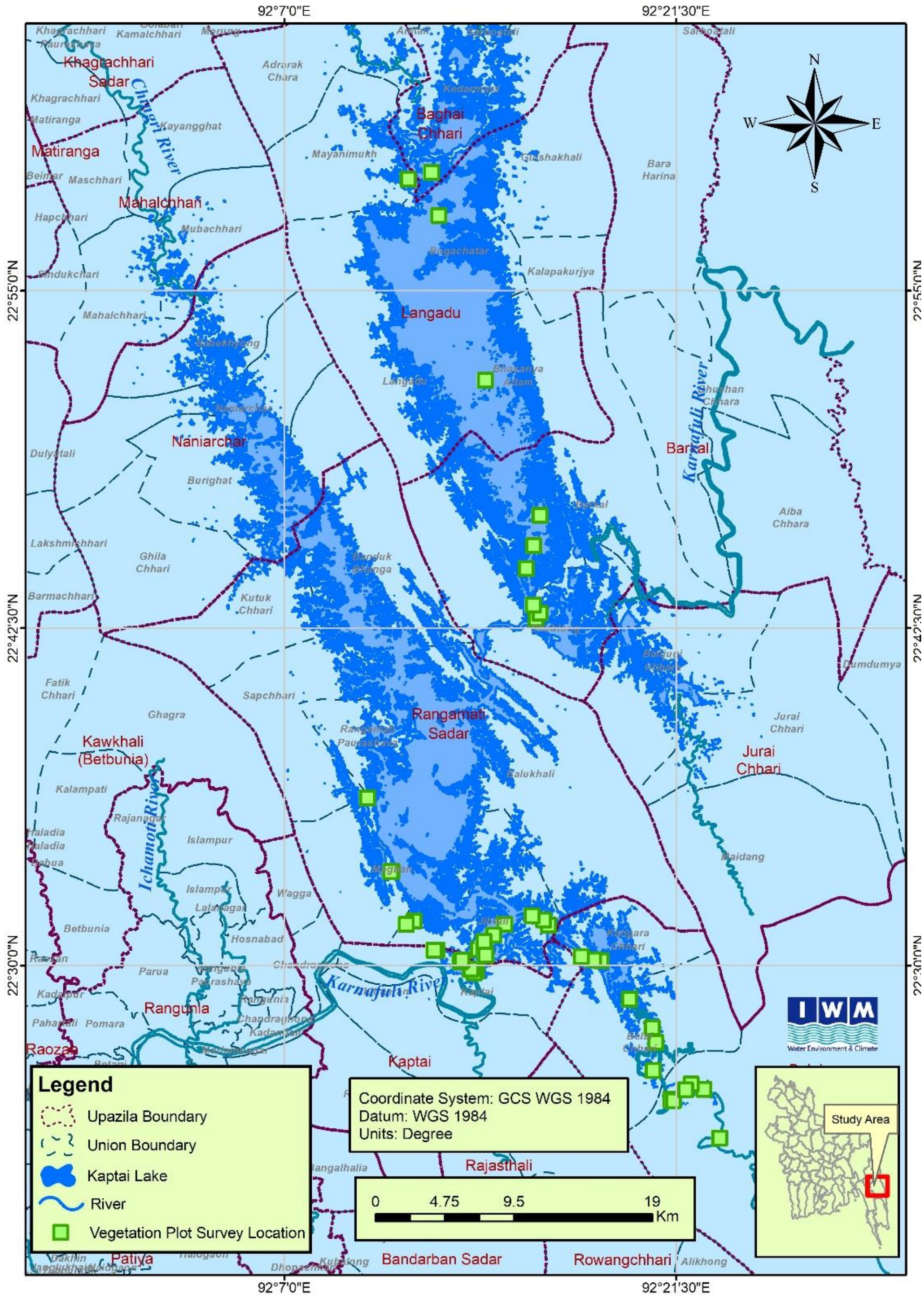


Figure 6-38: Vegetation Inventory Plots in Kaptai Lake (Dry Season)

Data Analysis for Ratargul Swamp Forest

Species Composition: Ratargul swamp forest is the only freshwater swamp forest of Bangladesh. The study finds found 6 trees species and 4 shrub species in the sample plots of the swamp. The forest is mostly dominated by *Barringtonia acutangula* (Hijol), *Millettia pinnata* (Koroch) and *Crataeva magna* (Barun). Among the shrub Murta is the most common plant found in the forest, which also have great importance for cottage industry in the region. Table 6-39 gives the list of species found in the swamp.

The study found the tree vegetation diversity is not rich as the Shannon index is around 0.27 in range of (0 to 1). The tree vegetation diversity of Ratargul Swamp Forest has been given in Table 6-40.

Table 6-39: List of Floral Species and their Status at the Ratargul Swamp Forest

Abundantly Found Trees	Trees Sparsely Found (becoming rare)	Trees Lost from Ecosystem
Barringtonia acutangula (Hijol)	*Crataeva magna* (Barun)	*Cordia dichotoma* (Bella)
Crataeva magna (Barun)	*Ficus bengalensis* (Bot)	*Diospyros peregrina* (Gaab)
Ficus bengalensis (Bot)		*Garcinia cowa* (Kaw)
Millettia pinnata (Koroch)		
Schumannianthus dichotomus (Murta)		
Calamus tenuis		

Table 6-40: Total Species Recorded and Studied with values of Shannon-Wiener Index (Diversity), Margalef Index (Richness) and Simpson Index (Dominance)

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Wet	28	0.27	0.26	0.17

Tree Biomass and Carbon Accumulation in both Above and Below Ground: Mean above-ground, below-ground, and total biomass carbon (TBC) of the studied areas were 26.20 Ton per ha, 5.34 Ton per ha and 31.54 Ton per ha respectively as shown in Table 6-41.

Table 6-41: Carbon Accumulation (Ton per ha) in along the Ratargul Swamp Forest Sylhet

Maximum Total Carbon (ton/ha) in a plot	Minimum Total Carbon (ton/ha) in a plot	Average Total tree Carbon stock per unit area (ton/ha)
54.46	0.82	31.54

Data Analysis for Baikka Beel

Species composition: Baikka Beel is a large, shallow beel at the southern part of the Hail Haor. The study found 16 trees species and 3 shrub species in the sample plots of the area. Table 6-42 gives the list of species found in the swamp. The study found the tree vegetation diversity is quite good as the Shannon index is around 0.68 in range of (0 to 1). The tree vegetation diversity of Baikka beel has been given in the Table 6-43.

Table 6-42: List of Floral Species and their Status at the Baikka Beel

Abundantly Found Trees	Trees Sparsely Found (becoming rare)	Trees Lost from Ecosystem
Acacia auriculiformis (Akashmoni)	*Anthocephalus indicus* (Kadam)	*Anthocephalus indicus* (Kadam)
Albizia lebbeck (Koroi)	*Barringtonia acutangula* (Hijol)	*Schumannianthus dichotomus (Murta)*
Barringtonia acutangula (Hijol)	*Ficus bengalensis* (Bot)	
Bombax ceiba (Shimul)	*Lagerstroemia speciosa* (Jarul)	
Elaeocarpus serratus (Jolpai)	*Millettia pinnata* (Koroch)	
Ficus bengalensis (Bot)	*Terminalia arjuna* (Arjun)	
Lagerstroemia speciosa (Jarul)	*Trewia polycarpa* (Pitali)	
Millettia pinnata (Koroch)	*Bombax ceiba* (Shimul)	
Samanea saman (Raintree)		
Spondias mombin (Amra)		
Syzygium cerasoides (Kalo Jam)		
Terminalia arjuna (Arjun)		
Trewia polycarpa (Pitali)		
*Arundo donax (*Nal Khagra) shrub		
Typha elephantiana		
Nymphaea nouchali (water lily)		

Table 6-43: Total Species Recorded and Studied with values of Shannon-Wiener Index (Diversity), Margalef Index (Richness) and Simpson Index (Dominance)

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	19	0.68	0.55	0.42

Tree Biomass and Carbon Accumulation in both Above and Below Ground: Mean above-ground, below-ground, and total biomass carbon (TBC) of the studied areas were 23.83 Ton per ha, 4.94 Ton per ha and 28.77 Ton per ha respectively as shown in Table 6-44.

Table 6-44: Carbon Accumulation (Ton per ha) in along the Baikka beel

Maximum Total Carbon(ton/ha) in a Plot	Minimum Total Carbon(ton/ha) in a Plot	Average Total Tree Carbon stock per unit area(ton/ha)
94.56	14.70	28.77

Data Analysis for Borobila Beel

Species Composition: The study found 23 trees species and 2 shrub species in the sample plots of the area. The forest is mostly dominated by *Psidium guajava* (Peyara), *Samanea saman* (Raintree), *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot) *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Albizia lebbeck* (Koroi) and *Lagerstroemia speciosa* (Jarul). Among the herbs and shrubs *Typha elephantiana* (Hogal) and *Saccharum spontaneum (kash ful)* are the most common plant found in the wetland, Table 6-45 gives the list of species found in the swamp. The study found the tree vegetation diversity is quite good as the Shannon index is around 0.72 in range of (0 to 1). The tree vegetation diversity of Borobila beel has been given in Table 6-46.

Table 6-45: List of Floral Species and their Status at the Borobila Beel

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Acacia auriculiformis (Akashmoni)	*Bombax ceiba* (Shimul)	*Barringtonia acutangula* (Hijol)
Acacia mangium (Mangium)	*Ficus bengalensis* (Bot)	*Butea monosperma* (Palash)
Aegle marmelos (Bel)	*Syzygium cumini* (Jam)	*Millettia pinnata* (Koroch)
Artocarpus heterophyllus (Kanthal)	*Trema orientalis* (Jibon)	
Azadirachta indica (Neem)		
Albizia lebbeck		
Bombax ceiba (Shimul)		
Eucalyptus globulus (Eucalyptus)		
Mangifera indica (Aam)		
Melia azedarach (Mohaneem)		
Syzygium cumini (Jam)		
Tectona grandis (Teak)		
Trema orientalis (Jibon)		
*Trewia polycarpa (*Pitali*)*		
Psidium guajava (Peyara)		
Samanea saman (Raintree)		
Swietenia mahagoni (Mahogany)		
Typha elephantiana (hogla)		
Saccharum spontaneum (kash ful)		
Zizyphus mauritiana (Boroi)		
Nymphaea nouchali (water lily)		
Nelumbo nucifera (Indian Lotus)		

Table 6-46: Total Species Recorded and Studied with Values of Shannon-Wiener Index (Diversity), Margalef Index (Richness) and Simpson Index (Dominance)

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	23	0.72	0.78	0.44

Tree Biomass and Carbon Accumulation in both Above and Below Ground: Mean above-ground, below-ground, and total biomass carbon (TBC) of the studied areas were 21.44 Ton per ha, 4.45 Ton per ha and 25.90 Ton per ha respectively as illustrated in Table 6-47.

Table 6-47: Carbon Accumulation (Ton per ha) in Along the Borobila Beel

Maximum Total Carbon(ton/ha) in a plot	Minimum Total Carbon(ton/ha) in a plot	Average Total tree Carbon stock per unit area(ton/ha)
59.73	3.95	25.90

Data Analysis for Beel Halti

Species Composition: The study found 23 trees species and 2 shrub species in the in the sample plots of the area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot), *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam) and *Borassus flabellifer* (Tal). Table 6-48 gives the list of species found in the Beel Halti. The study found the tree vegetation diversity is quite good as the Shannon index is around 0.53 in range of (0 to 1). The tree vegetation diversity of Beel Halti has been given in the Table 6-49.

Table 6-48: List of Floral Species and their Status at the Beel Halti

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Albizia lebbeck (Koroi)	*Anthocephalus indicus* (Kadam*)*	*Millettia pinnata* (Koroch)
Anthocephalus indicus (Kadam)	*Barringtonia acutangula* (Hijol)	*Butea monosperma (Palash)*
Artocarpus heterophyllus (Kanthal)	*Ficus religiosa* (Ashwatta)	*Lagerstroemia speciosa* (Jarul)
Azadirachta indica (Neem)	*Syzygium cumini* (Jam)	
Barringtonia acutangula (Hijol)	*Bombax ceiba* (Shimul)	
Borassus flabellifer (Tal)		
Dalbergia sissoo (Sissoo)		
Eucalyptus globulus (Eucalyptus)		
Ficus religiosa (Ashwattha)		

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Mangifera indica (Aam)		
Moringa Oleifera (Sajina)		
Polyalthia longifolia (Debdaru)		
Spondias mombin (Amra)		
Swietenia mahagoni (Mahogany)		
Syzygium cumini (Jam)		
Tamarindus indica (Tentul)		
Tectona grandis (Teak)		
Trewia polycarpa (Pitali)		
Zizyphus mauritiana (Boroi)		
Albizia lebbeck (Koroi)		
Ipomoea carnea (Dhol kolmi)		
Chitki bush (local name)		
Motmote (local name)		

Table 6-49: Total Species Recorded and Studied with values of Shannon-Wiener Index (Diversity), Margalef Index (Richness) and Simpson Index (Dominance)

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	23	0.53	0.55	0.31

Tree Biomass and Carbon Accumulation in both Above and Below Ground: Mean above-ground, below-ground, and total biomass carbon (TBC) of the studied areas were 42.67 Ton per ha, 8.07 Ton per ha and 50.74 Ton per ha respectively as shown in Table 6-50.

Table 6-50: Carbon Accumulation (Ton ha-1) in Along the Beel Halti

Maximum Total Carbon(ton/ha) in a plot	Minimum Total Carbon(ton/ha) in a plot	Average Total tree Carbon stock per unit area(ton/ha)
119.60	8.10	50.74

Data Analysis for Baluhor Baor

Species Composition: The study found 32 trees species and 2 shrub species in the sample plots of the area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot) *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Acacia auriculiformis* (Akashmoni) and *Acacia catechu* (Khoi Babla). Table 6-51 gives the list of species found in the wetland and its periphery.

The study found the tree vegetation diversity is very rich as the Shannon index is around 0.91 in range of (0 to 1). The tree vegetation diversity of Baluhor Baor has been given in the Table 6-52.

Table 6-51: List of Floral Species and their Status at the Baluhor Baor

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Acacia auriculiformis (Akashmoni)	*Alstonia scholaris* (Chatim)	*Barringtonia acutangula* (Hijol)
Acacia catechu (Khoi Babla)	*Annona squamosal* (Ata)	*Butea monosperma* (Palash)
Albizia lebbeck (Koroi)	*Anthocephalus indicus* (Kadam)	*Millettia pinnata* (Hijol)
Alstonia scholaris (Chatim)	*Aphanamixis polystachya* (Roina)	
Annona squamosa (Ata)	*Diospyros malabarica* (Gaab)	
Anthocephalus indicus (Kadam)	*Ficus bengalensis* (Bot)	
Aphanamixis polystachya (Roina)		
Artocarpus heterophyllus (Kanthal)		
Azadirachta indica (Gora Neem)		
Azadirachta indica (Neem)		
Bombax ceiba (Shimul)		
Dalbergia sissoo (Sissoo)		
Diospyros malabarica (Gaab)		
Ficus bengalensis (Bot)		
Litchi chinensis (Litchi)		
Mangifera indica (Aam)		
Polyalthia longifolia (Debdaru)		
Samanea saman (Raintree)		
Spondias mombin (Amra)		
Streblus asper (Sheora)		
Swietenia mahagoni (Mahogany)		
Syzygium cumini (Jam)		
Tectona grandis (Teak)		
Trewia polycarpa (Pitali)		
Ipomoea carnea (Dhol kolmi) (shrub)		
Typha elephantiana (Hogla)		
Saccharum spontaneum (kash ful)		
Nymphaea nouchali (water lily)		
Nelumbo nucifera (Indian Lotus)		

Table 6-52: Total Species Recorded and Studied with values of Shannon-Wiener Index (Diversity), Margalef Index (Richness) and Simpson Index (Dominance)

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	32	0.91	0.99	0.57

Tree Biomass and Carbon Accumulation in both Above and Below Ground: Mean above-ground, below-ground, and total biomass carbon (TBC) of the studied areas were 44.12 Ton per ha, 7.86 Ton per ha and 51.97 Ton per ha respectively as given in the Table 6-53.

Table 6-53: Carbon Accumulation (Ton per ha) in along the Baluhor Baor

Maximum Total Carbon(ton/ha) in a plot	Minimum Total Carbon(ton/ha) in a plot	Average Total tree Carbon stock per unit area(ton/ha)
268.42	6.62	51.97

Data Analysis for Borni baor

Species Composition: The study found 29 trees species and 2 shrub species in the selected plots of the area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Acacia auriculiformis* (Akashmoni) and *Albizia procera*. Table 6-54 gives the list of species found in the wetland and its periphery. The study found the tree vegetation diversity is rich as the Shannon index is around 0.70 in range of (0 to 1). The tree vegetation diversity of Borni Baor has been given in the Table 6-55.

Table 6-54: List of Floral Species and their Status at the Borni Baor

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Aegle marmelos (Bel)	*Anthocephalus indicus* (Kadam)	*Butea monosperma* (Palash)
Albizia lebbeck (Koroi)	*Barringtonia acutangula* (Hijol)	*Millettia pinnata* (Koroch)
Albizia procera (koroi)		
Alstonia scholaris (Chatim)	*Ficus bengalensis* (Bot)	
Annona squamosa (Ata)	*Trewia polycarpa* (Pitali)	
Aphanamixis polystachya (Roina)		
Artocarpus chaplasha (Chapalish)		
Artocarpus heterophyllus (Kanthal)		
Bombax ceiba (Shimul)		

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Citrus limon (Lemon)		
Dalbergia sissoo (Sissoo)		
Eucalyptus globulus (Eucalyptus)		
Ficus hispida (Dumur)		
Leucaena leucocephala (Ipil-Ipil)		
Mangifera indica (Aam)		
Polyalthia longifolia (Debdaru)		
Psidium guajava (Peyara)		
Samanea saman (Raintree)		
Swietenia mahagoni (Mahogany)		
Trewia polycarpa (Pitali)		
Typha elephantiana (hogla)		
Saccharum spontaneum (kash ful)		
Nymphaea nouchali (water lily)		

Table 6-55: Total Species Recorded and Studied with Values of Shannon-Wiener Index (Diversity), Margalef Index (Richness) and Simpson Index (Dominance)

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	29	0.70	0.82	0.42

***Tree Biomass and Carbon Accumulation in both Above and Below Ground*:** Mean above-ground, below-ground, and total biomass carbon (TBC) of the studied areas were 27.43 Ton per ha, 5.133 Ton per ha and 32.56 Ton per ha respectively as shown in Table 6-56.

Table 6-56: Carbon Accumulation (Ton per ha) in Along the Borni Baor

Maximum Total Carbon(ton/ha) in a plot	Minimum Total Carbon(ton/ha) in a plot	Average Total tree Carbon stock per unit area(ton/ha)
147.95	3.73	32.56

Data Analysis for Kaptai Lake

Species Composition: The study has recorded 52 species and 487 woody individuals along with 4 species of bamboos in the sampling plot. The vegetation is mostly dominated by *Gmelina arborea* (Gamar), *Dipterocarpus turbinatus* (Garjan), *Artocarpus chaplasha* (Chapalish), *Albizia lebbeck* (Koroi), *Hopea odorata* (Telsur), and *Syzygium grande (*

dhaki Jam). Out of the 4 bamboo species, *Melocanna baccifera (*Muli Bansh) is the most common species. Table 6-57gives the list of species found in the lake and its periphery. The study found the tree vegetation diversity is rich as the Shannon index is around 0.78 in range of (0 to 1). The tree vegetation diversity of Kaptai Lake has been given in the Table 6-58.

Table 6-57: List of Floral Species and their Status at the Kaptai Lake

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Albizia lebbeck (Koroi)	*Anisoptera scaphula* (Boilam)	*Podocarpus neriifolius (bash pata)*
Anisoptera scaphula (Boilam)	*Aquilaria malaccensis* (Agar)	*Toona ciliate (toon)*
Aquilaria malaccensis (Agar)	*Artocarpus chaplasha* (Chapalish)	
Artocarpus chaplasha (Chapalish)	Baklak (Local Name)	
Artocarpus heterophyllus (Kanthal)	Bella ((Local Name)	
Averrhoa carambola (Kamranga)	*Bombax ceiba* (Shimul)	
Azadirachta indica (Neem)	*Diospyros malabarica* (Gaab)	
Baklak (Local Name)	*Engelhardtia spicata* (Baadi)	
Barringtonia acutangula (Hijol)	*Ficus hispida* (Dumur)	
Bella (Local Name)	Kruj (Local Name)	
Bombax ceiba (Shimul)	*Portium serratum* (Gutgutia)	
Buragach (Local Name)	*Streblus asper* (Sheora)	
Citrus limon (Lemon)	Suraj (Local Name)	
Diospyros malabarica (Gaab)	*Terminalia arjuna* (Arjun)	
Dipterocarpus turbinatus (Garjan)	*Trewia polycarpa* (Pitali)	
Engelhardtia spicata (Baadi)	*Swintonia floribunda (civit)*	
Eucalyptus globulus (Eucalyptus)	*Protium serratum (ghut ghutia)*	
Ficus hispida (Dumur)	*Smoora Spp. ; Dysoxylum Spp. (pit raj)*	
Gmelina arborea (Gamar)	*Teinostachyum griffithii (Basali Bansh)*	
Hopea odorata (Telsur)	*Dendrocalamus longispathus (Orah bansh)*	
Kruj (Local Name)		
Lagerstroemia speciosa (Jarul)		
Litchi chinensis (Litchi)		
Mangifera indica (Aam)		
Millettia pinnata (Koroch)		
Phyllanthus emblica (Amloki)		

Abundantly Found Trees	Trees Sparsely Found (Becoming Rare)	Trees Lost from Ecosystem
Portium serratum (Gutgutia)		
Samanea saman (Raintree)		
Senna siamea (Minjiri)		
Streblus asper (Sheora)		
Suraj (Local Name)		
Swietenia mahagoni (Mahogany)		
Syzygium grande (dhaki Jam)		
Syzygium cumini (Jam)		
Tectona grandis (Teak)		
Terminalia arjuna (Arjun)		
Terminalia chebula (Horitoki)		
Trewia polycarpa (Pitali)		
Zizyphus mauritiana (Boroi)		
Bambusa vulgaris (Bariala bansh)		
Melocanna baccifera (Muli Bansh)		

Table 6-58: Total Species Recorded and Studied with Values of Shannon-Wiener Index (Diversity), Margalef Index (Richness) and Simpson Index (Dominance)

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	52	0.78	0.88	0.49

Tree Biomass and Carbon Accumulation in both Above and Below Ground: Mean above-ground, below-ground, and total biomass carbon (TBC) of the studied areas were 50.73Ton per ha, 8.49 Ton per ha and 59.21 Ton per ha respectively as given in the Table 6-59.

Table 6-59: Carbon Accumulation (Ton per ha) in the Kaptai Lake

Maximum Total Carbon (ton/ha) in a plot	Minimum Total Carbon (ton/ha) in a plot	Average Total tree Carbon stock per unit area (ton/ha)
218.23	0.16	59.21

The details analysis of vegetation survey has been presented in Volume-II: Appendix-G.

6.6.4 Data collection for Agricultural Development of Borobila and Beel Halti Area

The data collection has been conducted to identify existing crop production, constraints and potentials of agricultural production and productivity at Borobila Beel and Beel Halti Area. The data has been collected through the RRA-cum-FGD exercises in different part of the area as well as review of secondary information available at different sources pertinent to the study. Four FGD-cum-RRA sessions were organized at Rangamatia, Hati laite, Anantapur, and Anuhadi in Rangamatia union of Fulbaria upazila surrounding the Borobila beel as shown in Figure 6-39. Three FGD-cum-RRA sessions were organized at Khajura, Madh Nagar and Piprul of Beel Halti area.


Figure 6-39: FGD-cum-RRA Sessions at Borobila Area

Crop Area Coverage, Soil and Water Condition of Borobila Beel: The beel area represented by Upper, Mid and Lower *catena* is 20, 70 and 10 percent, respectively. The upper *catena* is flooded during June-July and floodwater recedes by the last week of October. The Mid *catena* being located at a lower position, is often flooded by around 3rd week of May and water recedes by 3rd week of November. The lower *catena*, however, remains flooded/wet throughout the year. In the years with very limited rainfall, the lower catena occasionally dries out for a brief period. The soil of the upper *catena* is predominantly silty clay with medium fertility levels and relatively low water holding capacity. While the soil of mid *catena* is clayey in nature with good fertility levels and water holding capacity as shown in Table 6-60. The land of lower *catena* is highly fertile and farmers apply MoP to prevent lodging of rice crop grow in very limited areas.

Table 6-60: Land Catena-Wise Crop Area Coverage, Flooding Duration and Other Soil Properties of Borobila Beel

Catena Position	% Coverage of crop land	Flooding Duration*		Soil Texture	Water Holding Capacity	Soil Fertility
		In	Out			
Upper	20	June-July	Oct. last week	Silty clay	Low	Medium
Middle	70	May 3rd week	Nov. 3rd week	Clay	Good	Good
Lower	10	May 1st week	Never dry out but rarely it may dry briefly in March	Dark clay	High, not counted as not irrigated	Highly fertile, needs MoP to check lodging
Total	**100**					

***Very erratic, fully depends on local rainfall**

Major Crops and Cropping Patterns of Borobila Area: About 80% cropped area of Borobila is planted to single Boro rice in Boro – Fallow - Fallow cropping pattern and only 20% area is covered by Boro – Fallow – T. Aman rice cropping pattern. The Boro rice is transplanted over a long period starting from December 15 and continuing up to February 15. However, in a very limited area of lower *catena* transplanting of boro rice goes well beyond February 15 as water recedes very late. Likewise, the T. Aman rice is transplanted during July 15 – September 15 depending on flooding situation. Boro rice is harvested during April 15 to May 20 while the T. Aman rice is harvested during November 10 to December 05 as shown in Table 6-61.

Table 6-61: Major Cropping Patterns of Borobila Beel Area

Cropping Patterns	Coverage (%)	Transplanting Dates	Harvesting Dates
Boro rice – Fallow- Fallow	80	Dec 15 - Feb 15	15 Apr-20 May
Boro –Fallow- T. Aman	20	*Boro:* Dec 15 - Feb 15 *T. Aman*: Jul 15 – Sep 15	*Boro:* 15 Apr-20 May *T. Aman*: 10 Nov-5 Dec.

Crop Coverage, Flooding Pattern and Soil Properties: Since the Beel is large and flat lowland, the topography is differentiated only upper and lower *catena*. The crop area coverage by *catena*, flooding duration and other important soil properties at three different sites of RRA-cum-FGD exercise is presented in Table 6-62. On an average, the area covered by upper *catena* is only 11% as against the lower *catena* coverage of 89%. Monsoon rainwater starts accumulating by 2nd to 3rd week of May in lower and 2nd to 3rd week of June in higher elevations. Likewise, water recedes by 1st week of December in upper and 1st week of January in lower *catena*. Due to this late water recession, farmers are forced to go for Boro rice production. The flooding duration is highly erratic and depends on onset and withdrawal of rainfall.

Table 6-62: Land Catena-Wise Crop Area Coverage, Flooding, Soil Texture, Fertility and Water Holding Capacity of Beel Halti

FGD sites/ Unions	Land Catena1	% Cropped Area Coverage	Flooding Duration		Soil texture	Water holding capacity	Soil fertility
			In	Out			
Khajura (Ekdala)	Upper	15	3rd Wk. Jun	1st Wk. Dec.	Silty clay	Poor1	Good but highly leached down
	Lower	85	3rd Wk. May	1st Wk. Jan	Clay	Poor-Medium	
Madh Nagar (Halti)	Upper	3	2nd Wk. June	1st Wk. Dec.	Silty clay	Bad1	
	Lower	97	2nd Wk. May	1st Wk. Jan	Clay	Poor-Medium	

FGD sites/ Unions	Land Catena1	% Cropped Area Coverage	Flooding Duration		Soil texture	Water holding capacity	Soil fertility
			In	Out			
Piprul (Kholabaria)	Upper	15	3rd Wk. June	1st Wk. Dec.	Silty clay	Poor1	
	Lower	85	3rd Wk. May	1st Wk. Jan	Clay	Poor-Medium	

[1]***Wide and deep cracks appear when dried. The cracks do not close fully even during next monsoon, needs frequent irrigation due to quick seepage and percolation.***

Major Cropping Patterns in Beel Halti: The major crops grown within the Beel area is Boro rice. However, some other Rabi crops such as mustard, onion, potato, wheat, groundnut and some winter vegetables are also grown but to a limited extent as given Table 6-63. However, maize has been recently introduced and doing good in terms of yield and profitability as compared to Boro rice.

Table 6-63: Major Cropping Patterns of Beel Halti Area

FGD Sites/ Unions	Cropping Patterns	% Area Covered	Sowing/ Transplanting	Harvesting
Khajura (Ekdala)	Boro-Fallow-Fallow	65	2nd Wk Dec-3rd Wk. Jan	3rd Wk. April- 4th Wk. May
	Rabi crop-Boro-Fallow	10	1st Wk. Dec-3rd Wk. Mar	2nd Wk. Feb-2nd Wk. Jun
	Rabi crop-Jute-Fallow	3	1st Wk. Dec-3rd Wk. Jan	2nd Wk. Feb- 3rd Wk. Mar
	Maize-Fallow-Fallow	7	1st Wk. Dec-1st Wk. Mar	3rd Wk. Apr- 4th Wk. Jun
	Boro-B Aman	4	4th Wk. Apr-2nd Wk. May	2nd - 4th Wk. Nov
	Others	11	Differs widely	Differs widely
Madh Nagar (Halti)	Boro-Fallow-Fallow	55.00	3rd Wk. Dec- 4th Wk. Jan	3rd Wk. Apr- 4th Wk. May
	Rabi crop-Boro-Fallow	12.50	2nd Wk. Dec-4th Wk. Mar	2nd Wk. Feb-2nd Wk. Jun
	Rabi crop-Jute-Fallow	7.25	1st Wk. Dec- 3rd Wk. Jan	2nd Wk. Feb- 3rd Wk. Mar
	Maize-Fallow-Fallallow	5.80	1st Wk. Dec-1st Wk. Mar	3rd Wk. Apr- 4th Wk. Jun
	Boro- B Aman	2.25	4th Wk. Apr-2nd Wk. May	2nd - 4th Wk. Nov
	Other Crops	17.20	Differs widely	Differs widely
Piprul (Kholabaria),	Rabi crop-Boro-Fallow	65.25	3rd Wk. Dec- 4th Wk. Jan	3rd Wk. Apr- 4th Wk. May
	Rabi crop-Boro-Fallow	4.50	2nd Wk. Dec-4th Wk. Mar	2nd Wk. Feb-2nd Wk. Jun

FGD Sites/ Unions	Cropping Patterns	% Area Covered	Sowing/ Transplanting	Harvesting
	Maize-Fallow-Fallow	9.25	1st Wk. Dec- 3rd Wk. Jan	2nd Wk. Feb- 3rd Wk. Mar
	Rabi crop-Jute-Fallow	5.00	1st Wk. Dec-1st Wk. Mar	3rd Wk. Apr- 4th Wk. Jun
	Other Crops	16.00	Differs widely	Differs widely

The details of the agricultural study of Borobila Beel and Beel Halti area have been given in Volume-II: Appendix-H.

6.6.5 Socio-Economic Data Collection of Beel Halti Area

The social assessment has been conducted based on primary and secondary data. The primary data has been collected through field survey to follow purposive random sampling technique using semi-structured questionnaire.

A total of 3 Unions namely Khajuria, Madhabnagar and Piprul were selected from Naldanga Upazila of Natore District for social base line survey. The appraisal was accomplished through inter-personal face to face interview with the head of the households. Moreover, the assessment involves a qualitative investigation using checklist for Key Informant Interview (KII) and guideline for Focus Group Discussion (FGD). For social impact study a total of 200 household's survey, 10 FGDs, and 2 KIIs were conducted. A semi-structured both open and close ended questionnaires was used for conducting survey, and checklist and guideline for KII, and FGD was used at field level. The distribution of household's survey has been shown in Table 6-64.

Table 6-64: The distribution of Household's Survey at Beel Halti Area

District	Upazila	Union	Population (HHs)	Sample Weight (HHs)	Sample Size
A	**B**	**C**	**D**	**E= (D/ΣD)×100**	**F=E (n)**
Natore	Naldanga	Khajuria	4,813.0	105	56
		Madhabnagar	5,710.0	124	66
		Piprul 87	6,791.0	147	78
		Total	**17,314**		**200**

The details of the Socio-Economic data collection of Beel Halti area have been given in Volume-II: Appendix-J.

7 STUDY FINDINGS

7.1 General

This chapter deals with the findings from the study to formulate a framework for future wetland management that will help to ensure the goals of sustainable livelihood and wetland resource conservation. The project has been formulated with a view to prepare an inventory of the wetlands through classification of satellite images, delineations of wetlands, study of interaction between haor and river ecosystems and LiDAR survey of Tanguar haor for an area of approximately 120 sq. km. for empirical data collection. To fulfill the study objectives, a comprehensive data collection program has been taken both from the secondary as well as from field survey. The findings from the field survey as well as from the secondary data have been outlined in the following sections.

7.2 Delineation and Inventory of Wetlands

The extent of the water bodies in the dry season has been extracted from Sentinel-2 satellite which carries an optical instrument payload that samples 13 spectral bands: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution. The orbital swath width is 290 km. In the present work spectral bands at 10 m resolution is used for dry season application.

Water body data layer of the wet season has been generated using microwave images acquired by Sentinel-1 satellite. Interferometric Wide swath (IW) Ground Range Detected (GRD) data product of has been used. This product provides microwave image having 250 km swath with 20x22 m spatial resolution and 10x10 m pixel spacing. Dates of the wet season Sentinel-1 images were selected based on the hydrological analysis of wet season river water level to reflect the average wet season scenario.

The National Water Management Plan, 2004 has delineated the eight Hydrological Regions in Bangladesh, based on the major river system, for planning and development of water resources. The Hydrological Regions are North West (NW), South West (SW), North East (NE), North Central (NC), South Central (SC), South East (SE), Eastern Hills (EH), River and Estuary Region (RE). The results of delineating wetlands have been presented in the following sections based on the hydrological regions. Table 7-1 shows that the total number of wetlands during wet season is about 61,150 with an area of about 1,687,312 ha whereas in dry season the number of wetlands is about 30,942 with an area of about 284,835 ha. Some of the water bodies losses their individual entity through mutually merging with each other in the wet season. This merging results new entity of water bodies having larger extent of water area. A sample map of wet season and dry season wetlands is shown in Figure 7-1 to Figure 7-3 whereas the details of delineation of wetlands for all the hydrological regions are given in Volume-II: Appendix-D.

Table 7-1: Statistic on Dry and Wet Season Extents of the Closed Water Bodies in the Different Hydrological Region

Hydrological Region	Season	Number	Area, hectares	Reduction in Dry Season			
				Area		Number	
				Hectares	% w.r.t. Wet Season	No.	% w.r.t. Wet Season
NW	Wet	17,786	305,070	275,158	90.20	11,832	66.52
	Dry	5,954	29,912				
NC	Wet	3,777	160,911	150,025	93.23	1,780	47.13
	Dry	1,997	10,886				
NE	Wet	3,970	694,689	667,868	96.14	2,264	57.03
	Dry	1,706	26,821				
SE	Wet	6,543	39,427	35,025	88.84	2,207	33.73
	Dry	4,336	4,402				
EH	Wet	12,608	112,808	67,166	59.54	1,265	10.03
	Dry	11,343	45,642				
SC	Wet	4,688	47,894	45,107	94.18	3,996	85.24
	Dry	692	2,787				
SW	Wet	11,778	326,513	162,128	49.65	6,864	58.28
	Dry	4,914	164,385				

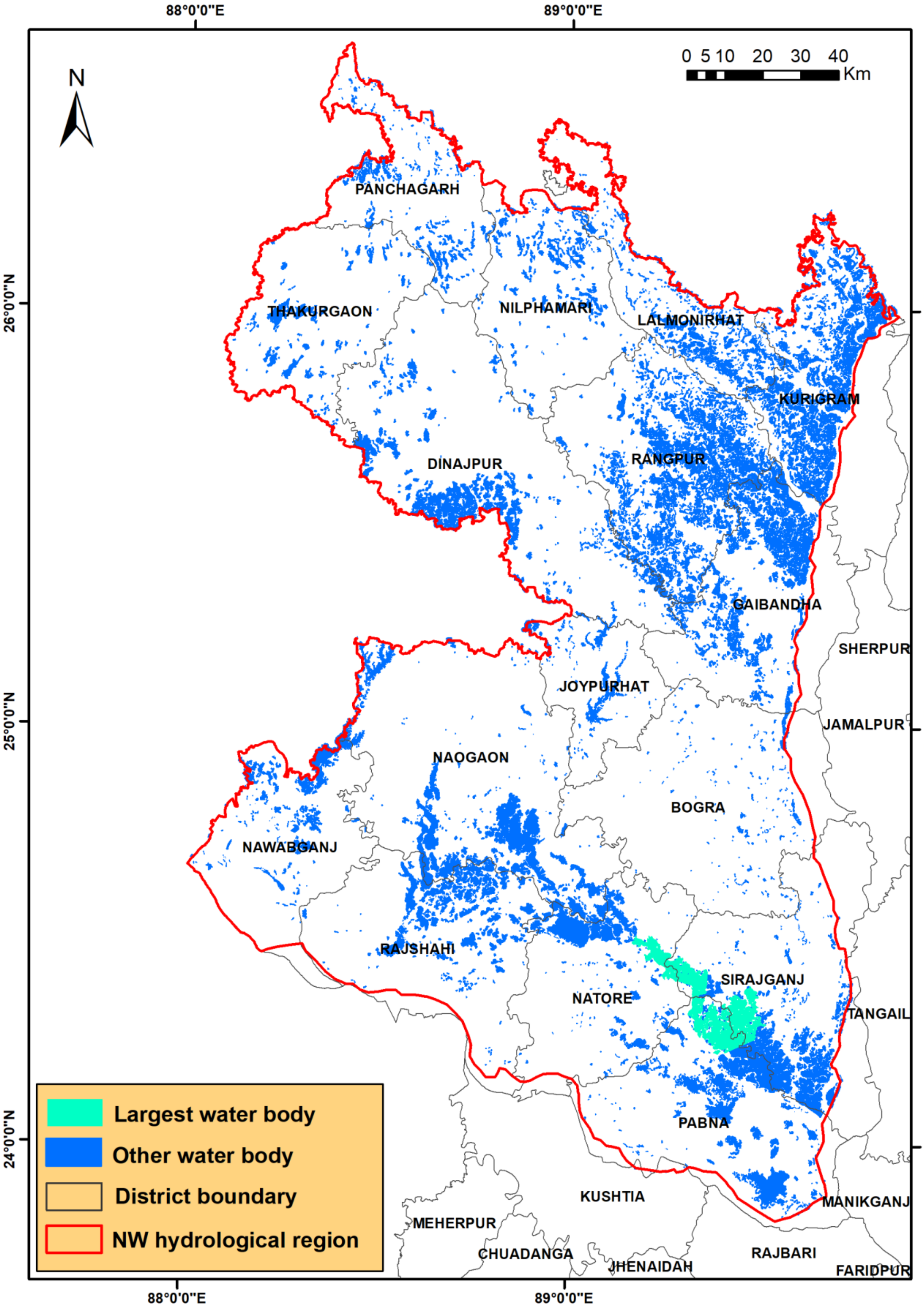


Figure 7-1: Wet Season Extent of the Closed Water Body in the NW Region

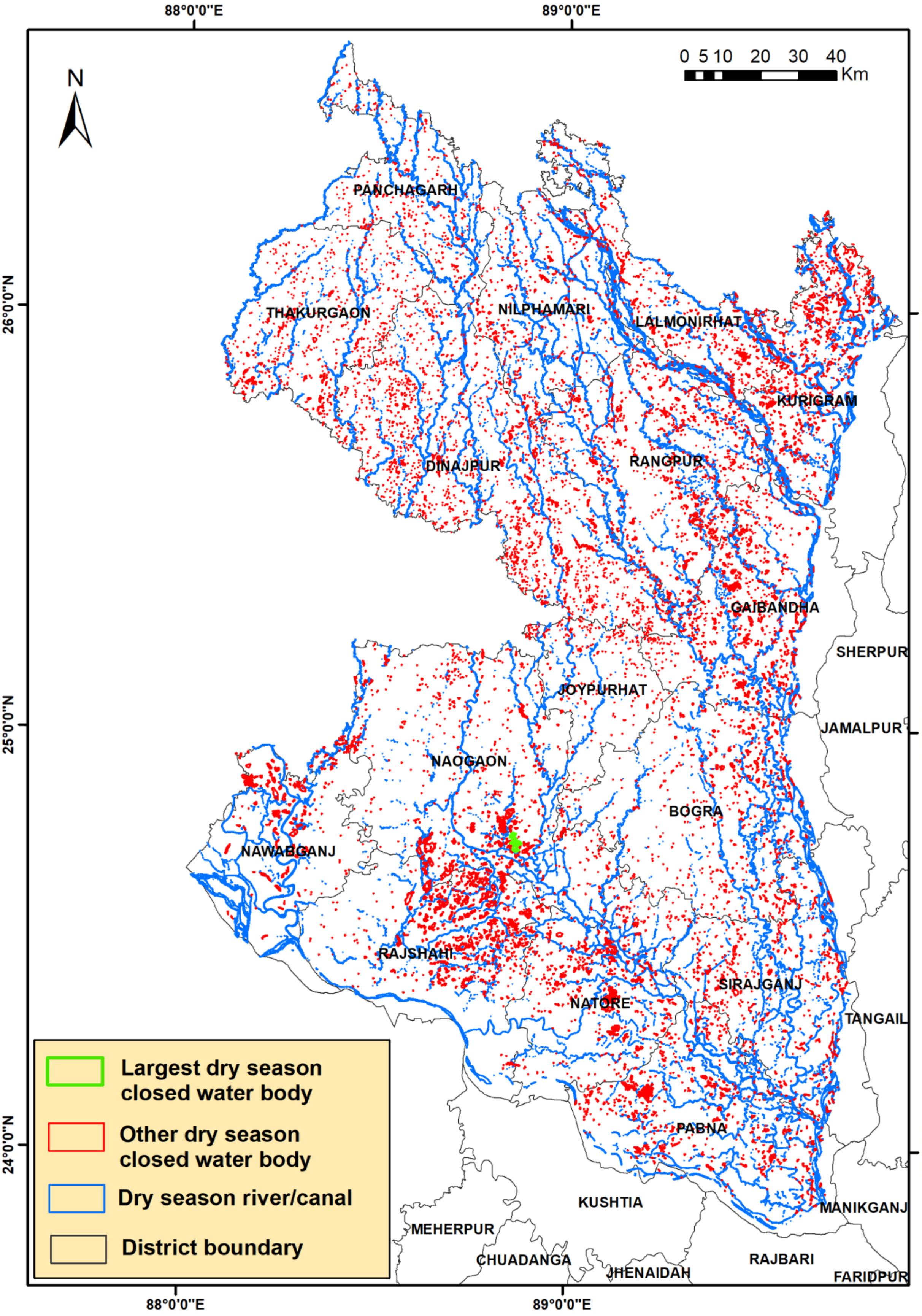


Figure 7-2: Dry Season Extent of the Closed Water Body and River/Canal in the NW Region

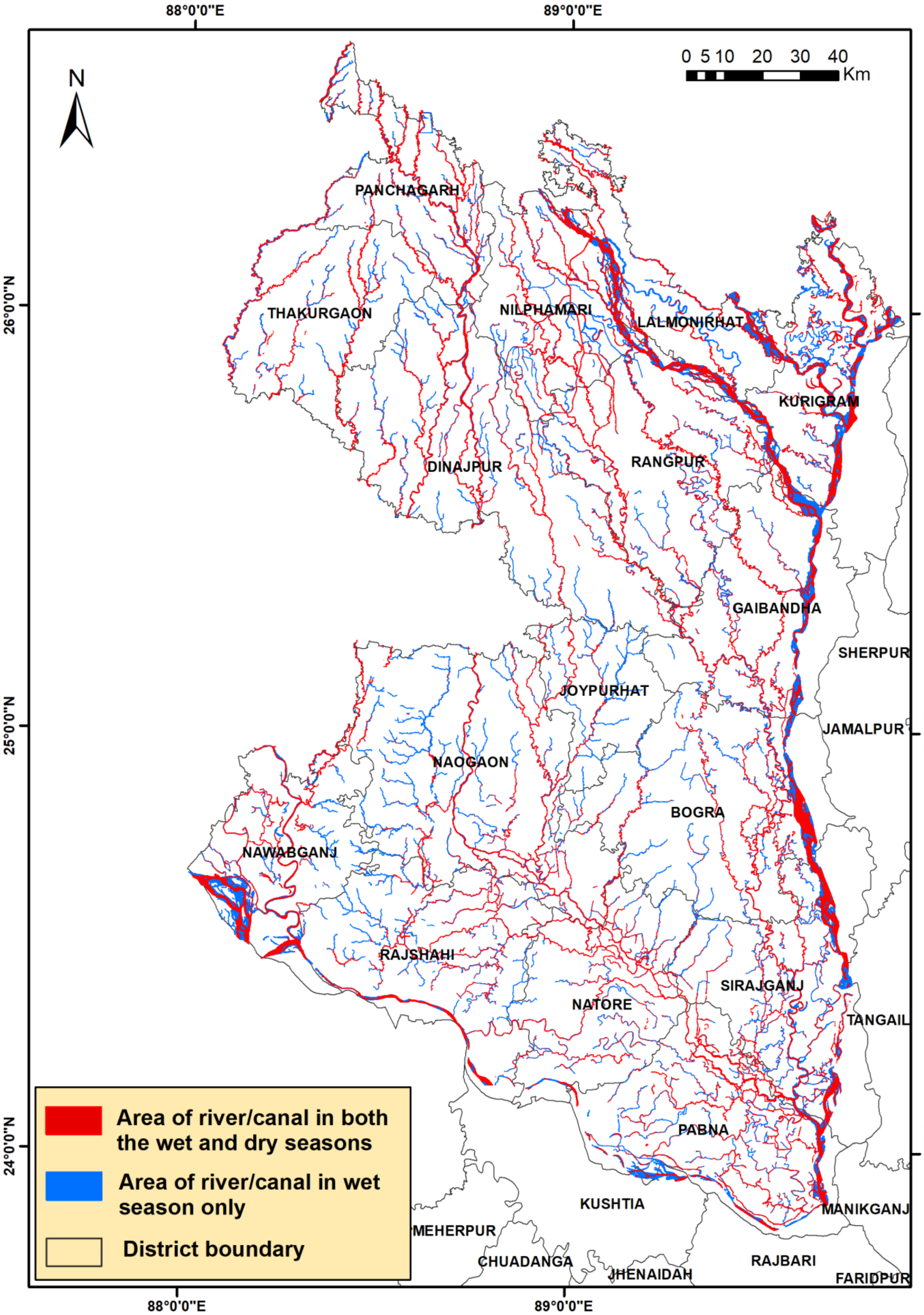


Figure 7-3: Seasonal Change of Rivers/Canals in the NW Region

The inventory of wetlands includes the production of hierarchical and map-based outputs. The level of detail is related to the scale of the maps that are contained within a standardized GIS format with a minimum core data set. The hierarchical approach comprises a progression in scale from river basins to individual sites. The initial analysis (level 1) involves delineation of geographical regions (major river basins) and encompasses a description of the geology, climate and ecology of each based on existing information sources. Level 2 analysis concerns delineation of wetland regions within each geographic region. This is done based on similar climatic, geologic, hydrologic and vegetation features. Several meetings and discussion were held among the different stakeholders to finalize the inventory method. The outcome from the meetings and discussion is to develop the inventory based on hydrological region of Bangladesh and prepare the map-based outputs in 1:10000 scale. A total 4443 nos. of maps have been produced to cover the whole country. As per the comments and suggestions from the expert, the inventory is presented in tabular format including the location (districts, upazila, union and mouza), area and other physical features such as geology, agro- ecological zone and bio-ecological zone and others. Accordingly, the inventory is developed and a sample of wetland inventory has been given in Table 7-2 whereas the details are given in Volume-III.

The wetlands that have been delineated is superimposed on the map of Agro-ecological zone of Bangladesh as shown in Figure 7-4 whereas the wetland area in different Agro-ecological zones is given in Figure 7-5. Figure 7-5 shows that most of the area of wetlands in Bangladesh falls under the category of Ganges tidal floodplain (41.37%) which is followed by high Ganges river floodplain (12.87%) and then Northern and Eastern hills (10.86%). The minimum area of wetland covers Akhaura terrace (0.01% of the total wetland area). The Figure 7-5 also reveals that about 65.45% area of wetlands is under three dominant agro-ecologiical zones namely Ganges tidal floodplain, Ganges river floodplain and Northern and Eastern hills.

The map of wetlands in Bio-ecological zones is given in Figure 7-6 whereas an analysis of wetlands in different zones is presented in Figure 7-7. The Figure 7-7 reveals that Saline Tidal Floodplain covers about 38% of the total wetland area in Bangladesh. The Chittagong Hills and CHTs is the 2nd highest bio-ecological zone which covers about 37322 ha (13%) of total wetland area which is followed by Ganges Floodplain (10%). The Figure 7-7 also indicates that Chakaria Sundarban zone contains the minimum wetland area (only 17 hectare).

Table 7-2: A Sample Inventory of Wetlands

WB Unique ID	Geocode	WBUPZ Code	WB FULL ID	Division	District	Upazila	Union	Mouza	Area (Ha)	TS	Hydrological Region	Waterbody Name	Bio-Ecological Zone Name	Agro-Ecological Zone Name	Geological Zone Name
1	557790	1	557790W1	Rangpur	Panchagarh	Tentulia	Banglabandha	Sipai Para	0.414	B4	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
2	557790	2	557790W2	Rangpur	Panchagarh	Tentulia	Tirnaihat	Tirnai	1.029	B4	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
3	557790	3	557790W3	Rangpur	Panchagarh	Tentulia	Banglabandha	Tirnai, Raushanpur	0.611	B4	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
4	557790	4	557790W4	Rangpur	Panchagarh	Tentulia	Tirnaihat	Khaikhat Para	0.785	BTp	NW	Ramchandi Khal	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
5	557790	5	557790W5	Rangpur	Panchagarh	Tentulia	Salbahan, Tirnaihat	Tulsia Bil, Raushanpur	7.666	BO	NW	Tulsia Beel	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
6	557790	6	557790W6	Rangpur	Panchagarh	Tentulia	Tirnaihat	Khaikhat Para	3.574	BTp	NW	Ramchandi Khal	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
7	557790	7	557790W7	Rangpur	Panchagarh	Tentulia	Tentulia, Tirnaihat	Sarkari Para, Khaikhat Para	1.234	BTp	NW	Ramchandi Khal	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
8	557790	8	557790W8	Rangpur	Panchagarh	Tentulia	Bhojanpur	Bhadreshwar	0.546	BL	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
9	557790	9	557790W9	Rangpur	Panchagarh	Tentulia	Salbahan	Salbahan	0.458	BTp	NW	Tulsia Beel	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
10	557790	10	557790W10	Rangpur	Panchagarh	Tentulia	Buraburi	Sarkar Para	0.394	BL	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
11	557790	11	557790W11	Rangpur	Panchagarh	Tentulia	Bhojanpur	Bhadreshwar	0.414	BL	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
12	557790	12	557790W12	Rangpur	Panchagarh	Tentulia	Salbahan	Balabari	1.439	BL	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
13	557790	13	557790W13	Rangpur	Panchagarh	Tentulia	Buraburi, Salbahan	Sarkar Para, Balabari	0.413	BL	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
14	557790	14	557790W14	Rangpur	Panchagarh	Tentulia	Salbahan	Balabari	0.398	BL	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
15	557790	15	557790W15	Rangpur	Panchagarh	Tentulia	Buraburi	Sarkar Para	0.468	BL	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
16	557790	16	557790W16	Rangpur	Panchagarh	Tentulia	Bhojanpur	Bhadreshwar	0.958	B4	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
17	557790	17	557790W17	Rangpur	Panchagarh	Tentulia	Bhojanpur	Bhadreshwar	0.501	B4	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
18	557790	18	557790W18	Rangpur	Panchagarh	Tentulia	Bhojanpur	Pradhangachh	0.651	B4	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
19	557790	19	557790W19	Rangpur	Panchagarh	Tentulia	Bhojanpur, Buraburi	Sarkar Para, Pradhangachh	0.441	B4	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
20	557790	20	557790W20	Rangpur	Panchagarh	Tentulia	Buraburi	Sarkar Para	0.475	BTp	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand
21	557790	21	557790W21	Rangpur	Panchagarh	Tentulia	Bhojanpur	Pradhangachh	0.773	B4	NW	-	Himalayan Piedmont Plain	Old Himalayan Piedmont Plain	Old Gravelly Sand

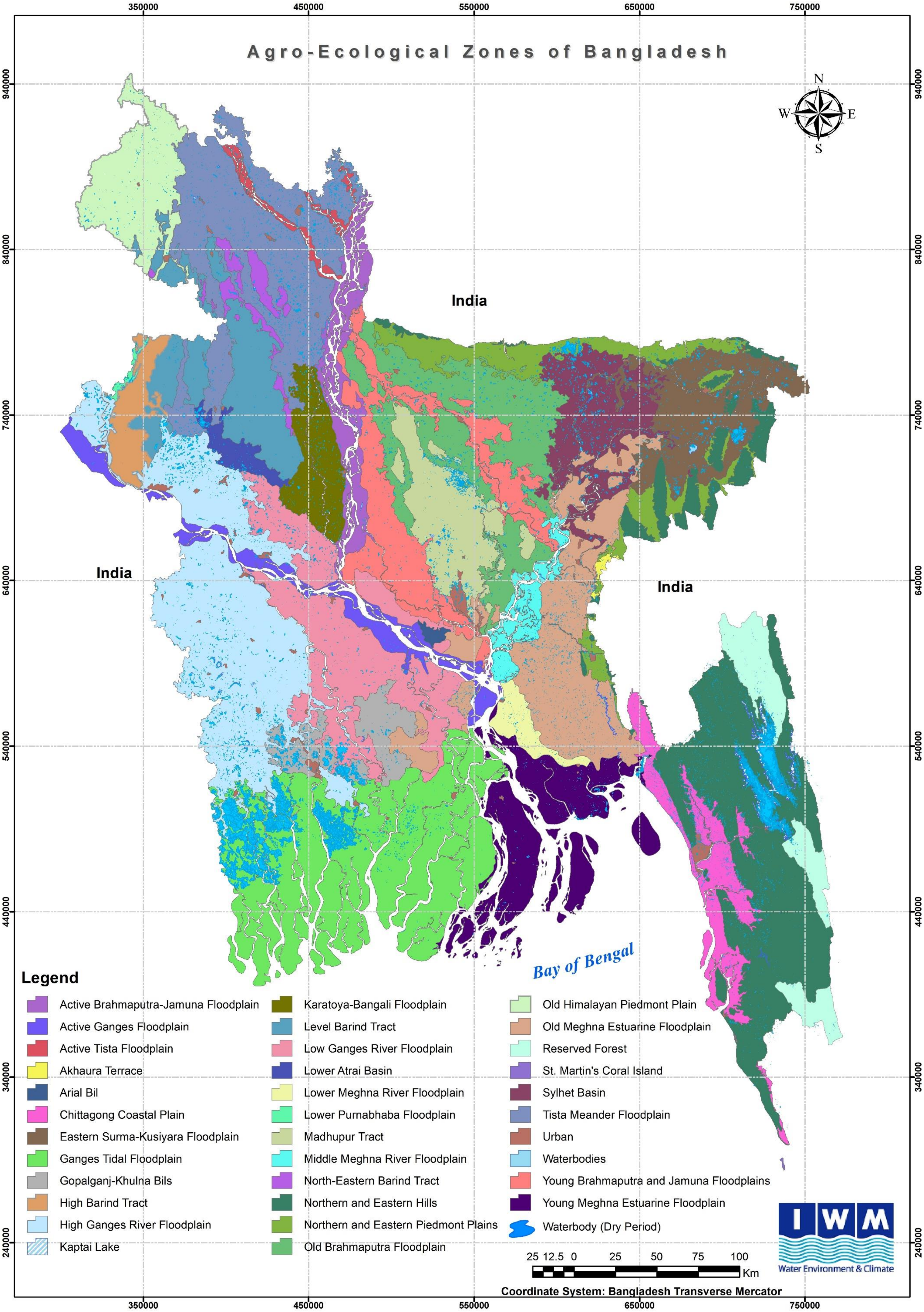


Figure 7-4: Map Showing Dry Season Water Body and Agro-Ecological Zone of Bangladesh

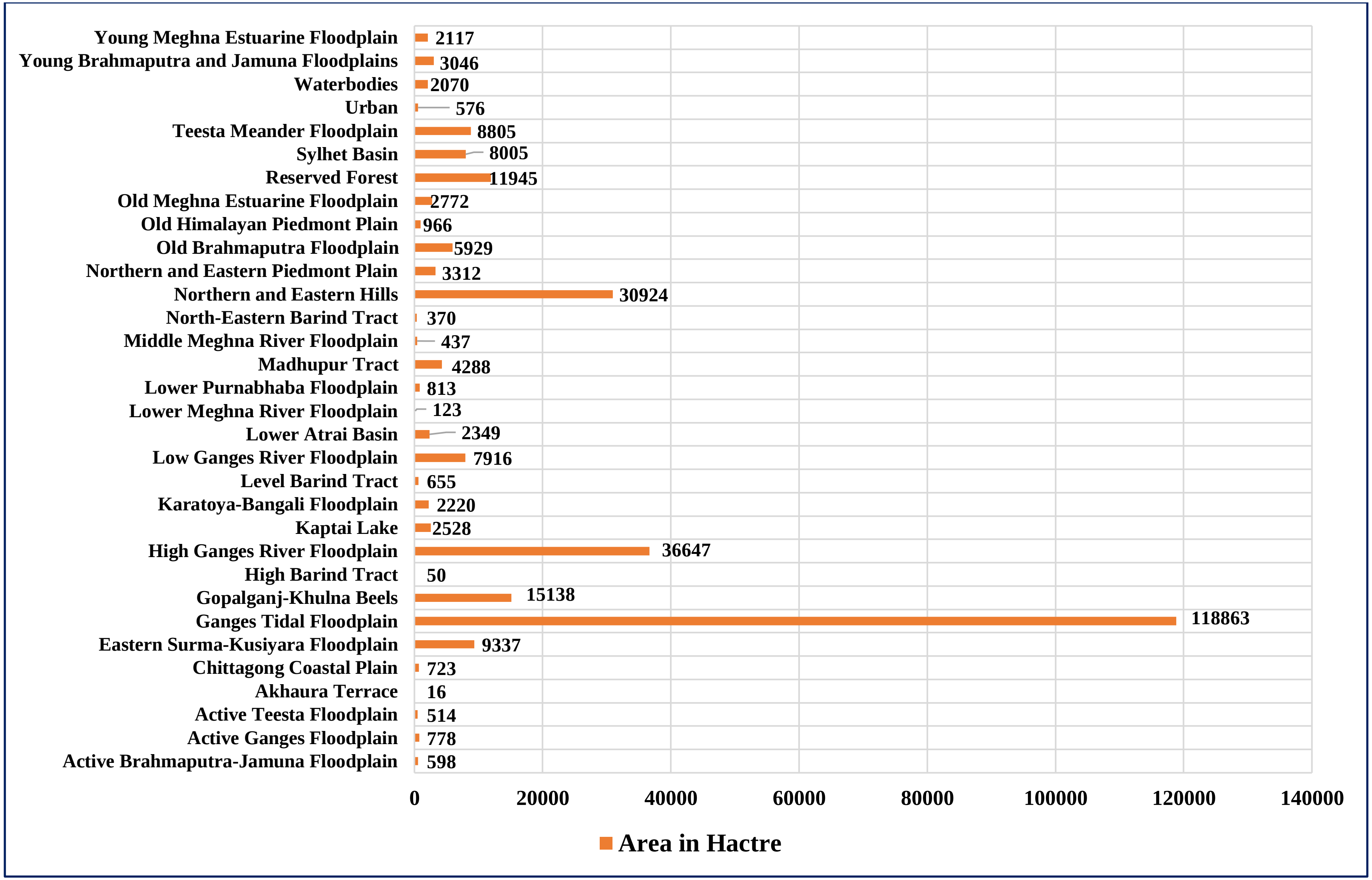


Figure 7-5: Area of Water Body in Different Agro-Ecological Zone of Bangladesh

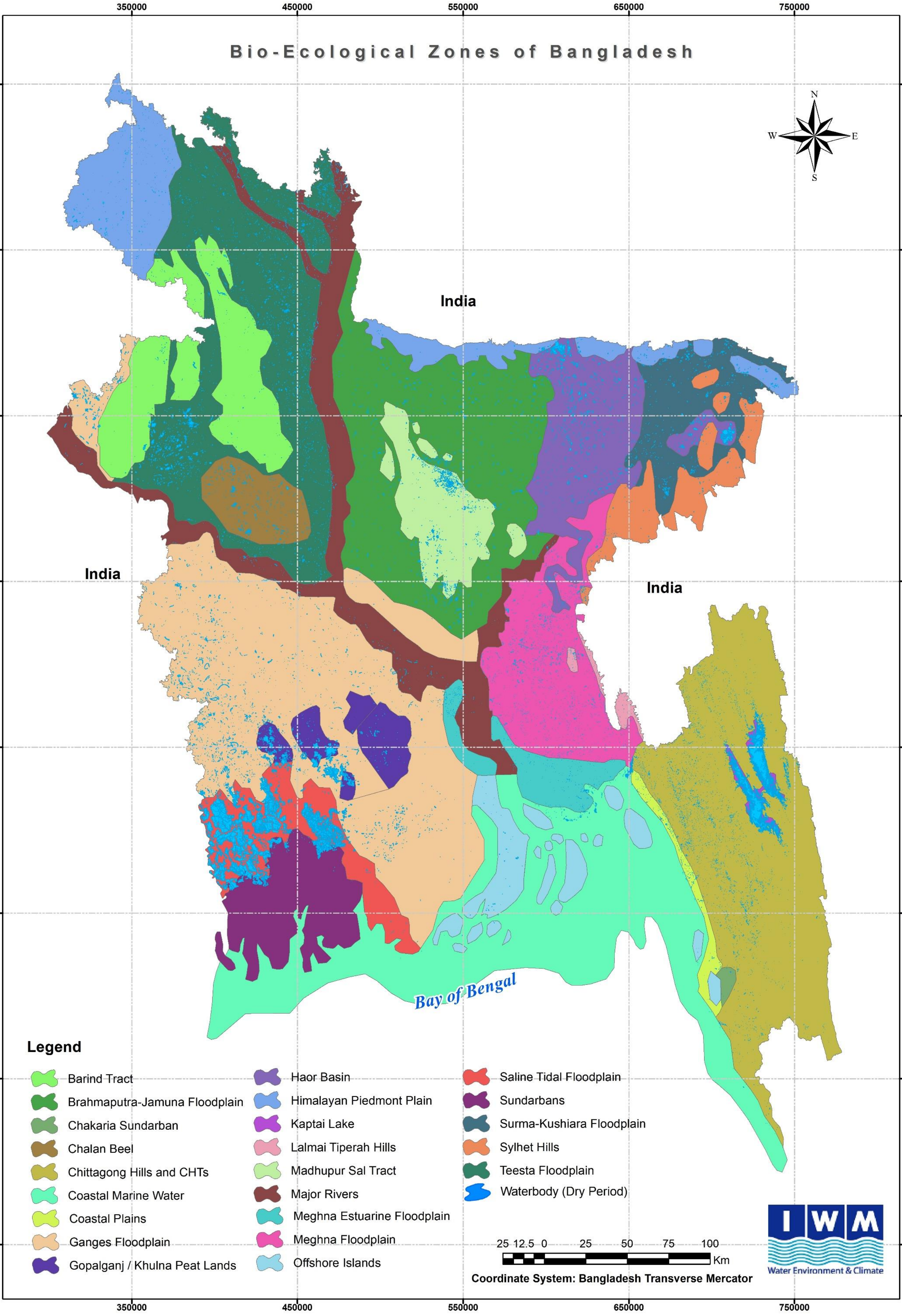


Figure 7-6: Map Showing Dry Season Water Body and Bio-Ecological Zone of Bangladesh

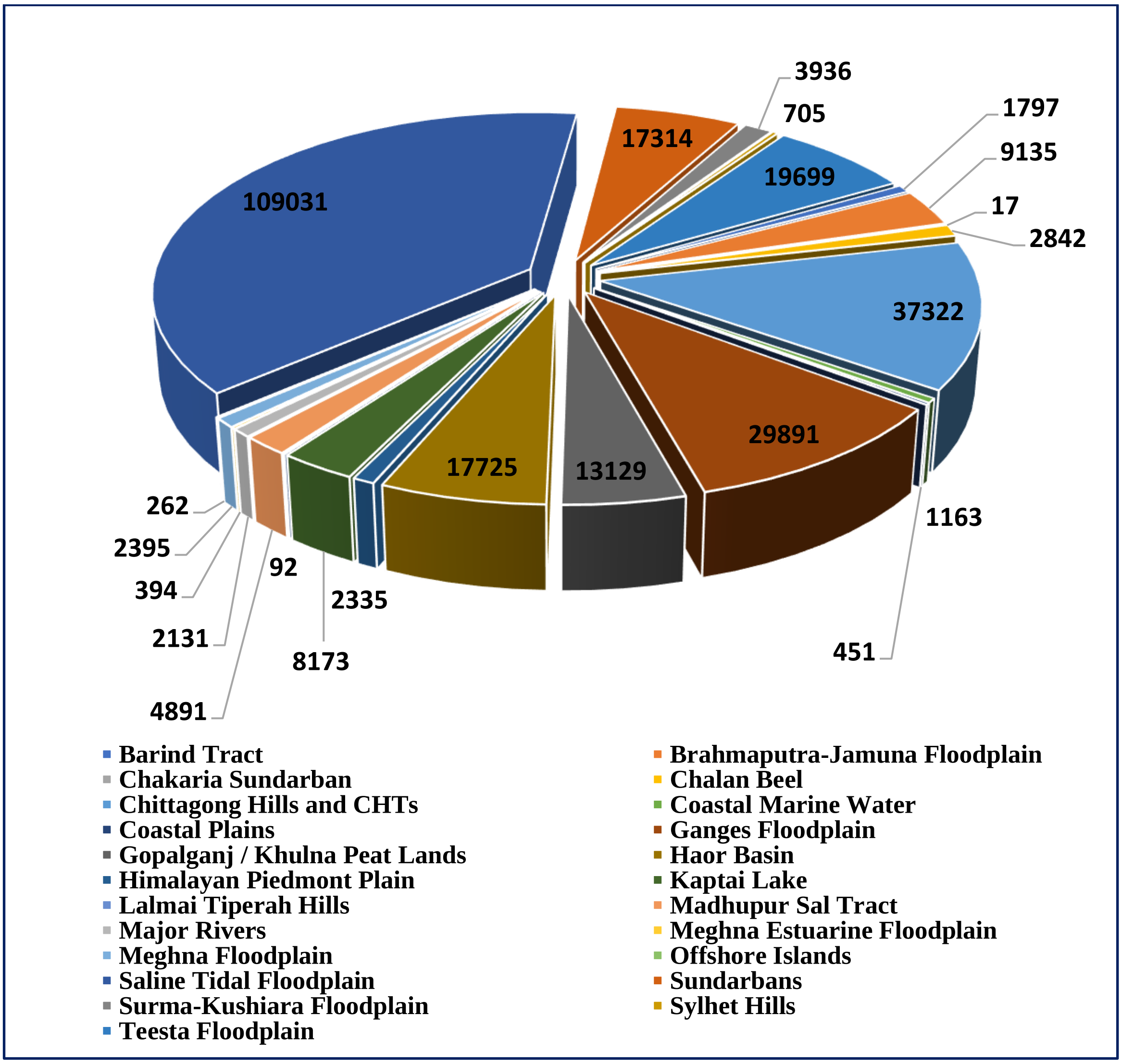


Figure 7-7: Area of Wetlands in Different Bio-ecological Zones

Information on Ponds

The data layers of ponds were added with the closed water body data layers for having a complete picture of the closed water body in the country. However, for having a picture of ponds, the relevant statistical information is given in Table 7-3.

Table 7-3: Statistical Information of Pond Based on Hydrological Regions

Hydrological Region	Number of Ponds	Total Area of Ponds, hectares	Average area/pond, hectares	Pond Concentration, Number/hectare
North Western	1,84,346	47,698	0.26	0.058
North Central	1,02,196	24,135	0.24	0.064
North Eastern	72,657	14,779	0.20	0.036
South Eastern	6,886	4,439	0.64	0.007
Eastern Hill	38,087	8,384	0.22	0.019
South Central	61,412	10,469	0.17	0.040
South Western	89,197	18,257	0.20	0.034

Table 7-3 shows that the North Western region has the highest number of ponds (1,84,346) and the South Eastern region has the lowest number of ponds (6,886). On average, the size of pond is the biggest (0.64 hectare) in the South Eastern region and smallest in the South-Central region (0.17 hectare). The concentration of pond is the highest in the North Central region (0.064) and lowest in the South Eastern region (0.007).

7.3 Results of LiDAR Survey for Tanguar Haor

One of the major and critical tasks of the study is to conduct the LiDAR survey of Tanguar haor area for empirical data collection. The Airborne LiDAR survey is the first in Bangladesh of this kind. Airborne LiDAR is one of most efficient technology for collecting spatial data in connection with development activities. Light Detection and Ranging (LiDAR) is a proven approach for creating fast and accurate spatial data for applications in various domains while the Integrated Water Resource Management (IWRM) is one of the most important one. The technology is based on a scanning laser device mounted on a small aircraft combined with GPS (Global Positioning System), GNSS (Global Navigational Satellite System) and INS (Inertial Navigation System) technology to create a three-dimensional set of points (point cloud). A medium format aerial camera (Hasselblad H60) with 100 Megapixel made the acquired data much more useful resulting in a very high resolution (10 cm) geo-rectified orthophotos for the project area. The LiDAR data along with aerial photographs fulfilled the project objectives to a great extent as stated below:

i. ***Identification of Wetland Boundaries:*** The LiDAR data used to delineate the boundaries of the wetlands very accurately in the project area which have been found highly validated by the wetlands separated from the high-resolution satellite image analysis as shown in Figure 7-8.

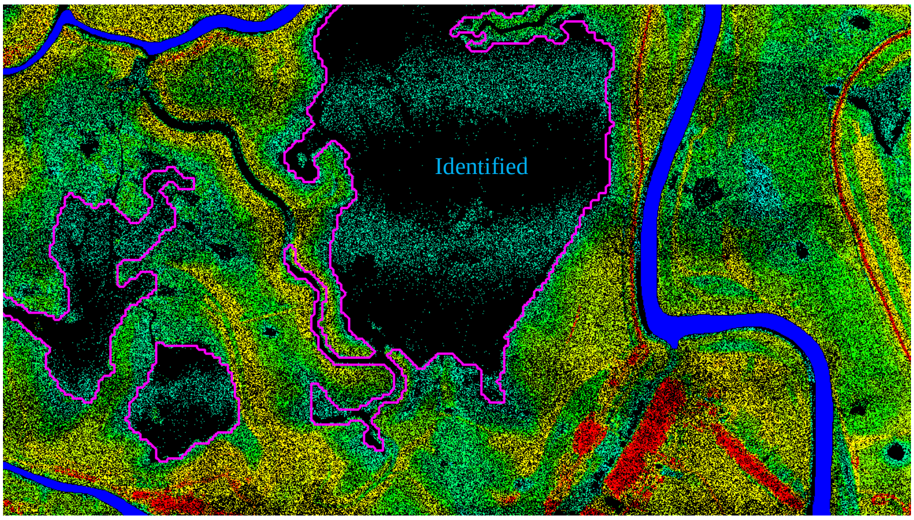


Figure 7-8: Delineating Wetland Boundaries from LiDAR Data

ii. ***Point Clouds for Accurate Terrain Models:*** The collected LiDAR data poses very high positional accuracy both in horizontal and vertical planes as they were collected and processed with ground survey values using RTK (Real-Time Kinematics) GPS Instruments. The point cloud density is 3 to 5 individual points in every meter square having both RGB (Red, Green, Blue) and elevation values from the Mean Sea Level (MSL). This highly dense point clouds made it possible to generate extremely representative Digital Terrain Model (DTM) and Digital Surface Model (DSM) of the of the earth surface in the project area as shown in Figure 7-9 and Figure 7-10.

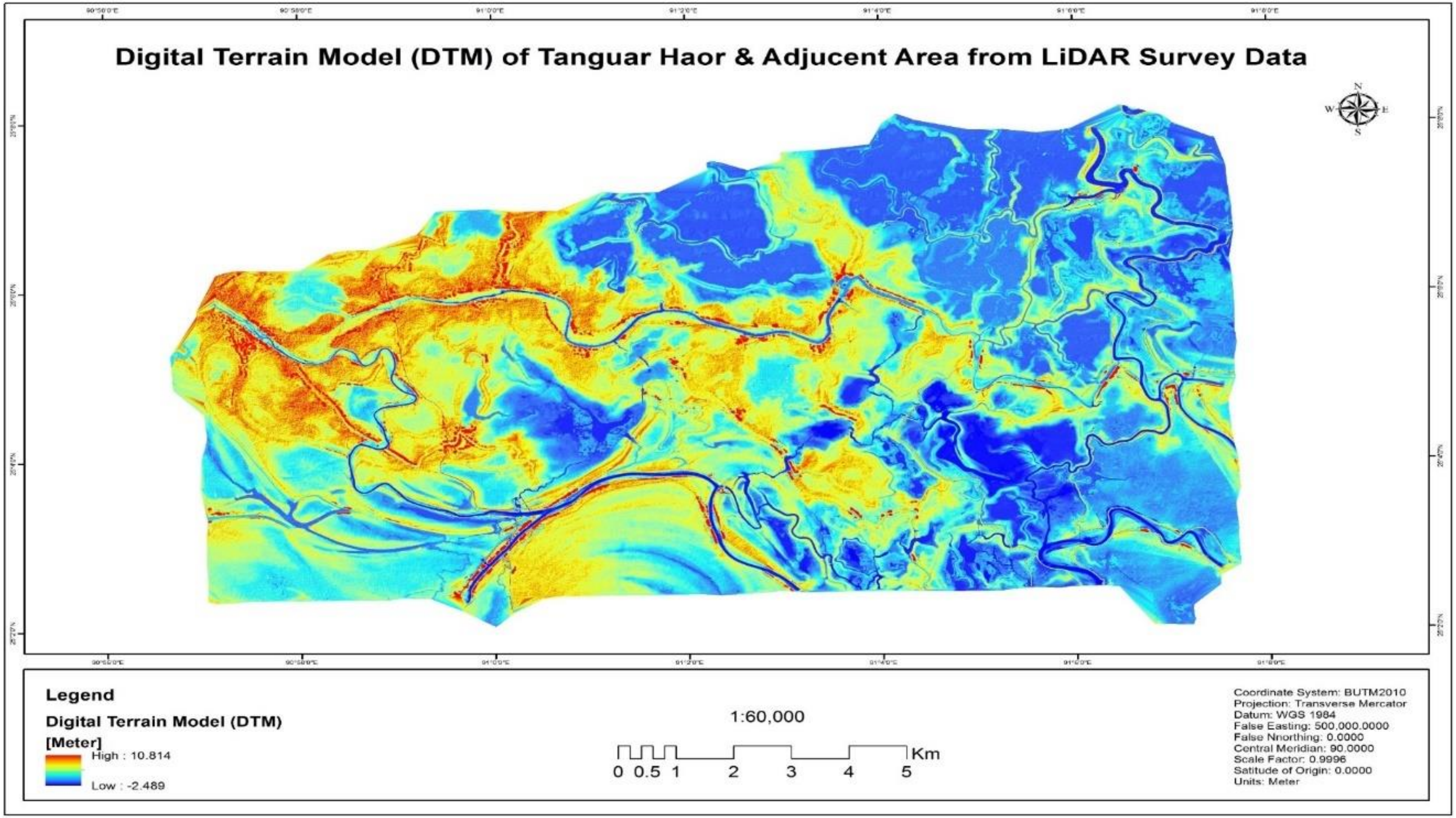


Figure 7-9: Digital Terrain Model (DTM) of Tanguar Haor and Adjacent Area from LiDAR Survey Data

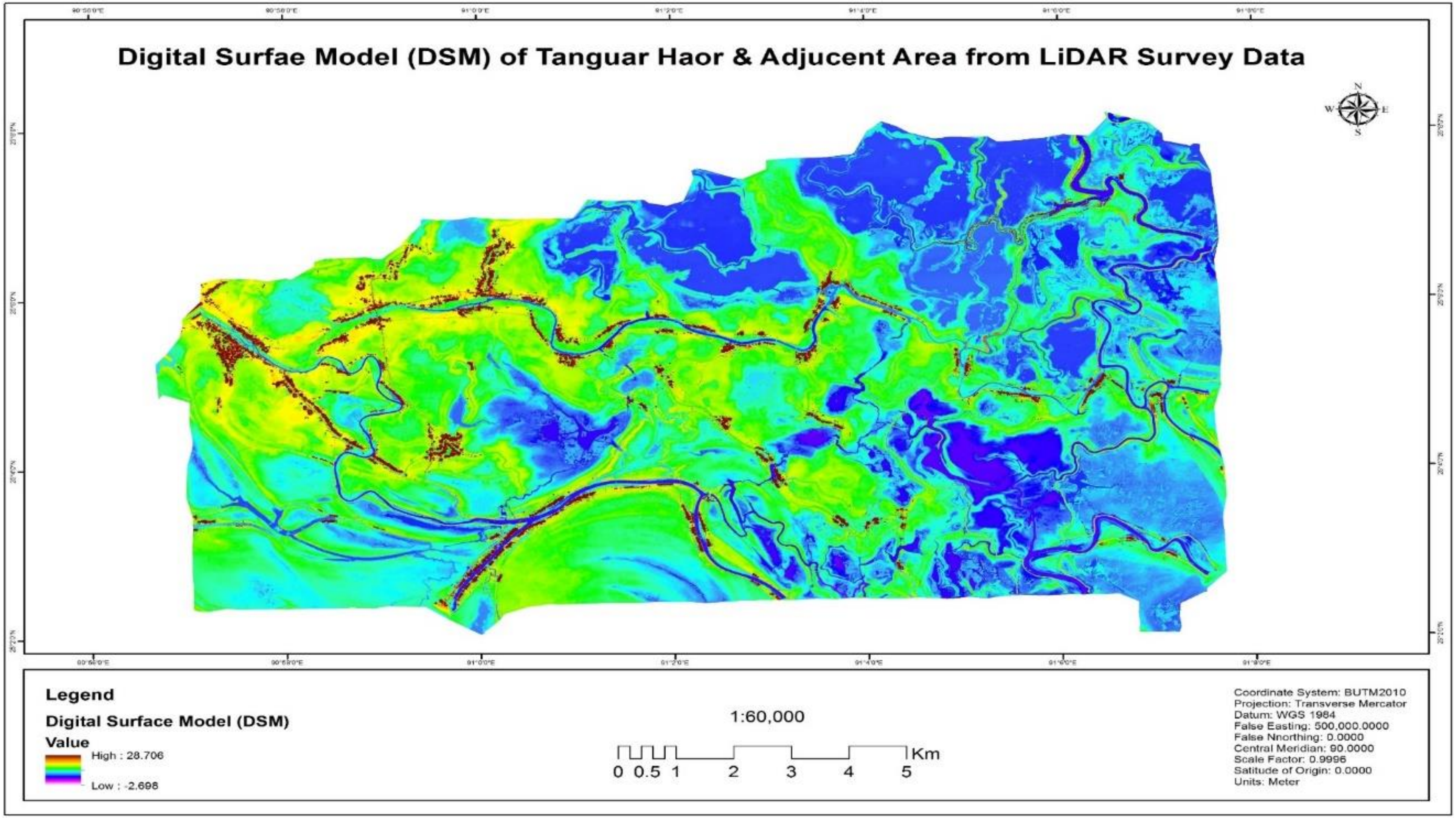


Figure 7-10: Digital Surface Model (DSM) of Tanguar Haor and Adjacent Area from LiDAR Survey Data

iii. ***Identification of Other Relevant Features:*** This LiDAR data has also made possible to identify the other critical facilities in the project area with accurate existing conditions. The Road networks, the Embankments, the Hydraulic Structures, Electrical Distribution Systems are just few among the identified features as shown in Figure 7-11. This data sets also pave the way for analysis of the forestry and agriculture from different useful dimensions.

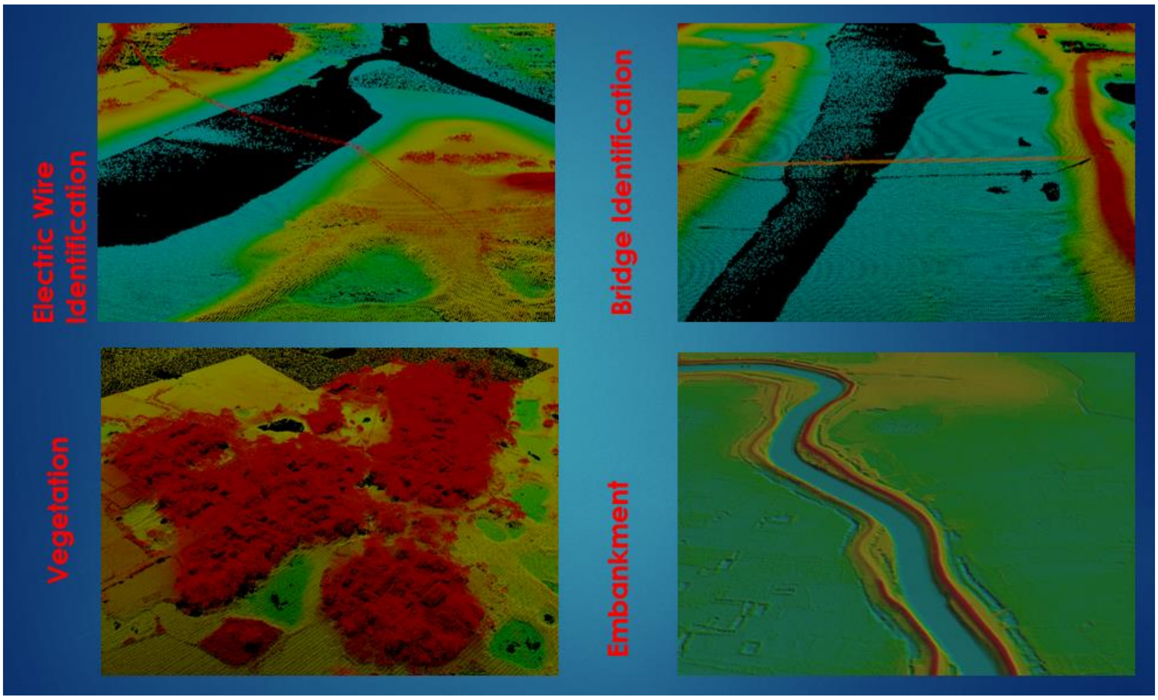


Figure 7-11: Identifying Relevant Features from LiDAR Data

iv. ***Time Dimension of the Data Acquisition:*** The Airborne LiDAR takes extremely small amount of time in comparison to other traditional data acquisition methods. The total flight was only 5 hours and 5 minutes ours while the actual data acquisition time was only in 3 hours and 20 minutes for the entire targeted area. The initial target was to cover approximately 120 square kilometer while the mission covered 152 square kilometers of the fresh data with a single go.

The Airborne LiDAR Technology is proved to be very successful in satisfying the project objectives in this case of Integrated Water Resource Management (IWRM) project. It has surpassed the expectation of the project management committee in quite a good number of dimensions. The Airborne LiDAR can be applied in any form of Development activities with special reference to the Development Design, Development Implementation, Development Control and Development Monitoring. The details of the LiDAR survey have been presented in Volume-II: Appendix-B.

7.4 Wetlands Classification

It has been mentioned earlier that the classification of wetlands of Bangladesh consists of four systems, namely:

1. Marine/Coastal Wetlands;
2. Inland Wetlands;
3. Human-made Wetlands and
4. Reversible Wetlands

It has two classes namely Permanent and Non-permanent and 30 types. Details of classification system of wetland of Bangladesh have been given in Chapter 5. A sample map of classified wetlands has been given in Figure 7-12 whereas the 1:10000 scale map has been supplied as hard copy separately.

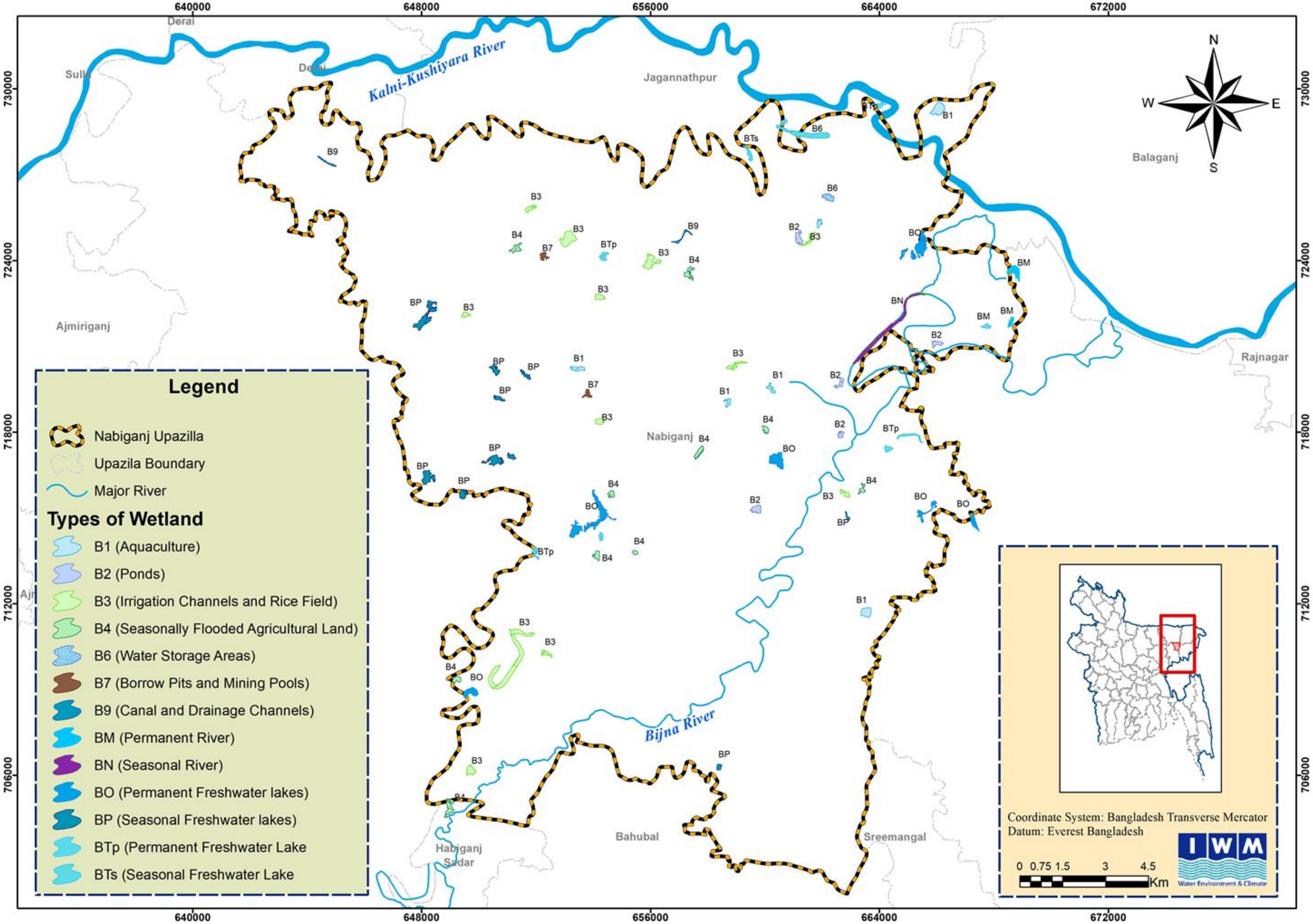


Figure 7-12: A Sample Map of the Classified Wetlands

Some examples of different system and types of wetlands of Bangladesh are given in Table 7-4. Moreover, brief descriptions of some important wetlands have also been A sample map of the classified wetlands has been presented in Figure 7-12.

Table 7-4: Statistic of Different Classes of Wetlands in Bangladesh

Systems	Classes	Types Symbols	Name of wetland types	Total Numbers in Whole Bangladesh	Examples
Marine/Coastal Wetlands	Permanent	BA	Permanent shallow marine waters in most cases less than six meters deep at low tide; includes sea bays and straits	78	Entire coastal belt up to a depth of 6m
		BB	Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows	57	Entire coastal belt and islands which remain inundated and where aquatic plants are grown
		BC	Coral Reefs	-	St. Martin's Island, some parts of Cox's Bazar
		BF	Estuarine waters; permanent water of estuaries and estuarine systems of deltas	-	Estuaries of Meghna and Karnaphuli, Shahbazpur Channel etc.
	Non- Permanent	BE	Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune	-	Sea beaches of Bay of Bengal
		BG	Intertidal mud, sand or salt flats	7	Sea beaches of Teknaf, Cox's Bazar and other sea shores
		BI	Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests	-	Sundarbans
Inland Wetlands	Permanent	BL	Permanent inland deltas	313	Char lands of rivers
		BM	Permanent rivers/streams/creeks; includes waterfalls	631	Permanent rivers of Bangladesh, waterfalls etc.
		BO	Permanent freshwater lakes (over 8 ha); includes large oxbow lakes	1350	Beels, Baors

Systems	Classes	Types Symbols	Name of wetland types	Total Numbers in Whole Bangladesh	Examples
		BTp	Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season	3568	Beels within haor areas
	Non- Permanent	BN	Seasonal/intermittent/irregular rivers/streams/creeks	521	Seasonal rivers of Bangladesh, hilly streams, springs etc.
		BP	Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes	362	Haors, Beels
		BTs	Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes	1999	Lowland, potholes etc. within haor area
		BU	Non-forested peatlands; includes shrub or open bogs, swamps, fens	7	Peatlands within haor areas, beels of Satkhira, Khulna & Gopalganj
		BW	Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils	34	haor area
		BXf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils	178	haor area
		BXp	Forested peatlands; peat swamp forests	172	Forested peatlands of lowlands of Satkhira, Khulna & Gopalganj
Human-made Wetlands	Permanent	B1	Aquaculture (e.g., fish/shrimp) ponds	2404	Dighi, ponds, shrimp ponds
		B2	Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha)	7632	Small ponds, including ponds for fish culture

Systems	Classes	Types Symbols	Name of wetland types	Total Numbers in Whole Bangladesh	Examples
		B6	Water storage areas; reservoirs/barrages/dams/ impoundments (generally over 8 ha)	3584	Reservoir of Teesta & Kaptai, Dams of Muhuri & reservoirs of Magura etc.
		B8	Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.	-	WWTP of Pagla (Dhaka WASA)
		B9	Canals and drainage channels, ditches	85	Madaripur Beel Route, Mongla-Ghashikhali Channel, Gab Khan Channel, Irrigation channels of BWDB, Teesta Irrigation Project
	Non- Permanent	B3	Irrigated land; includes irrigation channels and rice fields	1142	Irrigation project areas of the BWDB
		B4	Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture)	2612	Floodplains of the rivers
		B5	Salt exploitation sites; salt pans, saline, etc.	-	Salt areas and salt cultivation areas of Teknaf and Barisal
		B7	Excavations; gravel/brick/clay pits; borrow pits, mining pools	185	Roadside borrow pits, Barapukuria Coal Mine etc.
Reversible Wetlands		Brvc	Coastal polders and embankments	3335	139 coastal polders of the country
		Brvi	FCD and FCDI projects; flood protected inlands with embankments	682	All inland BWDB FCD & FCDI projects
		Brve	Environmentally degraded, but restorable wetlands	4	Polluted rivers, encroached rivers, khals, lowlands etc.

[Note 1:
BX – 'B' stands for Bangladesh, 'X' stands for corresponding X type of Ramsar wetland type
Example:
BA – 'B' stands for Bangladesh, 'A' stands for Ramsar type (A: Permanent shallow marine waters in most cases less than six meters deep at low tide; includes sea bays and straits)
B1 – 'B' stands for Bangladesh, '1' stands for Ramsar type (1: Aquaculture (e.g., fish/shrimp) ponds)
Note 2:
Brvc – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands; 'c' stands for Coastal Polders and embankments.

Brvi – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands, 'i' stands for FCD and FCDI projects; flood protected inlands with embankments.
Brve – 'B' stands for Bangladesh, 'rv' stands for Reversible Wetlands, 'e' stands for environmentally degraded, but restorable wetlands.]

The classification of wetlands has been summarized as shown in Figure 7-13 which reveals that about 25% of wetlands falls under B2 type whereas B6, Brvc and BTp ranges closely with each other. The study also illustrated that only seven nos. of Non-forested peatlands; includes shrub or open bogs, swamps, fens etc. are exists in Bangladesh.

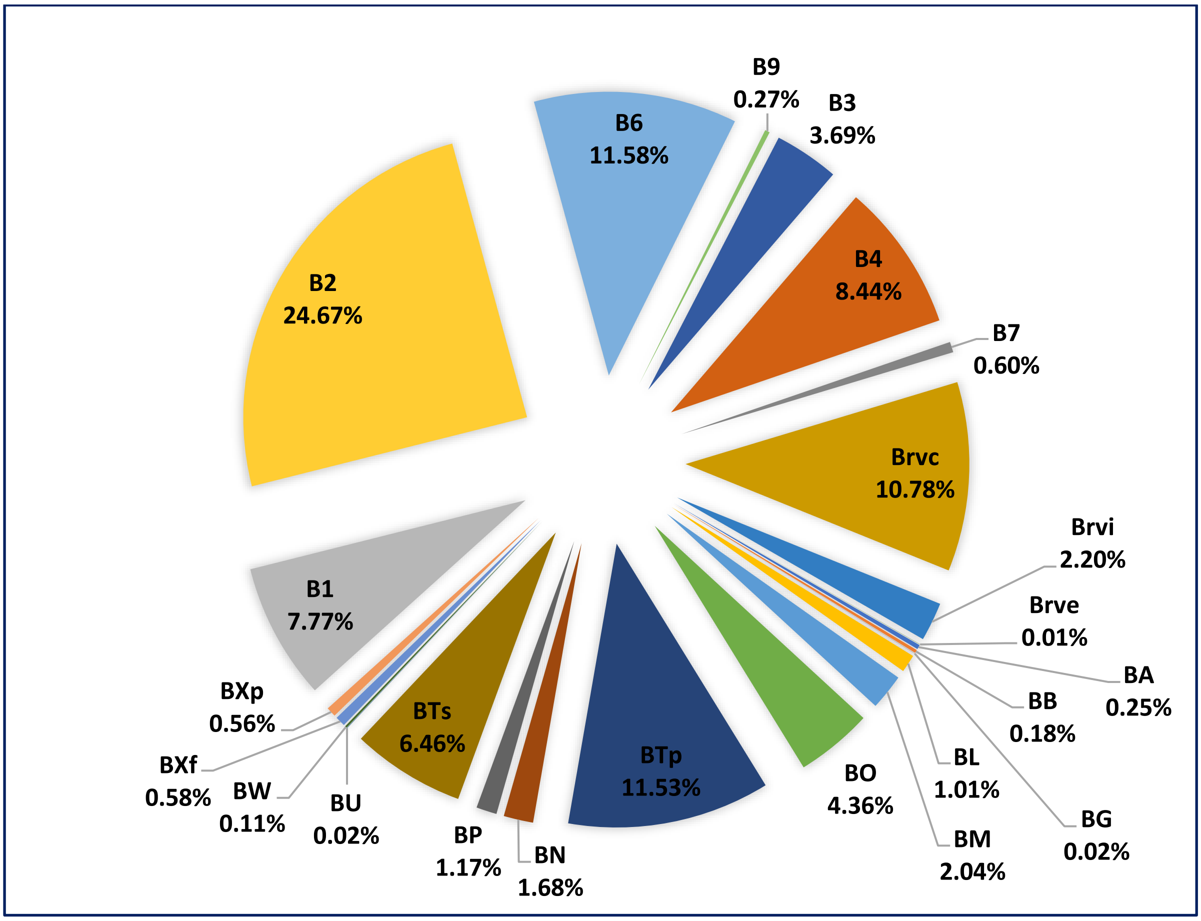


Figure 7-13: Percentage wise Classified Wetlands in Bangladesh

7.5 Interaction of Haor and Wetlands with Adjacent River System

The interaction between wetlands with the adjacent river has been assessed based on the historical time series analysis of river water level data. To conduct the hydrological analysis, potential water level river gauge stations and their respective 20 years historical time series water level data have been considered. The hydrological analysis considered 20 years observed water level time series data to identify the optimum wet land extents for both dry and wet seasons. A sample plot of hydrograph analysis is shown in Figure 7-14.

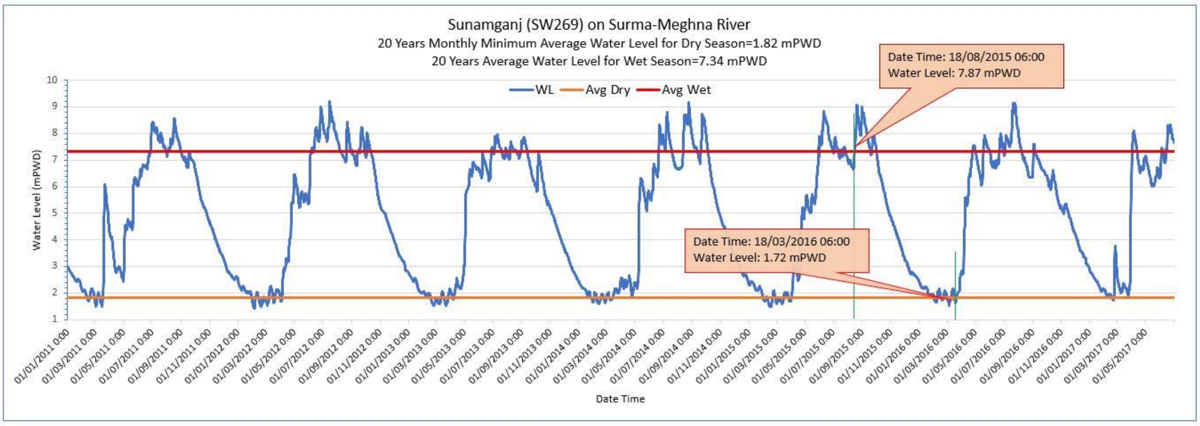


Figure 7-14: Sample Hydrograph of River Gauge Station at Sunamganj on Surma-Meghna River System

For delineation of wetland extent for dry season, the satellite image acquired date has been chosen at the time when 20 years average monthly minimum observed water level found during dry season. Similarly, to delineate the wet land extent for wet season, the satellite image acquired date has been chosen at the time when 20 years average of observed water levels found during wet season. Table 7-5 represents the dry and wet season extents of the rivers and canals in the different hydrological regions.

It is seen from the Table 7-5 that in average year hydrological condition, the NW region loses about 64% area of the rivers and canals in dry season with respect to the wet season water area. In terms of length the reduction of the extent of the rivers and canals in dry season is 46.69% (5,721 km) with respect to the wet season extent. Through these reductions of the dry season extents, the rivers and canals lose their connectivity with the closed water bodies in large scale. In wet season the rivers and canals are connected to the closed water bodies in 725 locations whereas in dry season the connecting points reduced to 30 locations. A sample map of Wet and dry seasons connecting points of the rivers with the water bodies is shown in Figure 7-15 whereas the details are given in Volume-II: Appendix-D.

Table 7-5 also shows that the NC region loses about 65% area of the rivers and canals in dry season with respect to the wet season water area for average year hydrological condition. In terms of length, the reduction of the extent of the rivers and canals in dry season is 49.5 % (3,003 km) with respect to the wet season extent. In wet season the rivers and canals are connected to the closed water bodies in 485 locations whereas in dry season the connecting points reduced to 47 locations.

The statistic on dry and wet season extents of the rivers and canals as shown in Table 7-5 reveals that the NE region loses about 47% area of the rivers and canals in dry season with respect to the wet season water area and in terms of length the reduction of the extent of the rivers and canals in dry season is 55% (5,916 km) with respect to the wet season extent. The rivers and canals are connected to the closed water bodies in 1315 and 56 points in wet and dry season respectively

The SE, SC and SW regions loses about 52.71%, 11.36% and 7.44% area of the rivers and canals in dry season with respect to the wet season water area respectively. In terms of length, the reduction of the extent of the rivers and canals in dry season is 62% (2,880 km), 18.47% (1,356 km) and 20.65% (3,720 km) with respect to the wet season extent for SE, SC and SW region respectively.

As illustrated in Table 7-5, the EH region loses about 17.33% area of the rivers and canals in dry season with respect to the wet season water area for average year hydrological condition. In terms of length, the reduction of the extent of the rivers and canals in dry season is 36.21% (2,882 km) with respect to the wet season extent. In wet season the rivers and canals are connected to the closed water bodies in 778 locations whereas in dry season the connecting points reduced to 79 locations.

Table 7-5: Statistic on Dry and Wet Season Extents of the Rivers and Canals in the Different Hydrological Region

Hydrological Region	Season	Length, km	Area, hectares	Reduction in Dry Season		Merging with Water Bodies in Wet Season		Connecting Points with Water Bodies
				Length, km (%)	Area, hectares (%)	Length, km (%)	Area, hectares (%)	
NW	Wet	12,254	1,54,542	5,721 (46.69)	98,716 (63.87)	1,127 (9.20)	6,570 (4.25)	725
	Dry	6,533	55,826			-	-	30
NC	Wet	6,068	50,972	3003 (49.5)	33,271 (65)	885 (14)	6,508 (13)	485
	Dry	3,065	17,701			-	-	47
NE	Wet	10,722	75,883	5,916 (55)	35,484 (47)	4,399 (41)	34,085 (45)	1314
	Dry	4,806	40,399			-	-	58
SE	Wet	4,637	65,022	2,880 (62)	34,275 (52.71)	177 (3.81)	1657 (2.55)	490
	Dry	1,757	30,747			-	-	88
EH	Wet	7,794	37,937	2,882 (36.21)	6,574 (17.33)	496 (6.36)	2,060 (5.43)	778
	Dry	4,972	31,363			-	-	79
SC	Wet	7,339	1,82,424	1,356 (18.47)	20,722 (11.36)	83 (1.13)	1,084 (0.59)	206
	Dry	5,983	1,61,702			-	-	23
SW	Wet	18,011	2,65,382	3,720 (20.65)	19,740 (7.44)	1,261 (7)	5,569 (2.01)	1954
	Dry	14,291	2,45,642			-	-	316

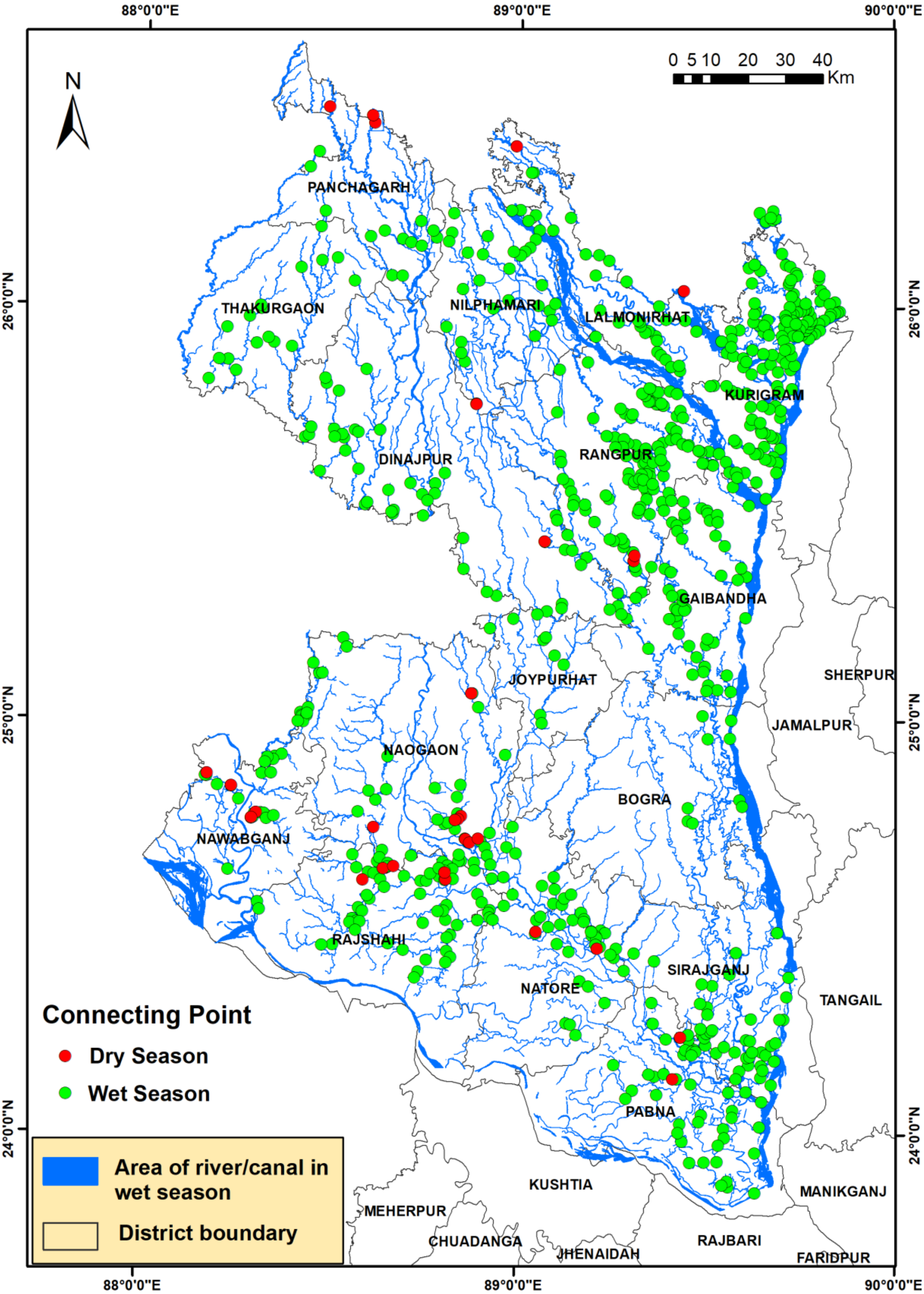


Figure 7-15: Wet and Dry Seasons Connecting Points of the Rivers with the Water Bodies in North West Region

7.6 Interaction Between Haor and River Ecosystem

Bangladesh is the largest delta in the world predominantly comprising large network of rives and wetlands. Wetlands in Bangladesh are represented by inland freshwater, estuarine brackish water and tidal salt-water coastal wetlands. Bangladesh possess enormous area of wetlands including rivers and streams, freshwater lakes and marshes, haors, baors, beels, water storage reservoirs, fish ponds, flooded cultivated fields and estuarine systems with extensive mangrove swamps.

Three major river systems govern in the haor area inside Bangladesh: the Surma-Baulai, the Kalni- Kushiyara and the Kangsa-Dhanu as shown in Figure 7-16. The Surma is the main river of this system which fed by Barak River. The Baulai is another important river of this system which flows entirely within Bangladesh. Major tributaries of Surma-Baulai river system are Sarigowain, Piyan, Dhalagang, Chela, Jalukhali, Jadukata and Someswari rivres. This river system meets the Kalni-Kushiyara system at Bajitpur upazila of Kishoreganj district. The main left tributaries of Kushiyara river are Sonai-Bardal river, Juri river and Manu river. The combined flow of the Dhanu River and Baulai River forms the Ghora-Utra River.

Almost all haor wetlands in the Sylhet basin are traversed by or connected to rivers and thus have a strong interaction with the river system. The hydrology of these haor wetlands depends on seasonal rainfall; in the wet season (April-November) haor wetlands are hydraulically connected with rivers due to the rise of water levels while in the dry season (December-March) they are isolated from the river system as water levels fall through drainage, evaporation, and seepage. Moreover, haor wetlands are a sanctuary of 260 fish species, 259 species of birds, 40 reptiles, 29 mammals and amphibians, and 300 flowering plants (Byomkesh et al., 2009; CEGIS, 2012a). Haor wetlands are the main breeding and feeding habitats for fish species. Haor is a great reservoir of aquatic biological resources and acts as the ecological safety net to the nature as well as to the dwellers of the haor. These resources are grass, reeds, submerged plants, mollusks, fishes, turtles, birds and the swamp forests.

The faunal biodiversity prefers to utilize some components of haor ecosystem, rather than river ecosystem, because resources collection from haor is quite easy, especially in winter season. It has been observed that native faunal species prefer to use the connecting areas of haor and river ecosystem in compare to migratory faunal species; this happened due to tolerance behavior of native fauna on presence of anthropogenic activities.

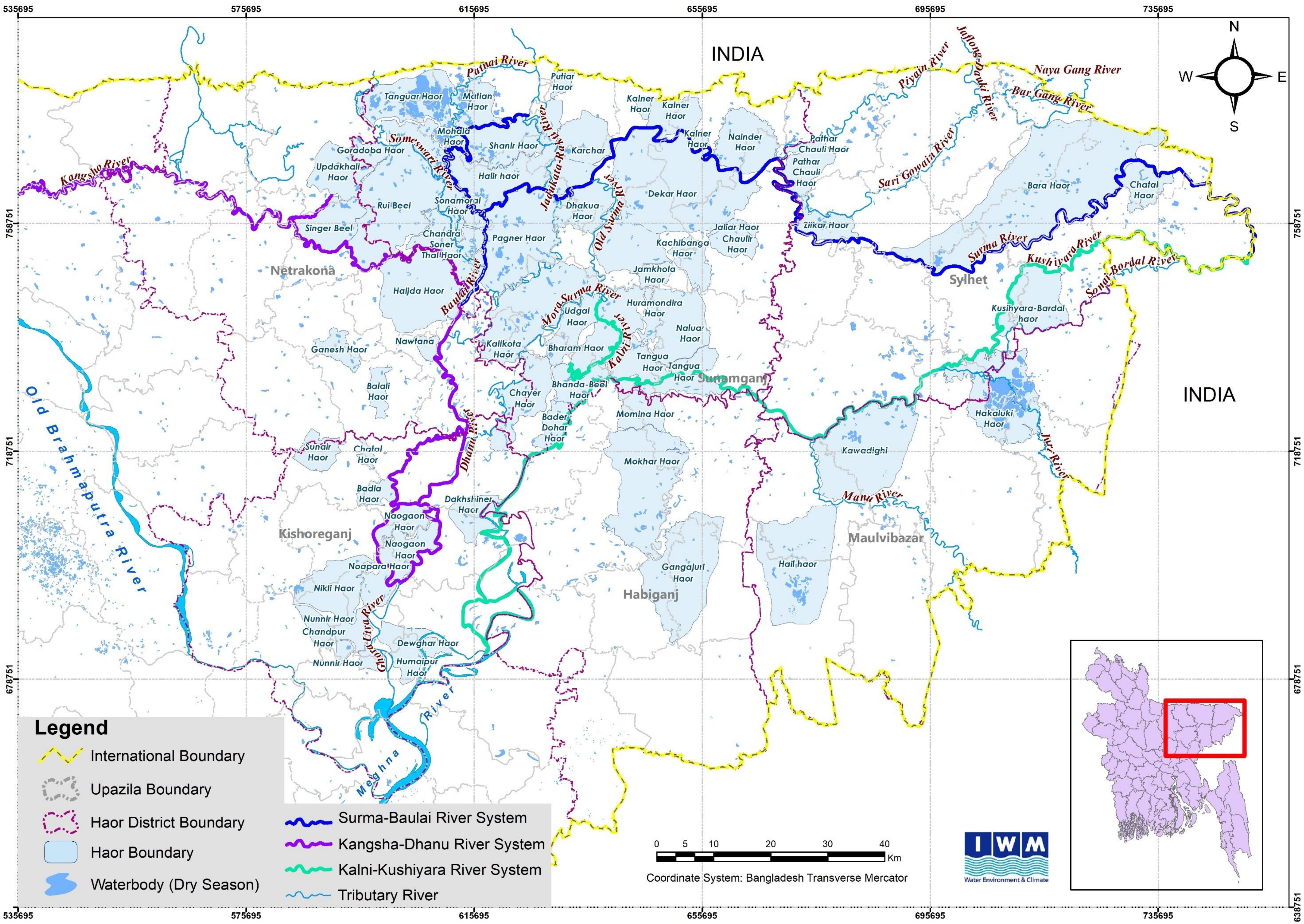


Figure 7-16: Connectivity of Haor and Major Rivers in Haor Area of Bangladesh

Hydrological disturbance shapes spatio-temporal pattern of fish in the haor. Backwater from the Surma- Jadukata-Baulai River system intrudes the haor in pre-monsoon. Simultaneously, rainwater from the Meghalayan hilly areas flows into the haor through a good number of small streams. Its morphological shape, topography, inter-connectivity among the water bodies, shallow and deep levees/ridges, emergent vegetation, reed lands and swamp forest serve as the most prolific ground for breeding, nursing, grazing and sheltering place for fish species. Its low sediment, less turbid and transparent water facilitates photosynthesis process that promotes huge phytoplankton growth. The rich nutrient content with good water quality of this wetland promotes the growth of zooplankton, bentho-zooplankton and periphyton. The reeds, grass, and emergent vegetation, rivers and streams facilitate breeding and hatching process of the fish species.

7.6.1 Tanguar Haor

Tanguar Haor falls under freshwater wetland and have a unique freshwater ecosystem where biotic [living (e.g. flora, fauna. microbes, etc.)] and abiotic [e.g. non-living (physical & chemical components)] community interact with each other at various trophic level as shown in Figure 7-17. The interactions within communities of organisms at population and community level play a key role in determining the stability and resilience of the ecosystem. Communities are structured by multiple biotic processes, and external conditions may strongly influence the outcome.

Tanguar Haor has lentic (still) water and its associated rivers have lotic (flowing) water. Three rivers such as Jadukata River, Boulai River and Patnai River have been identified that have direct connection with Tanguar Haor as shown in Figure 7-17. It has known from stakeholder consultations that upstream water, from more than 30 streams of Meghalaya Hills of India, also enters into the Tanguar Haor in the rainy season and enriches its ecosystem. Ecosystems of associated rivers of Tanguar Haor are influenced by natural processes and anthropogenic impacts at different spatial and temporal scales. Climate change also causes alterations of hydrologic patterns of associated rivers of Tanguar Haor such as seasonal flow and extreme flow.

It has been observed that native faunal species prefer to use the connecting areas of Tanguar haor and river ecosystem in compare to migratory faunal species; this happened due to tolerance behavior of native fauna on presence of anthropogenic activities. However, sedimentation and / or siltation have been observed at some section of associated rivers and Tanguar Haor as given in Figure 7-18 which prevent flowing of water smoothly and thus, degraded both ecosystems, especially the components of faunal biodiversity habitat.

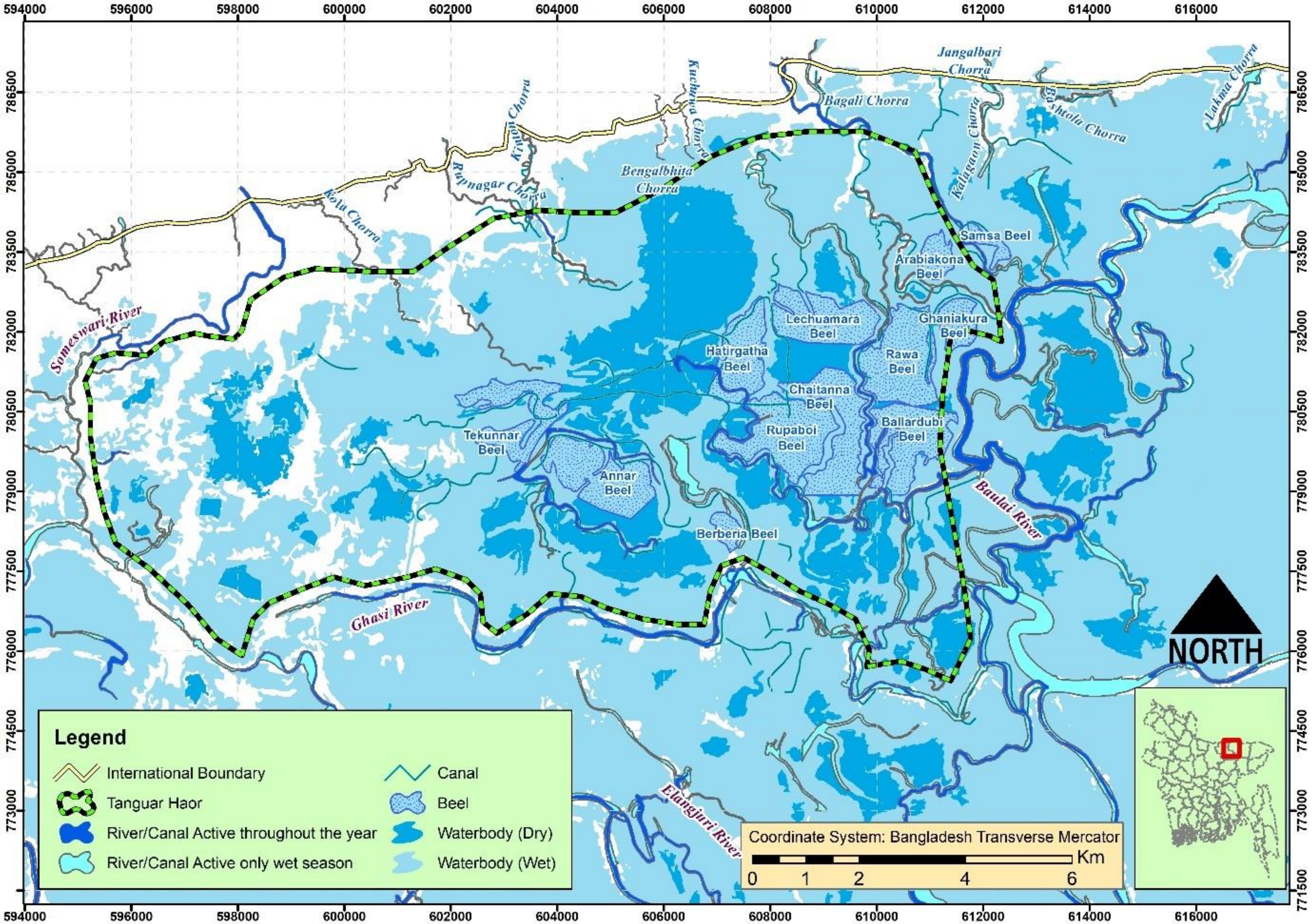
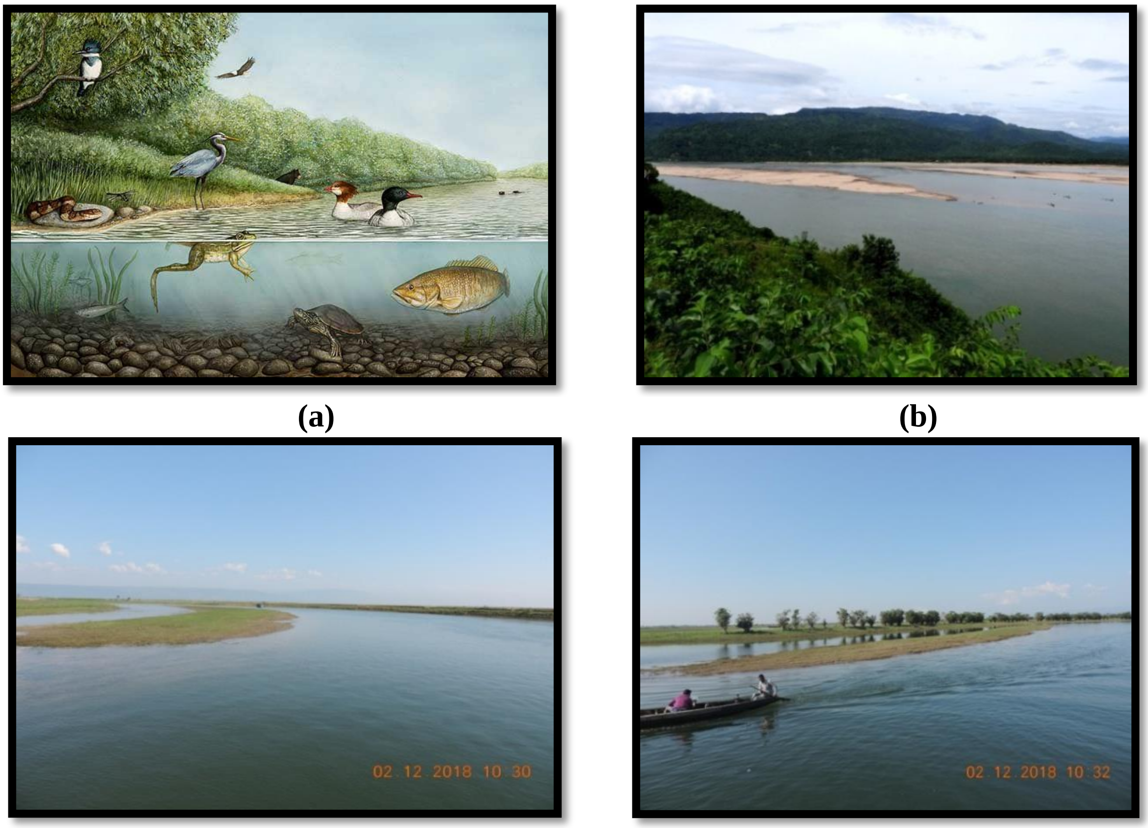


Figure 7-17: Connectivity between Tanguar Haor and Rivers



(a) **(b)**

(c) **(d)**

Figure 7-18: (a) Typical Wetland Ecosystem, have Similarity With Tanguar Haor and its Associated Rivers, Provide Habitat for all Sort of Faunal Biodiversity, and (b) Siltation or Sedimentation at Jadukata River that have Direct Connection With Tanguar Haor, (c) and (d) Siltation with the Haor Rivers.

The fish population dynamics of Tanguar Haor is intensively influenced with the hydrological regime of this wetland. Fish movement from beel to beel also common in the Tanguar Haor. Different types of migration occur, or migratory fishes stay in Tanguar Haor which supports movement and migration of fishes. Movement occurs beel to beel and migration occurs beel to river or vice-versa. In Tanguar Haor, migration takes place beel to beel through a river, Tanguar Haor to the Surma River, Tanguar Haor to the Jadukata River or vice-versa.

In the pre-monsoon, major carps like Rui, Catla and Mrigel go long distances to find suitable place and environment for breeding. The fertilized eggs roll down with river current and within 4 days’ time they enter into the floodplain adjacent to the river (Ahmed, 2015). Minor carps, catfishes and barbed fish species move to the flowing rivers/streams/ canals and breed in the shrubs/grasses of the adjacent levees/ridges in the early monsoon.

7.6.2 Hakaluki Haor

Hakaluki Haor falls under freshwater wetland and have a unique freshwater ecosystem where biotic [living (e.g. flora, fauna. microbes, etc.)] and abiotic [e.g. non-living (physical and chemical components)] community interact with each other at various trophic level as shown in Figure 7-19. The interactions within communities of organisms at population and community level play a key role in determining the stability and resilience of the ecosystem. Communities are structured by multiple biotic processes, and external conditions may strongly influence the outcome.

Like Tanguar Haor, Hakaluki Haor has also lentic (still) water and its associated rivers have lotic (flowing) water. A total of five rivers namely (i) Juri / Kantinala River, (ii) Sonai / Bordol River, (iii) Damai River, (iv) Fanai River and (v) Kuiachara River, have direct connection with the Hakaluki Haor as shown in Figure 7-19. Stakeholder consultation reveals that in the rainy season upstream water also enter into the Hakaluki Haor. All the rivers water and upstream water enrich the haor ecosystem, and later, all rivers and upstream water drain-outs through Kushiara River - a single outlet.

Ecosystems of associated rivers of Hakaluki Haor are influenced by natural processes and anthropogenic impacts at different spatial and temporal scales. Climate change also causes alterations of hydrologic patterns of associated rivers of Hakaluki Haor such as seasonal flow and extreme flow.

It has been observed that native faunal species prefer to use the connecting areas of haor and river ecosystem in compare to migratory faunal species; this happened due to tolerance behavior of native fauna on the presence of anthropogenic activities. However, sedimentation and / or siltation have been observed at some section of associated rivers and Hakaluki Haor as given in Figure 7-20 which prevent flowing of water smoothly and thus, degraded both ecosystems, especially the components of faunal biodiversity habitat.

The haor Hakaluki offers a very different type of ecosystem and haor basin supports a variety of aquatic habitat. It has also an appreciable amalgamation of rare vulnerable endangered of fishes or another animal or plant species. Having a wide variety or peculiarities of its flora and fauna, it performs a special role for maintaining the genetic and ecological diversity.

From the river Kushiyara there are frequent upstream movement of fish towards the beels and tributaries of Hakaluki haor. The beels in Hakaluki haor provide winter shelter for the mother fisheries. In early monsoon these mother fisheries produce millions of fries for the entire downstream fishing communities. Floodplains are also an important source of fisheries resources within the area. However, many of the beels have lost their capacity to provide shelter for mother fisheries because of sand deposits from upstream rivers and canals, use of complete dewatering technique for fishing and lack of aquatic plants to provide feed and shelter for parent fish.

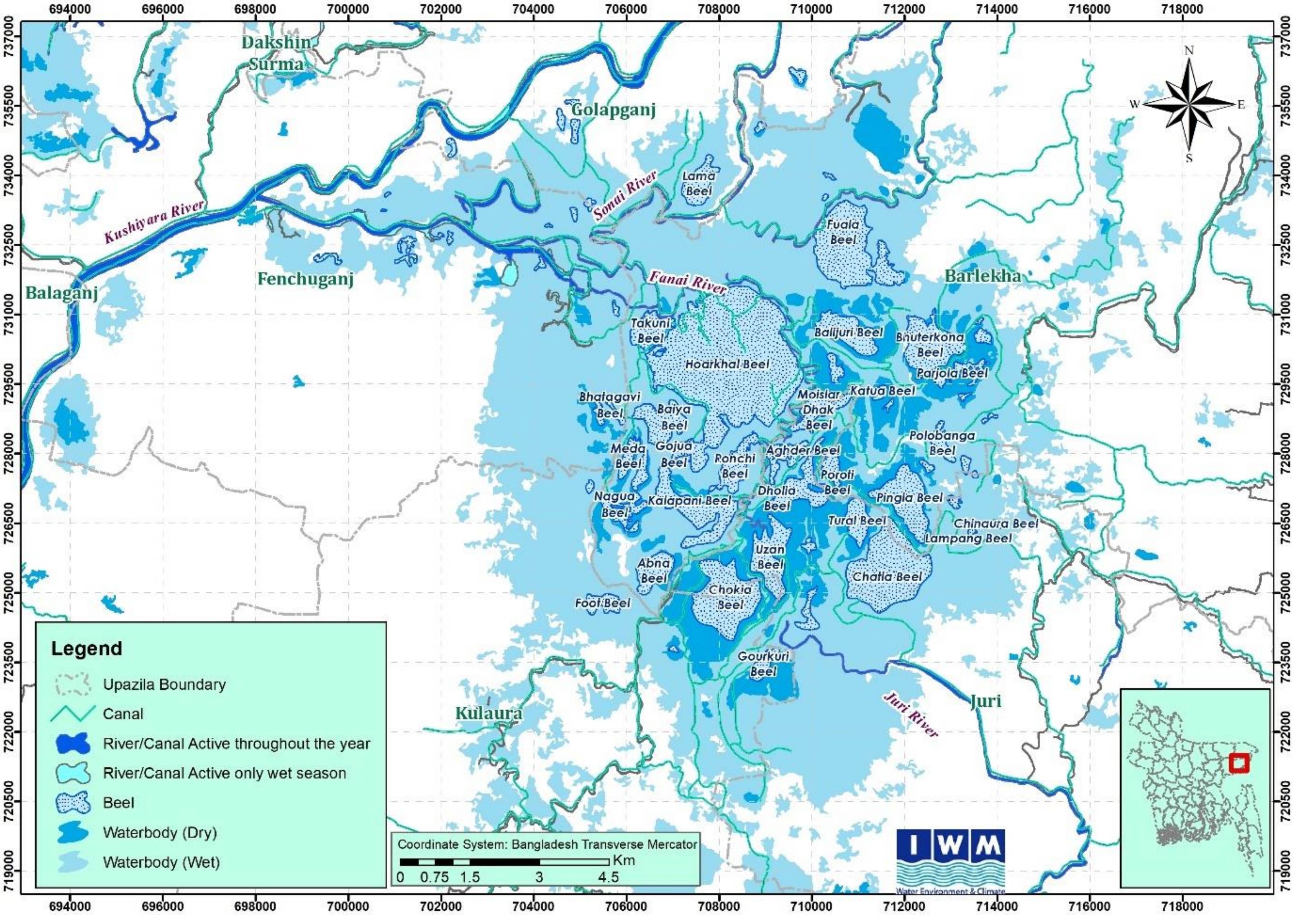


Figure 7-19: Connectivity between Hakaluki Haor and Rivers

(a)

(b)

(c)

(d)

Figure 7-20: (a) & (b) Ecosystem of Hakaluki Haor (Wet Season & Dry Season) and its Associated Five Rivers, Provide Habitat for AllSort of Faunal Biodiversity, and (c) & (d) Water With Silt or Sediment at Sonai River & Juri River that have Direct Connection With Hakaluki Haor

7.7 Causes of Wetland Degradation and Sources of Pollution

Biodiversity of wetland is declining due to multifarious reasons. Prime causes of biodiversity degradation are unawareness and mismanagement of wetland and its natural resources. The following describe the causes of biodiversity degradation of Tanguar haor and Hakaluki haor as well as for clustered wetland. The causes of wetland degradation are mentioned below:

7.7.1 Causes of Wetland Faunal Biodiversity Degradation and Sources of Pollution of Tanguar Haor and Hakaluki Haor

Wetland faunal biodiversity degradation or loss is primarily related with human interactions with natural resources. In early phases of life, humans remained as one component of natural ecosystem but, very recently, humans have become a factor of ecosystem and started reshaping the biodiversity. However, biodiversity of Tanguar haor and Hakaluki haor has been depleting due to the following factors / reasons:

- Habitat loss and fragmentation

- Overexploitation of natural resources
- Hunting and poaching
- Fishing and aquaculture
- Agricultural practice
- Siltation on Haor/River
- Tourism
- Natural calamities and climate change
- Invasive exotic species
- Diseases

Pollution is one type of threat to faunal biodiversity of Tanguar haor and Hakaluki haor, and one of the most difficult problems to overcome. Some sources of pollutions at Tanguar haor and Hakaluki haor have been identified as mentioned below:

- Use of fertilizer and pesticide in agricultural land
- Water with silt
- Decomposed aquatic flora
- Human stools and kitchen wastage
- Boat engine oil and carrying goods
- Non-degradable plastic
- Dead domestic animal

The details cause of wetland faunal biodiversity degradation and sources of pollution of Tanguar haor and Hakaluki haor has been presented in Volume-II: Appendix-E.

7.7.2 Causes of Wetland Faunal Biodiversity Degradation and Sources of Pollution of Clustered Wetlands

One the component of this study is to cluster the identified wetland according to their characteristics and functions. The clustering has been introduced based on hydrological regions. Baikka Beel was selected from North East wetland cluster. Borobila beel was selected from North Central wetland cluster. Beel Halti was selected from North Western wetland cluster. Baluhor Baor and Borni Baor were selected from south western wetland cluster and Kaptai Lake was selected from Eastern hill cluster. The causes that have been identified for wetland degradation and sources of pollution of the clustered wetlands during stakeholder’s consultation has been presented in Table 7-6. The details cause of wetland faunal biodiversity degradation and sources of pollution of clustered wetlands has been presented in Volume-II: Appendix-E.

Table 7-6: Causes of Wetland Faunal Biodiversity Degradation and Sources of Pollution of the Clustered Wetlands

Causes of Wetland Faunal Biodiversity Degradation and Sources of Pollution	Clustered Wetland
Sediment deposition	All
Wildlife killing due to unaware of its contribution to the existing ecosystem	All
Wildlife hunting by poacher at early morning and night	All
Degradation as well as shortage of food and habitat for wild fauna	All
Degradation as well as disturbance of wetland faunal biodiversity and their habitats including breeding places via multi-dimension anthropogenic activities.	All
Degradation due to climate change and flood	All
Reduction of fish & fish diversity due to over harvesting of fish & fish fry.	All
Human pressure over the natural resources.	All
Increase use of agro-fertilizer and agro-chemical in peripheral agricultural land	All
• Massive natural resources collection (e.g. fuel wood, bamboo, etc.) from Kaptai Lake and its associate hills. • Tree cutting and shifting cultivation in the hills and villages, especially the nesting trees. • Week management of Kaptai Lake and associate hill forest by fishery and forest department. • Encroachment of lake associate hill forest lands and conversion of those lands • Fuel-wood supply from the lake associate forests for the brickfields whose numbers are increasing	Kaptai Lake
Tourism activities inside the prime biodiversity habitat area	Kaptai Lake and Beel Halti
Discharge of sewer and other items in the water by villagers and business community people,	Kaptai Lake, Baluhor Baor, Borni Baor, Baikka Beel, Beel Halti
Water pollution through engine boat oil throughout the year	Kaptai Lake, Baluhor Baor, Borni Baor, Beel Halti
Floral destruction especially the nesting trees inside the beel and adjacent areas	Baluhor Baor, Borni Baor, Baikka Beel, Borobila Beel and Beel Halti
• Baikka Beel is weekly managed by the Resource Management Organization (RMO), a local committee, involve through co-management system; the RMO face multi-dimensional problem	Baikka Beel

Causes of Wetland Faunal Biodiversity Degradation and Sources of Pollution	Clustered Wetland
to manage it such as shortage of manpower, fund, boat, equipment, etc. • Conversion of beel land as agricultural land • More water extraction from beel for agricultural practices. • Water comes from tea garden with herbicide that pollutes the water. • Few terrestrial flora including bushes exists inside the Baikka Beel that goes under water in the rainy season, and thus, it degrades the faunal habitat, especially for the land & flora dependent faunas. • Peripheral beel land use as grassing ground for cattle and water is use for duck rearing; probability increase for disease transmission between wild vs domestic animals.	
• Few terrestrial flora including bushes exists inside the Beel Halti that goes under water in the rainy season, and thus, it degrades the faunal habitat, especially for the land & flora dependent faunas. • Frequent use of submersible beel road, causing faunal disturbance	Beel Halti

7.7.3 Potential Causes of Fish Biodiversity and Habitat Degradation of Tanguar Haor and Hakaluki Haor

Some common causes of fish biodiversity and habitat degradation of Tanguar Haor and Hakaluki Haor are as below:

- Overfishing by illegal and lethal gears, which damaged the breeding, feeding and nursery ground of the indigenous fish of the haor ecosystem.
- Indiscriminate catching of fry/fingerlings, juvenile and gravid fish.
- Increasing fisherman and fishing pressure day by day in haor area.
- Fishing by dewatering or complete drying the beel ditches, the most threating factor for fish biodiversity.
- High rate of kata or brush fishing in many areas of haor deleting juvenile gravid fish population.
- Indiscriminate rate of harmful and toxic pesticide uses in agricultural lands that directly effect on nearby beels, canal and haor fish population due to acute toxicity in the water body.
- Unplanned construction of dam, embankment, roads and bridge that separate the shallow water portion from deeper portion of Haor adjacent rivers that blocking the migratory path way of fish and hinder in normal water flow

- Decreasing overall depth of the haor and beels by heavy siltation day by day

Causes of Fish Biodiversity and Habitat Degradation of Tanguar Haor:

- De-weeding and deforestation are practiced for fishing, navigational and fuel collection purposes, which have negative impacts on fish biodiversity
- Fishing by bamboo fencing (bana) or nets with fixed fishing gears across sluice gate, canals, rivers or other water ways become common practice during the post-monsoon season become most threating factor for fish biodiversity
- Rearing of aquatic birds especially ducks is a common business in the haor region which has harmful and detrimental effects on fish biodiversity

Causes of Fish Biodiversity and Habitat Degradation of Hakaluki Haor:

- Catching of birds by using pesticides that can be dangerous in haor biodiversity.
- Weak haor management system
- Effect of global climate Changes
- During navigation oil spillage that may pollutes surface water
- NGO does not work properly in haor management like IUCN, CNRS etc.

The details cause of fish biodiversity and habitat degradation and sources of pollution of Tanguar haor and Hakaluki haor has been presented in Volume-II: Appendix-F.

7.7.4 Potential Causes of Fish Biodiversity and Habitat Degradation of Clustered Wetlands

Causes of Fish Biodiversity and Habitat Degradation of Kaptai Lake:

- Poor enforcement of fishing rules and regulations by the concerned Govt. departments;
- Increased number of fishermen and high fishing pressure over the lake;
- Dramatic increase of clupeid species viz. Keski; Corica soborna and Chapila, Gudusia chapra in the lake;
- Use of illegal and banned fishing nets and gears viz. seine net, fine threaded current net, small meshed keski net, harpoons etc.;
- Banning period time does not follow and not being implemented by the local fisher groups and rather unrestricted catching of gravid fishes, juveniles and fry/fingerlings of major commercial fish species;

- Unregulated human settlement at the banks and inside the lake and dumping of excreta wastes, banned pesticides and other chemicals from joom cultivator in the lake water;
- Increased rate of decreasing water depth due to high rate siltation and sedimentation in the lake;
- Increased rate deforestation enhances the cause of siltation and sedimentation in in the lake;
- Excess water flow of the Kaptai electric dam makes the river turbulence, this condition become unfavorable for fish spawning and breeding habitat at adjacent Karnafuli river channel(s);

Causes of Fish Biodiversity and Habitat Degradation of Baluhor Baor:

- High fishing pressure and overfishing in the baor area.
- Use of illegal fishing gears like current jal, Ber jal etc. by the unauthorized local fishermen.
- Release and culture of carp species within the baor indirectly affect the habitat of SIS species.
- Heavy growth of aquatic weeds like water hyacinth, water lily, lotus etc. in the baor directly detrimental to the existing fish species by causing water quality deterioration.
- Decreasing of water depth, low water velocity, reduction of connection with the river canals and adjacent beels due to heavy siltation and sedimentation.
- Kata fishing also responsible for fish biodiversity declination.
- Poor implementation of Govt. fishing rules and regulations in the baor.
- Use of insecticides and pesticides at the surrounding agricultural crop lands become a source of chemical pollution during rainy season due to surface run off to the baor water body cause a great threat to fish biodiversity.
- Lack of enough fish sanctuaries.
- Fishing by dewatering in the shallow areas of the baor become a cause of SIS habitat destruction.
- Baor area encroached by the local people for agricultural farming that’s why the total area of the baor decreasing day by day.
- Climate changes causes rising temperature, drought, less rainfall etc. which are negatively affect the fish biodiversity of the baor ecosystem.
- Socio-economic conditions of fishermen around the baor are very marginal. Majority of them are landless people and desperately depends on the baor for their livelihood.

Causes of Fish Biodiversity and Habitat Degradation of Borni Baor:

- The Borni Baor has open access to all local people including all fisher groups as declared by the Hon'ble Prime Minister but the present management practices are different.
- In fact, actual fishermen have minimum access in the baor due to control of entire fishing by a group of financially capable and influential people, who have already set up >200 komor or brush shelter fishing at the baor and they fish time to time by hiring their own fisher groups.
- The baor is connected with Madhumati river having minimum tidal flow for maintaining maximum water level hindering natural habitat of SIS and other fish species.
- Other two sites of the baor are nearly dried and decreased water depth due to siltation and sedimentation; as a result, dry peripheral areas are being used as agricultural land, home vegetable gardening and housing etc.
- Higher growth of aquatic vegetation ie. water hyacinth, Eichhornia crassipes, is a common problem in the baor that causes deterioration of water quality due to weed decomposition.
- Fishing by dewatering in the shallow area of the baor is detrimental and harmful for total aquatic habitat.
- Band period time does not follow by the local fishers, this time they used to catch brood fishes, fry and fingerlings indiscriminately.
- Responsible Fisheries Officers have minimum control over the baor management due to influence of local political leaders, baor management system is not properly effective in this baor.
- There is acute lacking Best Management Practices (BMP) over the baor and lacking of implementation of Govt. fishing rules and regulation.

Causes of Fish Biodiversity and Habitat Degradation of Borobila Beel:

- High vegetative growth of various aquatic weeds at beel waters
- Decomposition of all these aquatic weeds and surface runoff of agricultural pesticide and harmful chemicals in to the beel causes high mortalities of fish population.
- Use of illegal fishing gear viz. fine threaded current net, fine meshed seine net, mambo made fishing traps, lift net, line and hook fishing etc.
- Leasing out of beel water body by the local fisher groups with influence of the local leaders from District Commissioner (DC) without involving District Fishery Officer

- High leased out value, which are too much to bear by the local fishermen community, therefore it allows illegal fishermen group to fish in beel waters taking some royalties to recover lease out value.
- Internal problems and conflicts between and among a number fisherman community around the Borobilla beel, which is the main obstacle for proper management of the wetland.
- High reduction in the water depth due to siltation and sedimentation, the main reasons for growing various aquatic weeds.

Causes of Fish Biodiversity and Habitat Degradation of Baikka Beel:

- Baikka Beel is one of the wetlands in Hail Haor areas, where sanctuary has been declared in 2003 and established by USAID funded MACH project being managed by a Beel Management Committee ie. fishermen association, with a minimum endowment funds amounting Tk. 124,00,000 without any other funding supports.
- The funds were given by the MACH project, which is kept in the bank as FDR to get minimum interest. Among that interest 90% remained with capital fund and other 10% interest is being used for beel management including the salary of the security guards, which is not enough as per requirement.
- Although fish catching is strictly prohibited round the year in this water body but often poaching is a problem due to lack of sufficient security guards supported by local fishermen as members of the beel committee.
- Heavy growth of aquatic weeds like water hyacinth, water lily, lotus etc. inside the beel area directly hampering fish species due to water quality deterioration.
- Insufficient number of brush shelter does not meet up fish breeding habitat to recruit enough quantity of SIS and other indigenous species for disbursement to adjacent water bodies of Hail Haor.
- Establishment of >30 fish farms surrounding to Baikka Beel by several groups of politically powerful people obviously hindering the healthy ecosystem of the beel and other adjacent wetlands due to dumping and draining of huge quantity of fertilizers and other harmful chemicals, which are ultimately running to the beel waters.
- Decreasing of water depth, low water velocity, reduction of connection with the river canals and adjacent beels due to heavy siltation and sedimentation.
- Severe lacking of trees within the surrounding banks enhances soil erosion during rainy season, climate change also causes rising temperature, drought, less rainfall etc. which are negatively affect the fish biodiversity of the Baikka beel.

Causes of Fish Biodiversity and Habitat Degradation of Beel Halti:

- Illegal construction of ponds inside the beel by the influential and rich people is a commonly practice and culture of other commercial exotic or farmed species rather than indigenous species, which is undoubtedly detrimental for biodiversity of native species.
- Heavy pressure of tourists during rainy season causes pollution in wetland.
- In the upstream area there is no connection between river and the other beels to allow migration of indigenous fish species.
- Discriminate use of illegal fishing gears like Seine net, Set bag net, Current net etc.
- Dam construction separates the beel area in two parts having only four culverts, these not sufficient for fish pass to the adjacent partitions of the beel.
- High level of brash or katha fishing and ditch fishing practices and harvesting all the fishes during dry season.
- Before 8 years back rapid spreader of EUS diseases and mass mortality occurs
- Fishing by dewatering is a common phenomenon and after fishing use of pesticides and other chemicals to capture all the remaining at deeper area of the ditches.
- Harvesting brood and juvenile’s fishes during banning period.
- Increasing fishing pressure due to increased number of unauthorized fisher groups.
- Lack of enough fish sanctuaries.
- There is acute lacking Best Management Practices (BMP) over the baor and lacking implementation of Govt. fishing rules and regulation.

The details cause of fish biodiversity and habitat degradation and sources of pollution of clustered wetlands has been presented in Volume-II: Appendix-F.

7.8 Valuation and Vulnerability Assessment of Wetlands

The vulnerability assessment on Tanguar haor has been done as per guidelines of Ramsar Convention (1971) & Convention on Biological Diversity (CBD, 2006) as well as Millennium Ecosystem Assessment (MEA, 2005) as discussed in Chapter 5. A total of four major issues have been considered to assess the vulnerability on Tanguar haor and descriptions of those issues are given below:

(A) Values of Tanguar Haor: A total of four types of values have been considered to assess the vulnerability of Tanguar haor; these are (i) Ecological value, (ii) Economical value, (iii) Hydrological value and (iv) Social value. The most significant benefits provided by the Tanguar haor are fishing, agricultural product, medicinal herbs, water for livestock, water for general use, transport and tourism, etc. A survey of stakeholders identified the following as the primary threats to the haor: excessive weed growth, flooding, erosion of top soil and increasing settlement areas. These data were fed into the assessment tool and an assessment table was produced.

Ecological Value: Ecological values include the presence of rare or endangered species or habitat (flora, fauna & fish), and biodiversity of Tanguar haor. For each of these, the value present at Tanguar haor is considered alongside the spatial distribution of the same value in a wider area and these two scores are entered in axes 1 and 2 in the combination matrix. The presence of faunal / floral / fish species or habitat at Tanguar haor is assessed as per IUCN Red List and a corresponding H / M / L score is assigned as presented Table 7-7. The presence of the same value in the surrounding area is assessed at levels corresponding to the field data sheets and an H / M / L score is assigned (Table 7-7). The aim of considering both aspects is to summarize both the importance of the species in its own right and the rarity of the species in the region of Tanguar haor area. The two H / M / L scores are then brought together using the assessment matrix to give a single H / M / L value which is then transferred to the assessment table. The details of ecological value assessment have been presented in Table 7-8.

Table 7-7: Ecological Value

Axis-1		:	**Axis-2**	
Threatened Species / Habitat	**Score**	:	**Present in Region**	**Score**
Critically Endangered / Endangered / Endemic	H	:	Only present within Tanguar haor area	H
Vulnerable	M	:	Present within & periphery of Tanguar haor	M
Near Threatened	L	:	Present within haor & associate rivers.	L

Table 7-8: Assessment of Ecological Value for Tanguar Haor

Ecological Values	**Threatened Species / Habitat**	**Score**	**Presence in Region**	**Score**
Fauna	Habitat of 11 species of amphibian, 27 species of reptilian, 219 species of avian and 19 species of mammalian.	H	Available in this region	H
	Low number of amphibian species / diversity, e.g. Ornate Microhylid - *Microhyla ornate*	M	Available in this region	M
	Low number of reptilian species / diversities, e.g. Spotted Pond Turtle - *Geoclemys hamiltonii*	M	Available in this region	M
	Medium number of avian species / diversity, e.g. Brown Fish Owlet - *Ketupa zeylonensis*.	L	Available in this region	L
	Maximum number of migratory avian species / diversity, e.g. Ferruginous Duck - *Aythya nyroca*.	L	Available in this region	L

Ecological Values	Threatened Species / Habitat	Score	Presence in Region	Score
	Low number of mammalian species / diversity, e.g. Smooth Coated Otter - *Lutrogale perspicillata.*	M	Available in this region	M
	Habitat for 134 native fish species.	H	Available in this region	H
Flora	Habitat for 104 species of aquatic floral species.	H	Available in this region	H
	Few Numbers of religious species exist within & periphery.	M	Available in this region	M
	Few numbers of medicinal species within & periphery.	M	Available in this region	M
	Few wild rice species grows; conserved genetic stock and provide service to people livelihood.	M	Available in this region	M

Economical Value: Economical values of Tanguar haor include tourism, fisheries, agriculture, additional goods & services, and other economic values. Each of these aspects is considered in terms of the proportion of wetland income that the value provides and the percentage of the adult community that are involved in the value as presented Table 7-9. By considering both aspects, the monetary and community importance of the value are represented and the dependency of the community on a wetland value is reflected. The two H / M / L scores are then brought together using the assessment matrix to give a single H / M / L value which is then transferred to the assessment table. The details of economic value assessment have been presented in Table 7-10.

Table 7-9: Economical Value

Axis-1		:	Axis-2	
Percentage of Wetland Derived Income Provided by Value	**Score**	:	**Percentage of Adult Community Involved in Value**	**Score**
> 40%	H	:	> 40%	H
10 – 40%	M	:	10 – 40%	M
<10%	L	:	<10%	L

Table 7-10: Assessment of Economical Value for Tanguar Haor

Economic Values	Economic Value	Score	Community Value	Score
Agriculture	• Each year ±1000 ton agricultural products collection occurred, and taken to the markets. • Agricultural Activities on the haor land serves **±1000** Households.	H	• Paddy, corps and vegetables are the major source of food for the area and provide the first greatest income after fishing.	H

	• Short rotation paddy variety introduced for more production.			
Fishery	• Each day ±1000 kg fish collection occurred and taken to the markets. • Fishing on the haor serves ±1000 households. • Various large carp fish species introduced and bred in the beels for more production.	H	• Fish are a major source of food for the area and provide the second greatest income after arable farming.	H
Tourism	• Each year ±10000 local tourists visit the Tanguar haor, along with ±500 foreigners and thus, contributes to the local economy.	M	• Tourism is not responsible for a great deal of income in the region	L
Additional goods & services	• Various types of fuel wood, fodder collection for domestic uses. • Engine boat rent to the local community people, businessmen and outsider people.	M	• Collection of fuel wood, fodder etc are not responsible for a great deal of income in the region • Boat renting for various purposes is responsible for a moderate deal of income in the region	M
Other economic values	• Domestic duck, cattle & goat rearing.	M	• Rearing of duck, cattle, etc is responsible for a moderate deal of income in the region	M

Hydrological Value: Hydrological values include provision of water for irrigation scheme, flood storage, future Hydro Electric Power (HEP) scheme**,** maintenance of flows during droughts and provision of drinking water. Each value is considered in terms of the size of the population that benefit from the value, and the feasibility of providing the value through another means. As the hydrological value can affect a large area downstream of Tanguar haor, the population affected by the value could be much larger than the community living directly around the Tanguar haor. The number of people that benefit from a hydrological value may vary greatly. For example, the provision of water for flood storage may affect millions of people, whereas the provision of a potable water supply may only affect several hundred people. However, both are of great importance to the communities that benefit. For this reason, very broad population size divisions are used in order to establish the H / M / L score as shown in Table 7-11. The feasibility of alternative provision should consider both practical and financial aspects and it is likely that different communities will have differing abilities to provide alternatives. The two H / M / L scores are then brought together using the assessment matrix to give a single H / M / L value which is then transferred to the assessment table. The details of hydrological value assessment have been presented in Table 7-12.

Table 7-11: Hydrological Value

Axis-1		:	**Axis-2**	
Size of population benefitting from value	**Score**	:	**Feasibility of alternative provision of value**	**Score**
Large	H	:	Difficult	H
Medium	M	:	Medium	M
Small	L	:	Easy	L

Table 7-12: Assessment of Hydrological Value for Tanguar Haor

Hydrological Values	**Size of Population Affected**	**Score**	**Feasibility of Alternative Provision**	**Score**
Provision of water for Irrigation	• Most farmers have some form of irrigation. • Most agro-lands of the villages & haors are irrigated by the haor water.	H	**±95%** of local population involved in farming	M
Provision of drinking water	• Peripheral villagers, who have not access on nearby tube-well, uses haor water for drinking purposes.	M	**±50%** of local population use existing tube-wells	M
Flood Storage	• During flood, haor act as storage unit and thus, save the peripheral villagers with their properties.	H	Most villagers get benefit for this natural event.	H
Maintenance of flows during droughts	• During droughts, the haor maintain the flows which helps the local communities.	H	Some peripheral villagers get advantages for this natural event.	M
Provision of water for future HEP	Not known	U	Not known	U

Social Value**:** The social values include the religious importance and cultural importance. By their nature, the assessments are likely to be prone to the greatest subjectivity. Each value is considered in terms of the importance of the site and the uniqueness of the site for the value as presented in Table 7-13 . The two H / M / L scores are then brought together using the assessment matrix to give a single H / M / L value which is then transferred to the assessment table. The details of social value assessment have been presented in Table 7-14.

Table 7-13: Social Value

Axis-1		:	Axis-2	
The importance of the value	**Score**	:	**Uniqueness of site for value**	**Score**
Global	H	:	Unique	H
Regional	M	:	Rare	M
Local	L	:	Widespread	L

Table 7-14: Assessment of Social Value for Tanguar Haor

Social Values	Importance of Site	Score	Alternative Provision of Value	Score
Religious Importance	• Every year, few numbers of Hindu religious events occur in the north-eastern part of haor, and bring people from local and abroad. • Several species of trees are said to be of religious importance in the area.	M	• There are other religious sites within the periphery of Haor.	M
Cultural Importance	• Few number of cultural activities / events occur within and peripheral side of haor.	M	• Haor is culturally important to the local community which may not extend outside of the immediate catchment.	L

(B) Threats to Tanguar Haor: All threats are considered using a simple method based on a severity and likelihood of occurrence analysis. Severity gives an indication of the magnitude of the impact of the threat if it occurred and likelihood gives an indication of how likely the threat is to occur. This approach is similar to that taken for risk assessment. As with the wetland values, the assessment starts with a standard list of potential threats. For each threat a brief description of the nature and cause has been given and H / M / L score for the likelihood of occurrence and severity has been assigned. The two H / M / L scores are then brought together in the same combination matrix where severity of threat is Axis 1 and likelihood of threat is Axis 2 as shown in Table 7-15.

Table 7-15: Assessment of Threats for Tanguar Haor

Threats		Drivers / Explanation	Severity Score	Likelihood Score
Pollution	Fertilizers & Pesticides	Most farmers use various types of chemical fertilizers and pesticides to grow more paddy and crops, and the uses of these chemical fertilizers and pesticides are increasing day by day. Much of these fertilizers are mixed up with water and contribute to eutrophication. Some farmers also use manure as fertilizer. Populations of large fish, both native and introduced contribute to nutrient loading.	M	M

Threats		Drivers / Explanation	Severity Score	Likelihood Score
	Industrial	No major industry in the area.	N	N
	Domestic	Most houses in the area have not been fitted with their own sewage treatment facility; hence domestic pollution is remarkable.	M	M
	Organic Waste	Unusually high plant growth and a major population of large fish (some introduced) contribute to a greater biological load. The breakdown of this organic waste increases the biological oxygen demand.	M	M
Encroachment	Housing	Encroachment of peripheral haor land is a common phenomenon and some lands are being use for house construction	M	M
	Agricultural	Encroachment of peripheral & central haor land is a common phenomenon and most lands are being use for agricultural purposes	M	M
Siltation / Sedimentation		Every year siltation occurs in the haor and contributes to change the deeper area of haor. The rivers that are connected with the haor bring the sediment, and some of those are deposited inside the haor. In the rainy season, land erosion / mudflows also contribute for siltation. Intensive cultivation practices on the upstream haor land have cause siltation which contributes an overall reduction in surface area and volume of water. Many flora and fauna have been adversely affected.	H	M
Flow Regime Change	Reduced Flows	Inside the haor, embankment and siltation have a great contribution to reduce the flows.	H	M
	Increased Flooding	Existing embankment and siltation inside the haor have a great contribution to increase the flooding events, especially in the rainy season.	H	M
Invasive Species	Aquatic	Inside the haor, some aquatic flora invasive species are grown in plenty which ultimately reduce the native aquatic floral species habitat.	H	M
	Terrestrial	Inside the haor, some terrestrial flora invasive species are planted in the specific locations that also help to reduce the native terrestrial floral species habitat.	M	M

(C) Links between Threats and Values: The next stage of the assessment process was to establish how the threats will impact on the values. An H / M / L score is given to each interaction. If no interaction occurs, then N is entered into the matrix.

(D) The Finished Assessment: All the values have been entered into the worksheet and thus, the finished assessment has been produced as shown in Table 7-16. In the finished assessment, the wetland values are listed in rows down the left-hand side of the spreadsheet and the threats are shown in columns across the top. The assessment aims to summarize a large amount of information and may, therefore, appear complicated; however, the following simple color codes and symbols are used.

Table 7-16: Vulnerability Assessment for Tanguar Haor

Threat on Impact														
Values	**Threats**	**Aspects**												
		Pollution				**Encroachment**		**Siltation / Sedimentation**	**Flow Regime Change**		**Invasive Species**			
											Aquatic		**Terrestrial**	
		Pesticides	**Industrial**	**Domestic**	**Organic Waste**	**Housing**	**Agricultural**		**Reduced Flows**	**Increased Flooding**	**Floral**	**Faunal**	**Floral**	**Faunal**
Ecological	Loss of rare fauna (aquatic)	H	L	L	M	L	M	M	L	L	L	H	N	N
	Loss of rare flora (aquatic)	H	L	L	M	L	L	M	M	M	H	M	N	N
	Loss of rare fauna (terrestrial)	M	L	M	M	L	L	L	L	L	N	N	L	H
	Loss of rare flora (terrestrial)	M	L	M	M	L	L	L	L	L	N	N	H	M
	Loss of important habitat	M	L	M	M	M	M	M	M	M	M	M	M	M
	Loss of biodiversity	M	L	M	M	M	M	M	M	M	M	M	M	M
Economical	Loss of Tourism	M	L	L	L	L	L	M	L	L	L	L	L	L
	Loss of Fisheries	H	L	M	H	L	L	M	M	L	L	M	N	N
	Loss of Agriculture	H	L	M	M	M	N	M	M	M	N	N	M	M
	Loss of Additional Goods & Services	M	L	M	M	M	M	M	M	M	M	M	M	M
Hydrological	Loss of Irrigation	M	L	M	M	L	L	L	H	N	L	N	N	N
	Increase in downstream flooding	N	N	N	N	M	M	M	N	H	N	N	N	N
	Reduce flows in lean period	N	N	N	N	M	M	M	H	N	N	N	N	N
	Loss of portable water supply	H	N	H	M	L	L	M	M	N	N	N	N	N
	Loss of provision of hydro-electric power	N	N	N	N	L	L	M	H	H	N	N	N	N
Social	Degradation of religious site	L	L	M	L	L	L	M	L	L	L	L	L	L
	Loss of cultural heritage	L	L	L	L	L	L	M	L	L	L	L	L	L

7.9 Delineation of Ecosystem Boundary

An ecosystem could simply be defined as a collection of communities of organisms (biotic) and the environment (abiotic) in which they live and interact with each other. It is normally an open system with a continuous but variable influx and loss of material and energy. It is a basic, functional unit with no limits of boundaries. It represents the highest level of ecological integration, which is energy based, and this functional unit is capable of energy transformation, accumulation and circulation. In ecological sense, its main function is to emphasize obligatory relationships, inter-dependence & casual relations. On the other hand, ecosystem boundaries are the locations exhibiting gradients of change in environmental conditions and a related shift in the composition of plant and/or animal communities.

In the context of Bangladesh, Tanguar haor could be place under large & unique freshwater ecosystem. Major eco-components are algae, plankton, flora, fauna, fish, mollusk, invertebrates, etc. Both Inter- and intra-relationship exist among these eco-components via their ecological niches.

Radio-telemetry technique is a common method which frequently is used to delineate the faunal biodiversity home range / ecosystem boundary. However, the probable faunal ecosystem boundary at Tanguar haor has been delineated in general-way, based on macro-scale assessment via field observation and literature review.

The major eco-components of faunal biodiversity are (i) Amphibia, (ii) Reptile, (iii) Aves and (iv) Mammal. Ecosystem boundary of these faunal biodiversity at Tanguar haor has been described below in brief:

Amphibia: The amphibian species require both water and land for their survival. Several amphibian species have been recorded within and peripheral side of Tanguar haor, Hakaluki haor and different clustered wetlands. The travel distance varies among the amphibian species, and in general, maximum travel distances of amphibian species (terrestrial & aquatic) is in between 300 to 500 meter from the wetlands. So, this range could be the probable home range / ecosystem boundary for the amphibian species.

Reptile: Reptilian species vary among themselves, and most species require both water and land for their survival. Some reptilian species has been recorded within and peripheral side of Tanguar haor, Hakaluki haor and different clustered wetlands. The travel distance varies among the reptilian species, and in general, maximum travel distance of reptilian species is in between 0.5 to 1.0 km from the wetlands. So, this range could be the probable range/ecosystem boundary for the reptilian species.

Aves: Avian species are diversified, and some species require both water and land for their survival. A remarkable number of avian species has been recorded within and peripheral side of Tanguar haor, Hakaluki haor and different clustered wetlands. The travel distance varies among the avian species, and in general, maximum travel distance of avian species is in between 2.0 to 4.0 km from the wetland. So, this range could be the probable home range / ecosystem boundary for the avian species.

Mammal: Mammalian species vary among themselves, and few species require both water and land for their survival. Some mammalian species has been recorded within and peripheral side of Tanguar haor, Hakaluki haor and different clustered wetlands. The travel distance varies among the mammalian species, and in general, maximum travel distance of mammalian species is in between 2.0 to 5.0 km from the haor. So, this range could be the probable home range / ecosystem boundary for the mammalian species.

The delineate ecosystem boundary for Hakaluki haor have been presented in Figure 7-21 whereas the ecosystem boundary for Tanguar haor and clustered wetlands have been shown in Volume-II: Appendix-E.

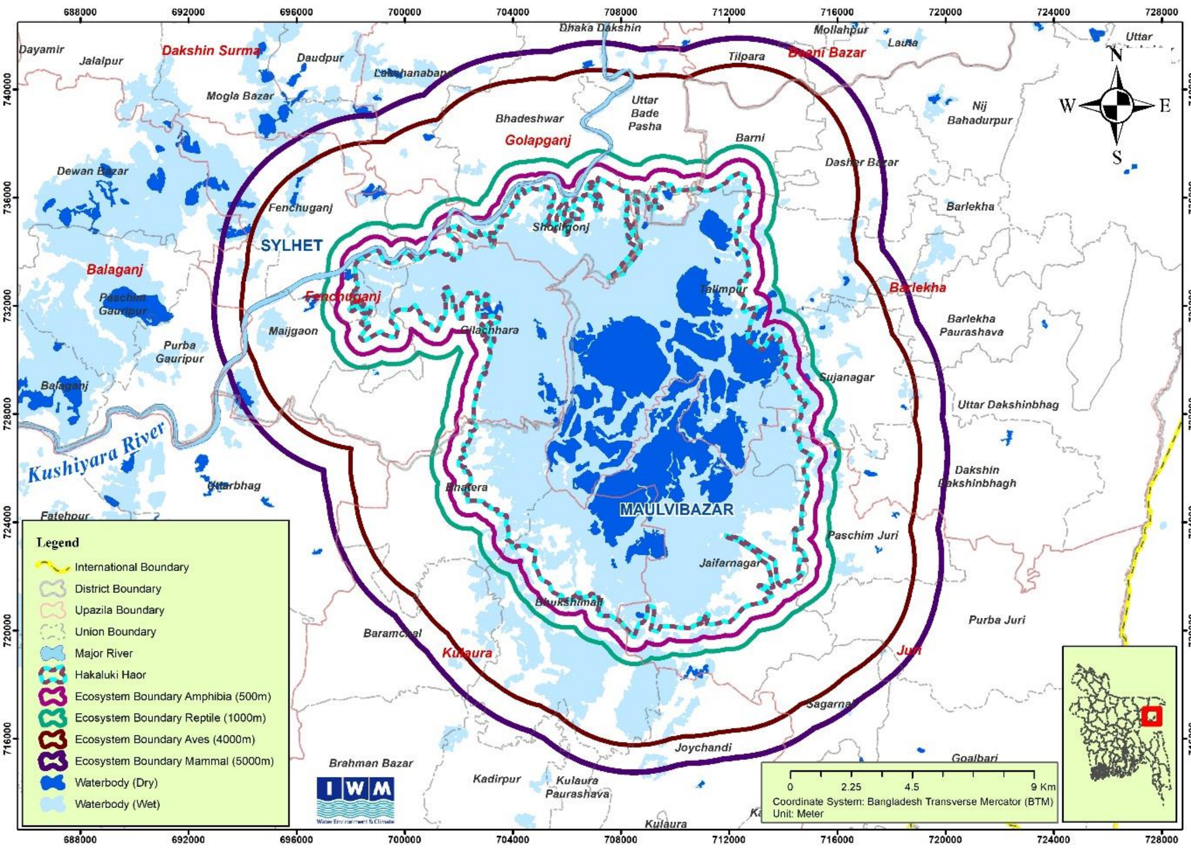


Figure 7-21: Ecosystem Boundary for Hakaluki Haor

7.10 Consultation

Stakeholder consultation has been conducted at different stages of the study with different users of wetland for gathering qualitative information to develop the Cluster-wise management framework. Stakeholder analysis has been carried out to address pertinent study objectives and to capture the diverse interests of different groups that are involved in these respective wetland management systems. Stakeholder selection criteria included: 1) dependency on wetland and floodplain resources, 2) diversity of the resource users, i.e. fishermen, farmers, small traders, women 3) resource users practicing traditional management approaches, 4) resource users involved in associations and networks, 5) most impacted resource users, 6) policy makers 7) local elites, NGOs and civil society. The study was conducted through applying participatory research methods, specifically Participatory Rural Appraisal (PRA) and also involved Key Informant Interviews (KII), semi structured interviews, Focus Group Discussions (FGD). Key Informant Interview, semi –structure interview, Focus Group Discussion were the chosen methods for stakeholder analysis. Previously mentioned stakeholders from different locations of Hakaluki haor, Tanguar haor, Ratargul Swamp Forest, Baikka beel, Kaptai Lake, Baluhor baor, Borni baor, Borobila beel & Beel Halti has been taken into consideration for stakeholder consultation.

The brief output of qualitative survey and findings for different sectors is given below whereas the details are provided in the Volume-II.

7.10.1 Inventory of Biodiversity

The identified faunal species at different wetland have been divided into four biological classes namely amphibia, reptilia, aves and mammalia. All identified faunal species play a vital role for balancing the existing ecosystem via intra-ecological and inter-ecological niches. Some species use the areas as their permanent habitat, while others use as temporary habitat. However, finding of inventory on faunal biodiversity of have been presented in Table 7-17. The details of the inventory have been presented in Volume-II, Appendix-E.

Table 7-17: Inventory of Biodiversity at Different Wetland

Wetland	Species Present Study				Species Present IUCN Study			
	Amphibia	Reptilia	Aves	Mammalia	Amphibia	Reptilia	Aves	Mammalia
Tanguar Haor	8	16	76	12	11	27	219	19
Hakaluki Haor	8	23	131	16				
Kaptai Lake	12	32	104	39				
Baluhor Baor	7	12	59	12				
Borni Baor	7	18	65	11				
Borobila Beel	9	15	52	12				
Baikka Beel	6	11	69	9				
Beel Halti	5	12	54	9				

7.10.2 Fish Sanctuary and Breeding Zone

Tanguar Haor: Small fishes of Tanguar Haor breed early (March-April). The nature of breeding is to use khals, connecting channels, hill streams and inlet channels. Big and medium-sized fishes also breed in the haor naturally. Medium-sized fishes breed in the connecting channel or near to that in Tanguar Haor. Carps and big fishes breed in late May to early June though carp breeds outside Tanguar Haor. Mrigel in May whereas Kalibaush, Boal, Ghonia breed in April to May. Carnivorous fishes carry out their breeding in May to June for the abundance of huge food in beel fisheries. Chital breeds in early April to early May but Shol and Gazar breed in June.

Field observation shows that the Jadukata River is a special breeding ground for many fishes of Tanguar Haor. Big fishes use the Jadukata River for breeding, and Rui and Catla go long distances for breeding. It is believed that Alamer Duar at Patlai River is an important breeding ground for Chital (*Humped featherback*). As per sayings of the fishermen in Tanguar Haor, Chital is also found in Tekunna, Kulma and Annya Paglakona beels. However, other fishes that breed in the Patlai River are Baila (*Bar-eyed goby*), Baghaayre (*Gangetic goonch*), Ayre (*Long-whiskered catfish*), Bacha (*River Catfish*), Pabda (*Pabo catfish*), Kajuli (*Jamuna ailia*), Baim (Onestriped Spiny Eel, Barred Spiny Eel, Zig-zag Eel), and Rani (*Bengal loach*). Some fish species such as Gonia (*Kuria labeo*), Lasso (*Reba carp*), and Baim breed in the beel, floodplain and canal of the haor. It reveals that Kalibaush (*Orangefin labeo*), Boal (*River shark*) and Shal Baim (*Zig-zag eel*) fish spawn in the flowing major hill streams (Rupnagar Chara, Koraibari Chara, and Bagli Chara) fall into Tanguar Haor. Some minor carps breed in the rivers/streams/canals/immersed levees of this wetland. Some carnivorous fish [e.g. Boal (*Helicopter catfish*), Chital (*Humped featherback*), Gazar (*Giant snakehead*), and Shol (*Striped snakehead*)] lay eggs in the suitable ground of the haor linked to the flowing canal/hill stream/river from April to June. Gonadal development of minor catfish occurs in the pre-monsoon, and they [e.g. Kajoli (*Jamuna ailia*), Batashi (*Indian potasi*), and Bacha (*River catfish*)] are said to breed in the Patlai River when backflow comes into Tanguar Haor. The list of the breeding zone of Tanguar Haor is given in Table 7-18.

Table 7-18: Preliminarily Identified few Spawning Grounds in Tanguar Haor

Sl. No.	Possible Breeding Spot	Location of the Spot in Relation to nearby Kanda/ Village/ Beel/ River name	Reported Fishes that may perform breeding	Possible Breeding Period	Condition of Breeding
1	Nazarkhali Khalerbak/ Bhanga	Nazarkhali *Kanda*, Rowa beel, Patlai River, near Golabari village	Ghonia, Boal, Ayre	May-June	River flow is high and grasses are more in the adjoining *kanda* on which gets higher velocity when inundated and Ghonia may breed on that and on that condition
2	Bagmara *Kanda*	*Kanda* of Rupaboi beel, near Lamargaon village	Gonia, Boal, Gazar, Shol, Puti	May-June for Gazar and Shol	High velocity on grassy kanda when inundated during flash flood
3	Near the right bank where bend and deeper part is there- Alamer Duar	Alamer Duar, Patlai River near Joypur-Golabari	Kalibaush		During high velocity and inundation
4	Shoshan *Kanda*, Chhara beel-Koraibari stream	Near Tekunna beel, Chhara beel, Ronchi	Ghonia, Boal, Kalibaush, Baim and many other small-medium sized fishes	May-June	During high velocity flowing over the *kanda*

A total of five fish sanctuaries were established in Tanguar Haor as shown in Table 7-19 and Figure 7-22. Out of these, four sanctuaries were in four beels and another one at Alamer Duar of the Patlai River. These fish sanctuaries play an important role for maintaining the fish stock and fish diversity in this wetland. For increasing the stock size, an advanced fish sanctuary (address the different needs and requirements of various fishes, non-fish organisms, aquatic vegetation and their different life stages) has been proposed for some of the beels in Tanguar Haor. If implemented successfully, it is believed that the fish sanctuaries of Tanguar Haor can contribute to increase the stock size and fish diversity in Tanguar Haor.

Table 7-19: Fish Sanctuaries in Tanguar Haor

Rank	Name of the Fish Sanctuary	Name of the Katha Materials
1	Rupaboi beel Fish Sanctuary	Hijol, bamboo, other tree branches
2	Rowa beel Fish Sanctuary	Hijol, bamboo, bamboo roots
3	Tekunna beel Fish Sanctuary	Hijol, bamboo, bamboo branches
4	Ballardubi beel Fish Sanctuary	Hijol and Bamboo
5	Alamer Duar River Fish Sanctuary	Hijol and Bamboo

Hakaluki Haor: Hakaluki haor is very famous for its production. At present the following areas of Hakaluki haor are identified as important for fish sanctuaries such as Takuni beel, Moishar Dhak beel, Ronchi beel, Bhuterkona beel, Lampang beel and the confluence of Juri River as shown in Figure 7-23. The environmental conditions in and around the Hakaluki haor are favorable for carp spawning. There is continuous flow from the inflowing rivers and occasionally there is some backflows of water from the Kushiyara river. As per the opinion of local fishermen, the carp breeding ground might exist near Islampur village where the Juri river join the Kushiyara river. The fishermen also reported that the zigzag movement and jumping behavior of carp of broodstock during the new full moon time in April/May when new flood water entered into the haor.

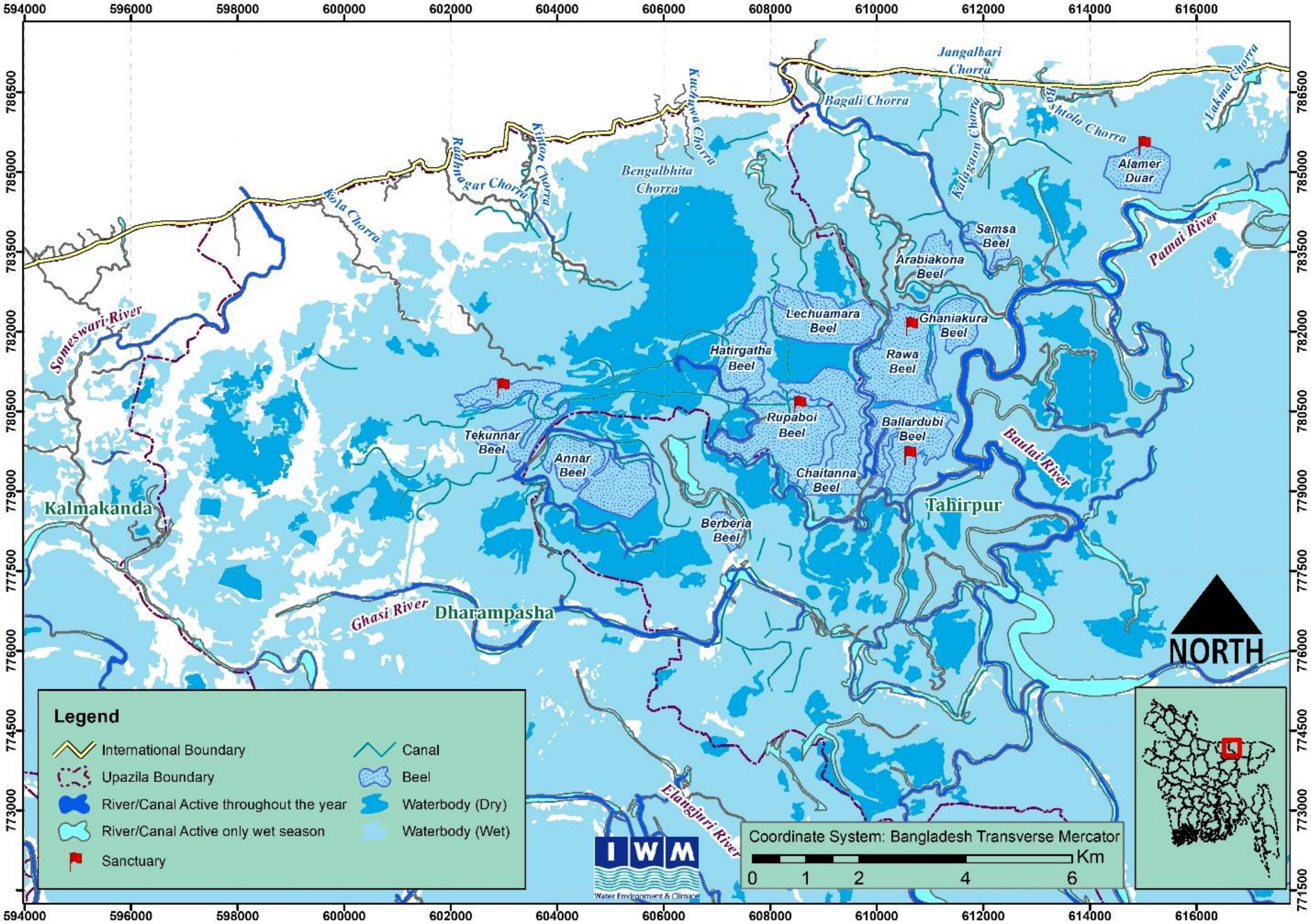


Figure 7-22: Map Showing the Fish Sanctuary at Tanguar Haor

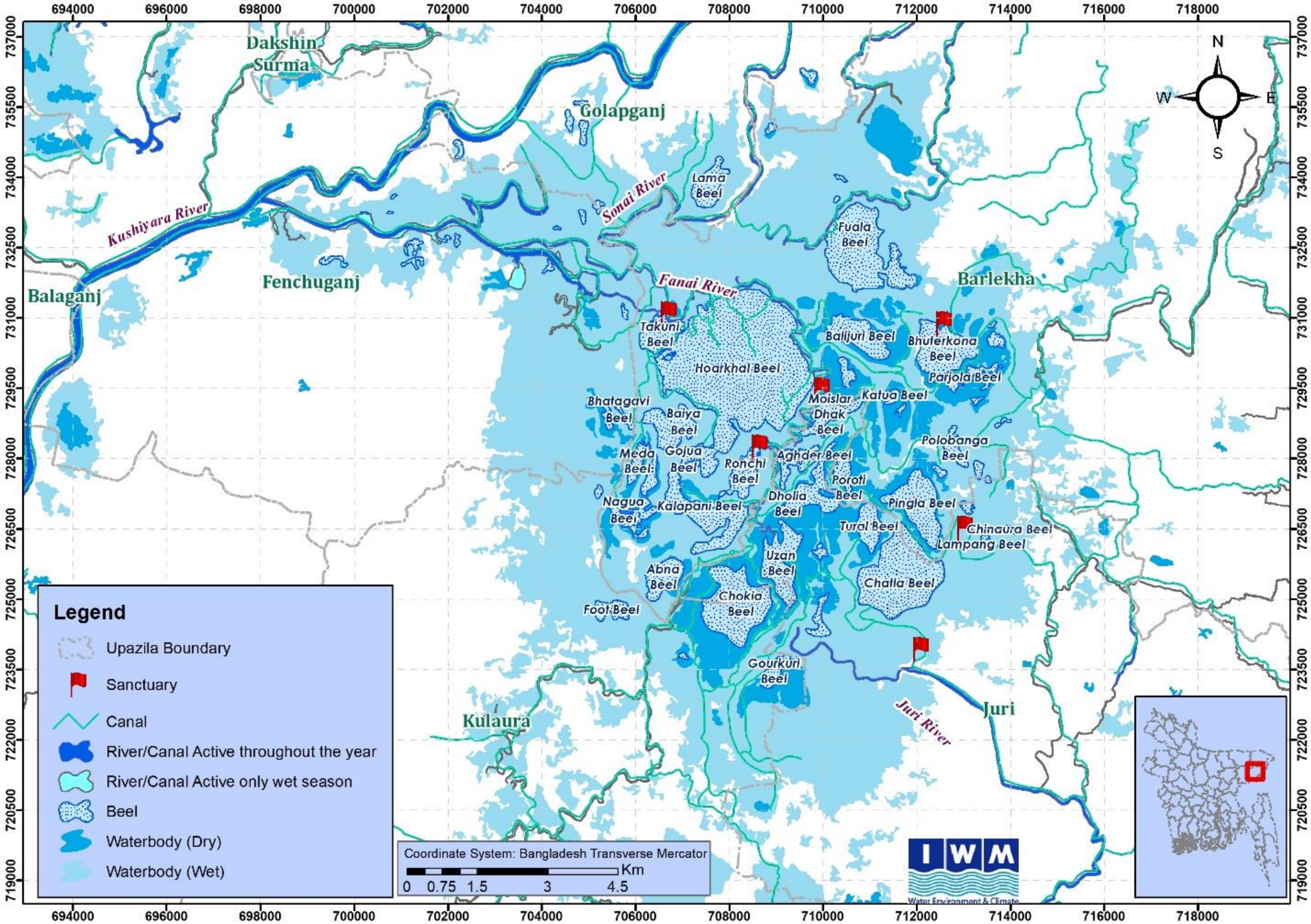


Figure 7-23: Map Showing the Fish Sanctuary at Hakaluki Haor

7.10.3 Comparative Scenarios and Analysis of Fisheries Resources

The comparative scenarios and analysis of fisheries resources has been conducted based on the stakeholder's consultations in the form of FGD, KII and PI which is presented in Figure 7-24.

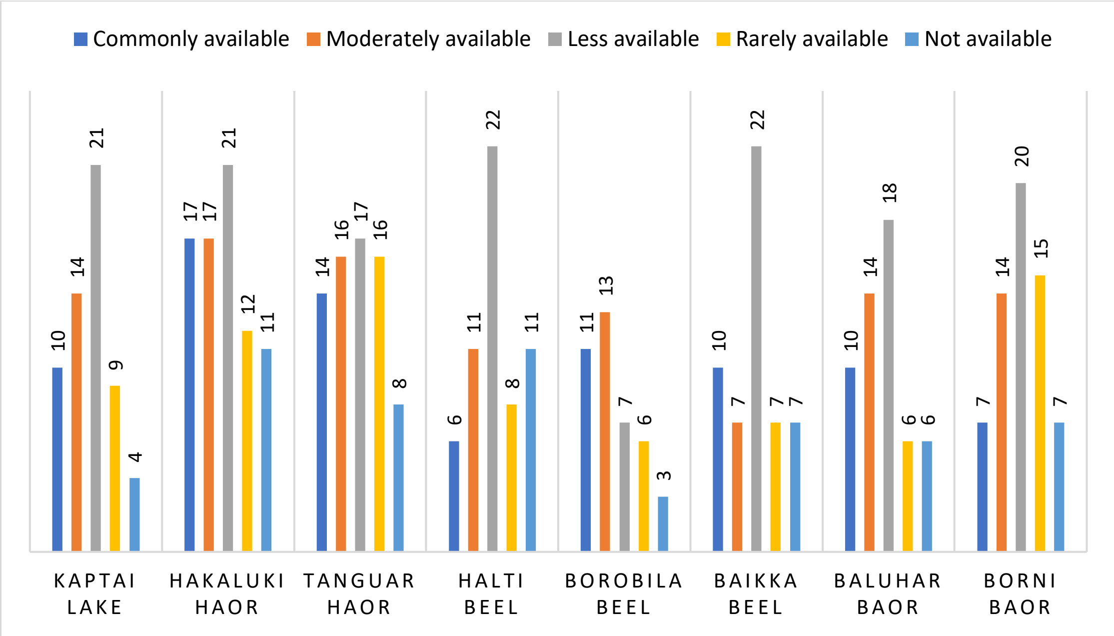


Figure 7-24: Comparative Numbers of Species Wise Fisheries Resources and Fish Biological Diversity of Presently Available and Not Available Species at Different Wetland

In case of Tanguar haor, number of commonly available, moderately available, less available, rarely available and not available species are respectively 14, 16, 17, 16 and 8. Similarly at Hakaluki haor, the values of commonly available, moderately available, less available, rarely available and not available respectively are 17, 17, 21, 12 and 11. In both haors, the less available and rarely available species can be considered as vulnerable species, will be threatened and endangered within a couple years. IUCN Bangladesh (2003) found 32 nationally threatened freshwater fish species in the Hakaluki haor, which was a positive indicator of declining fish biodiversity in that aquatic ecosystem.

In Kaptai Lake, commonly available, moderately available, less available, rarely available and not available respectively are 10, 14, 21, 9 and 4. Both less available and rarely available species can be categorized as vulnerable species, which is sharing 56% of species (both 39% less available + 17% rarely available species) are in alarming stage; those are on the way to be endangered within few years of time.

Category wise availability of fishes at both Baluhor Baor and Borni Baor shows that, in both cases there are major proportions of these fish species become vulnerable, which are in the line of critically threatened or endangered soon or later.

The trend of availability of vulnerable species (both less available + rarely species) and declining species biological diversity are very close between Baikka Beel and Beel Halti. Although at Borobila Beel number of vulnerable species having lower trend but huge vegetative growth at shallow water depth of the beel ecosystem during dry/winter season occurred huge mortality of the existing fish stocks due to deterioration of water quality parameters viz. dissolved oxygen, pH, alkalinity and hardness etc. The details have been presented in Volume-II: Appendix-F.

7.10.4 Findings from the Stakeholder Consultation of Vegetation Survey

Wetlands of Bangladesh have been divided into 7 different clusters based on hydrological, biological, vegetation zones. Among those 7 clusters, 9 different wetlands from 5 clusters were selected for vegetation study. Additionally, from North East cluster Hakaluki haor and Tanguar haor were visited twice; in both wet and dry season. In the following subsection cluster wise vegetation study results have been presented.

A semi structure questioner and open ended interview method were followed for all the three data collection methods (PI, KII, and FGD). Each of respondent's response coded to obtain numerical value where a manifest coding system with a category table was used. These numerical values were then plotted in SPSS software for analysis. In the SPSS category data inter-phase classified numerical values against responses were entered. Leichardt, Ordinal and Nominal scale for different category/ variable were used. Every respondent was treated as individual case. Cross-tabulation and frequency analysis were carried out to draw inference. Results were presented in tabular and bar diagram with logical qualitative interpretation.

Personal Interviews Result:

This study carried out 355 personal interviews in all the selected wetlands. From the forest perspective the personal interviews give the information about the missing tree species in the locality. Figure 7-25 shows the missing species form respective study site.

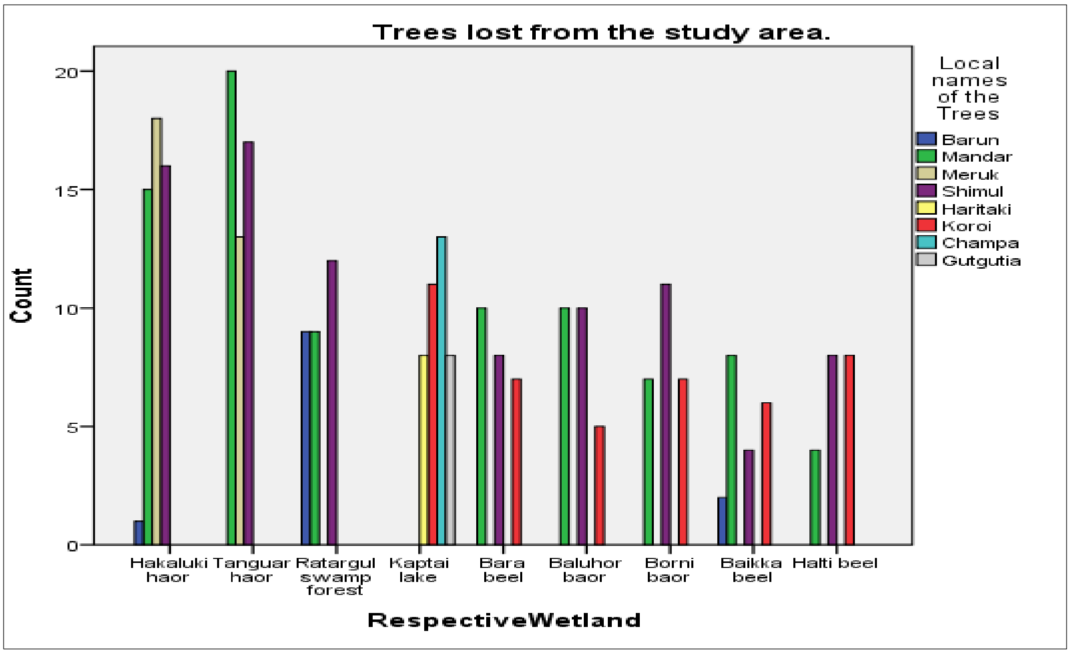


Figure 7-25: Informants Perception on Lost Trees from the Wetland Ecosystem

As it was evident that few tree species have been lost and few are found in sporadically, additionally the woody vegetation are disappearing from those wetlands. There by the study tries to find out that if the trees are reintroduced then how that will be taken by the local stakeholders. Additionally, which species are their first priority for reintroduction? The Figure 7-26 shows the results of these two questions.

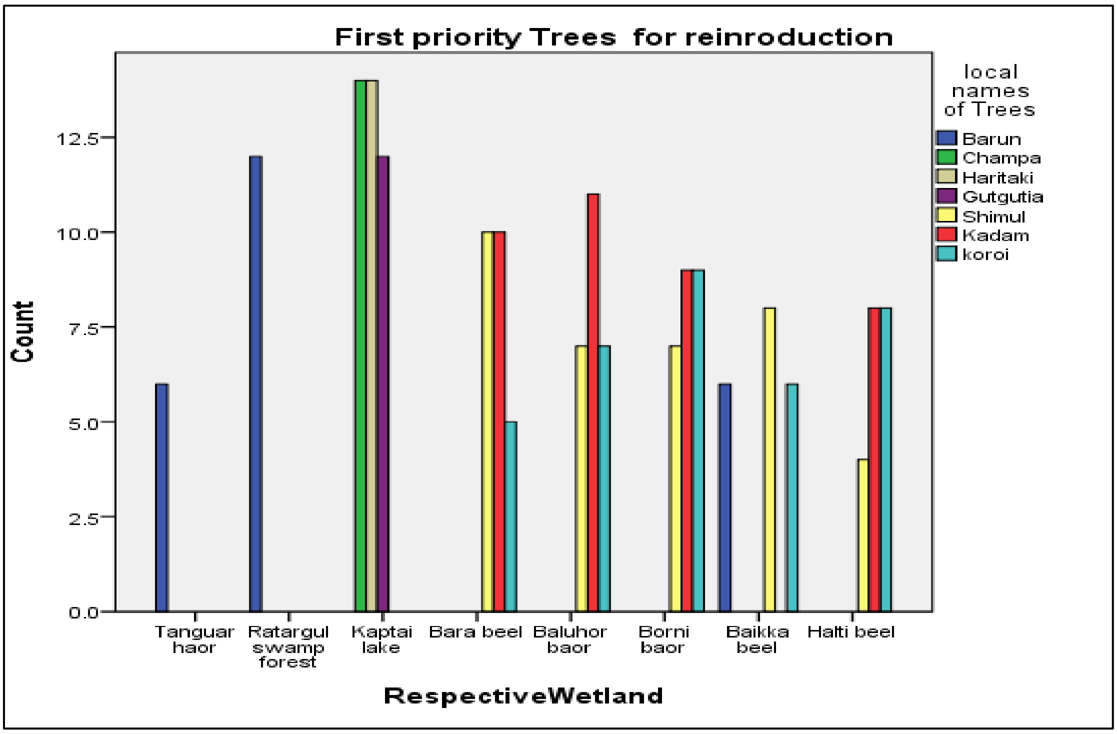


Figure 7-26: Informants First Priority Species for Reintroduction

This study categorized management option from extreme conservation to extreme product along with a combination of production-conservation and conservation-production. The Figure 7-27 to Figure 7-28 indicates the local people's perception about their wetland management regime.

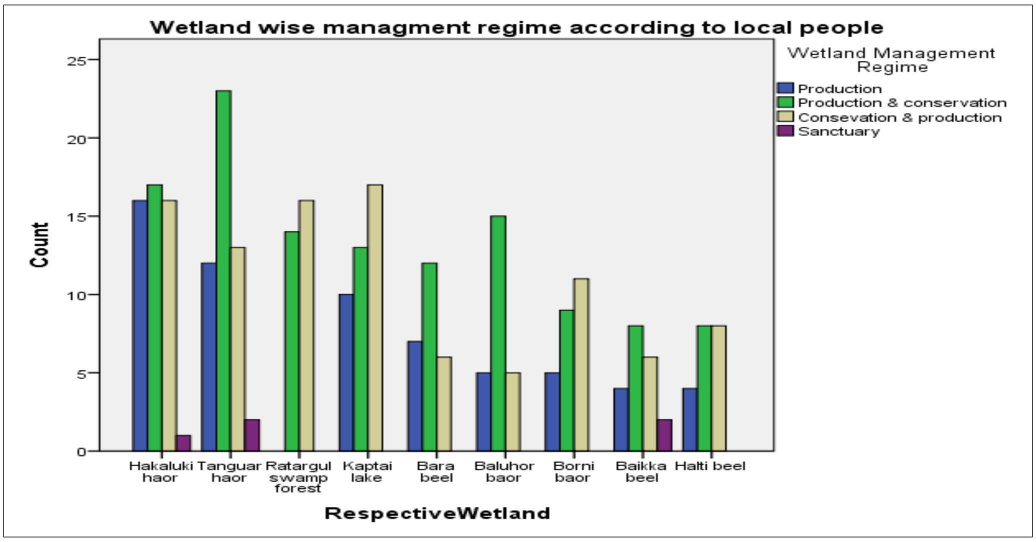


Figure 7-27: Wetland Wise Management Regime as per Peoples Chose

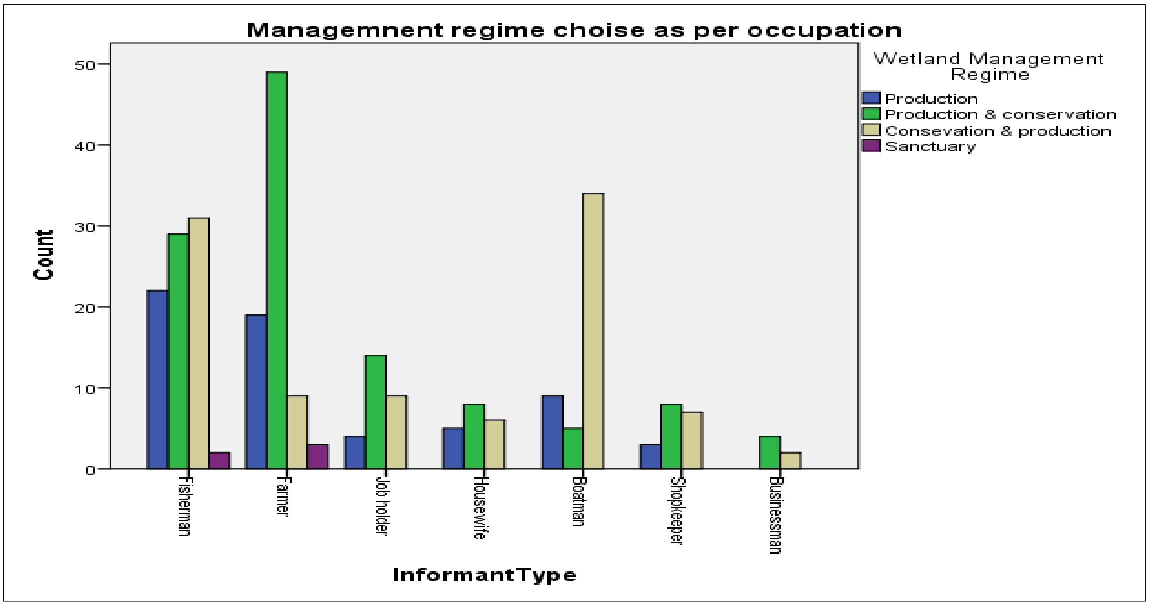


Figure 7-28: Occupation Wise Management Regime as per Peoples Chose

Key Informant Interviews:

This study carried out 35 KII from local to national level. Those selected experts and regional to field officials who are dealing the wetlands gave vital information regarding issues and suggestion to address those issues. Based on experts 'opinion wetland wise findings is prepared to present the results as shown in Table 7-20.

Table 7-20: Issue, Threats and Suggestions

Name	Issues	Threats	Suggestions
Tanguar Haor	• Land tenure • Habitat degradation	• Water extraction and dam building • Illegal filling and habitat destruction • Hunting and trapping • Introduction of exotic specie • Ground trolling of fishing net • Grazing	• Poverty reduction measure • Proper ecosystem friendly fishing technique be introduced • Alternative jobs of local people • Afforestation • Eco-tourism • Banning of engine boat and introduce manually driven boat.
Hakaluki Haor	• Land tenure • Sedimentation • Habitat degradation	• Illegal filling and habitat destruction • Hunting and trapping • Introduction of exotic specie • Ground trolling of fishing net • Reduction of fish catch and • Grazing	• Poverty reduction measure • Community based management • Alternative jobs of local people • Afforestation • Eco-tourism • Upland hill excavation should be stopped
Ratargul Swamp Forest	• Siltation • Habitat degradation	• Uncontrolled tourism • Illegal felling and habitat destruction • Wildlife –human conflict	• Enrichment plantation • Community based management • Stop illegal sand lifting from the river • Protect river bank erosion • Visitor management
Bikka Beel	• Land grabbing by local pressure group • Wildlife depletion	• Bird poaching • Illegal fishing • Illegal tree felling	• Strong community based management • Land reclamation by the government • Civil administration lead multi departmental management organization along with local stakeholders
Borobila **Beel**	• Habitat degradation • Lack of tourism facility	• Over exploitation of fishes • Poverty	• Income generating activity • Eco-tourism • Afforestation
Beel Halti	• Connectivity to Atrai river • Habitat degradation	• The running cannel has been closed. • Closure of the Atrai Dam.	• Re - excavation of Atrai River

	• Siltation of rivers and canals • Faulty sluice gate design	• Illegal fish catching from the sanctuary. • Environmental pollution • Replacing indigenous tree (like palash, kadom) by valuable timber specie (like mahaguni)	• Plantation around the beel, and roadside with indigenous tree species • Eco-tourism • Carrying capacity of the tourists needs to be determined
Baluhor Baor	• Hydrological dynamics change • Indigenous fish (RANI MACH) depletion • Management	• Encroachment • Illegal harvesting • Environmental pollution • Incremental target bound fishing by the DOF	• Promoting eco-tourism. • Promoting fish production • Collaborative Management having multilevel stakeholder's participation
Borni Baor	• Over exploitation of resources • Navigation problem • Siltation • Deforestation	• Illegal occupation of the baor area (pen culture- Bengali: katha). • Environmental pollution. • Illegal fishing by powerful. • Using of illegal mash size Net 'current Jal'. • Waste line of municipality is connected to the baor water body. • Hunting and poaching of birds.	• Promotion of Eco-tourism • Development of permanent fish sanctuary. • Law enforcement against illegal fishing and encroachment • Reintroduction of Hijol tree. It provides habitat for fish and birds. • Promoting Collaborative management. • Dredging
Kaptai Lake	• Habitat degradation • Landslides and soil erosion • Siltation of the lake • Anti-social criminal activity by different groups • Governance & Management • Conflict between tribal and Bengali community	• Shifting cultivation. • Illegal hunting of poaching of wildlife and birds. • Environmental pollution. • Siltation in Kaptai lake • Encroachment • Soil erosion • The powerful people/tribal people occupies the land illegally • Corruption • Extortion and anti-social activity • Conflict for land and resource right between tribal and Bengali community. • Leasing out system. • Security	• Introducing TAUNGYA and proper agroforestry system outside forest reserve • Ecotourism. • Reforestation with indigenous trees on the barren hills immediate to stop soil erosion and land slides • Illegally occupied land should be reclaimed. • Assurance of security • Conflict management around land and resource right. • Co-management of forest and fishery resources

Focus Group Discussion (FGD):

It is a widely used method in participatory research to get an in-depth understanding of the broad community context and social complexities. The focus group discussion was done in wetland site. As these group discussions were done in both heterogeneous and homogenous stakeholder setup, the study was able to get both aspects of conflicts and potentials. The summery of all FGD transcripts are given in the Table 7-21 according to issue, measures need to be taken in relation to Cluster.

Table 7-21: Outputs from Focus Group Discussion (FGD)

North East	**Tanguar Haor**
	Issues: • Water withdrawal or extraction • Controlling water levels • Illegal tree felling & habitat alteration • Hunting & Trapping • Introduction of exotic species • Over extraction of fisheries resources • Use of insecticide in the crop field
	Suggested Measures: • Poverty reduction measures are priorities • More job creation in the local economy for local people • NGOs activities shall be enhanced to provide credit to developing alternative income generation outside haor resources • Duck rearing and • Afforestation and reforestation within the kandas of haor with hijol, koroch and borun • Promotion of systematic Ecotourism with visitor management
	Hakaluki Haor
	Issues: • Sedimentation or siltation of the beels within the haor • Reduction in fish diversity and catch volume • Limited availability of fishing grounds • Fishing cost increased in relation to market sell value • Environmental factors affecting the ecosystem • Destruction of important habitats • Agriculture related problems like using pesticide and chemical fertilizer • Cattle grazing in dry season inhibit natural regeneration and young plantation • Ground trolling of nets, creation earth dam for boundary delineation inhibit natural water flow and movement of fishes. • Illegal bird hunting
	Suggested Measures: • Seizure of upstream hill excavation, deforestation, drain construction & uncontrolled stone quarrying • Construct embankments or raise the level of the banks of large beels to retain water in the dry season & protect some areas from flash flood. • Deploy guards to protect sanctuaries & migratory waterfowl • Involve local community in management i.e. introducing effective collaborative management. • Ensuring Access to existing resource and Investment • Explore scopes from exiting legislations rather than having new law • Involve/Establish a community institution for monitoring • Making conservation/protection economically valuable to community • Respecting and Integrating Indigenous Knowledge

- Practice a culture of sharing benefit among the stakeholders
- Ensure involvement of Government in every stage.
- Ensuring forest department's authority in collaboration with civil administration in protecting the habitat and plantation/ tree stand within the haor area.
- Land leasing should be ecosystem friendly

Choice of species to be reforested and reason given by the participants

From the perspective of hakaluki & tanguar haor, the stakeholder has suggested to plant Hijol, Koroch & Barun. They have mentioned some causes for which they have selected these species. The causes are;

- They have suggested to plant Hijol, Koroch, Barun because these are the native plants of haor areas & it is wise to plant native plants under any plantation program & native plants are crucial in habitat restoration. They help to restore plant diversity, stabilization and replenish soil.
- Fresh water swamp forest consists of flood-tolerant evergreen trees & they are adapted to monsoon flooding for three to four months to depths of .5 to 2.5 m
- The swamp plants provide habitat for fishes & birds & thus increase the number of fishes & birds.
- The suggested plants can also give protection against wave action, storm action, erosion
- Hijol is used to make Kathha for fishery purpose.
- Capable of withstanding the flood, these particular trees may be conserved and protected as seed trees for future propagation.

The stakeholders have also suggested to reintroduce Kadam, Shimul, Raintree, Bot, Pitali because these plants were there in the recent past & they can be grown & survived in such environment.

Ratargul Swamp Forest

Issues

- Illegal tree felling in recent past degrade the ecosystem and habitat
- No governing rule or ticket system to enter the forest, so huge number of visitors are entering the forest
- Wildlife is spread out from the forest because the forest is sub-merged by water.
- River bank erosion and siltation of the swamp

Suggested Measures:

- Enrichment plantation of Hijol, Koroch and Murta in the Ratargul swamp forest.
- Determining tourism carrying capacity and strict visitor's management
- Boundary delineation and ecosystem zonation needs to be done
- Delineation of core and buffer zone
- Measures against river bank erosion and swamp siltation
- If necessary building sluice gate between river channel and Ratargul swamp forest to maintain water level.
- Establishment of plantation outside of the Ratargul swamp forest meeting the local demand for forest product.

Baikka Beel

Issues

- Illegal bird hunting from the beel, so the number of birds are decreasing day by day. It is a threat for the nature.
- Illegal Fishing from the sanctuary zone
- Encroachment by and land grabbing by local political leaders.

<table>
<tr><td rowspan="3">North Central</td><td>Borobila Beel</td></tr>
<tr><td>Issues:
• Poverty
• Over exploitation of resources
• Deforestation</td></tr>
<tr><td>Suggested Measures:
• Income generating activity
• Ecotourism
• Afforestation</td></tr>
<tr><td rowspan="3">North Western</td><td>Beel Halti</td></tr>
<tr><td>Issues:
• Closer of active cannel hinders water flow and causing siltation
• Atrai Dam.
• Siltation Atrai River.
• Fish catching from the sanctuary.
• Environmental pollution.
• Fish habitat and breeding ground hampered</td></tr>
<tr><td>Suggested Measures:
• Choice for box culvert.
• Strip plantation beside the road from patul- Naldanga, the villagers have suggested to plant trees. The trees will provide the habitat for the birds. Preferred species kodom, shimul, hijol.
• Plantation surrounding the sanctuary.
• Establishing and maintain bush of chitki, motmote and kolmi as those provide refuge to fishes.
• Promotion Ecotourism with financial support to small business.
• Carrying capacity of the tourists needs to be determined and visitor management.</td></tr>
<tr><td rowspan="3">South Western</td><td>Baluhor Baor</td></tr>
<tr><td>Issues
• Water level has been decreasing since 5 years.
• Encroachment of Baor area by local elites
• The DoF appointed guards are suspect for illegal fishing and abetting illegal fishing outside the fishing season.
• Environmental pollution.
• The land of the baor has been decreased due to agricultural practice
• Depletion of Indigenous fish stock (Rani Mach)</td></tr>
<tr><td>Suggested Measures:
• Promoting ecotourism.
• Effective collaborative/ co-management approach for Baor management.
• Promoting indigenous fish production by enforcing and implementing fishing ban period.
• DoF total fish catch volume should be revisited to ensure having indigenous fish instead of hybrid carps.</td></tr>
</table>

	Borni Baor
	Issues: • The powerful people occupy baor area illegally (pen culture –Bengali-Katha). • Environmental pollution. • Powerful people's illegal fishing and recreational fly fishing. • Using of illegal fishing nets (current Jal) • Waste line of municipality is connected to the baor water body. • Illegal bird hunting
	Suggested Measures: • Ecotourism • Development of permanent fish sanctuary. • Reintroduction of Hijol tree. It provides habitat for fish and birds. • Promoting effective Co-management with participation government agencies, local government and local stakeholder. • Ban on using 'current jal'. • Dredging of baor.
Eastern Hill	**Kaptai Lake**
	Issues: • Shifting cultivation. • Poaching of wildlife. • Environmental pollution. • Siltation in Kaptai lake • Encroachment • Soil erosion • The powerful people/tribal people occupy the land illegally • Lack of honesty for the forest department officials • Trees are cut down to pay NGO loan.
	Suggested Measures: • Reforestation with indigenous trees on the barren hills immediate to stop soil erosion and land slides • agroforestry system outside forest reserve • corruption should be stopped • Assurance of security • Conflict management around land and resource right. • Co-management of forest and fishery resources • Effective microfinance for alternative income generation.

The details of the stakeholder's consultations of vegetation survey has been given in Volume-II: Appendix-G.

7.10.5 Findings from the Stakeholders Consultations of Agricultural Study

Focus Group Discussion (FGD):

FGD is a widely used method in participatory research to get an in-depth understanding of the broad community context and social complexities. The focus group discussion was done in wetland site. As these group discussions were done in both heterogeneous and homogenous stakeholder setup, the study was able to get both aspects of conflicts and potentials. The summery of all FGD transcripts are given in following according to issue, measures need to be taken in relation to cluster.

North East Region: Tanguar Haor and Hakaluki Haor

Issues:

Vulnerability to Early Flash Flood: Boro rice, being the only crop grown in haor basin is vulnerable to early flash floods due to sudden heavy rainfall within and outside haor basin as well in upstream beyond the boarder. In case early onset of monsoon, early flash flood is almost inevitable causing total crop damage.

Scarcity of Irrigation Water: Though haors remains submerged for about a half the year, Boro rice is exposed to water stress in the reproductive and grain growth stages due to lack of adequate irrigable water and infrastructure facilities for water conveyance and distribution. In fact, only 19-20 percent of Boro land is irrigated in Hakaluki and Tanguar haor area. The crop grown in upper catena along ridges (Kanda) suffers most as available surface water sources dries out. Farmers have no alternative but to depend on uncertain rainfall. The available water remaining at haor basins (beels) cannot be used for irrigation at upper catena due to absence of proper water conveyance and distribution infrastructure against the slope gradient. This adds to the uncertainty of the crop and discourages desired investment due to risk of crop failure.

Lack of Communication Facilities: Due to inaccessibility of the area, lack of communication facilities exists and thus farmers have minimal access to modern technological opportunities and extension services making farmers dependent on traditional practices of crop production and management.

Low Input Use in Boro Production: Boro rice is the only crop for livelihood for most of farming community of the area. Accordingly, farmers make efforts to cover all their land with boro rice even beyond their capacity to manage it well in terms resource use to increase yield and productivity. Hence, available investment is distributed to more lands rather than adopting optimum management packages to have a reasonable vertical growth.

Blast Disease in BRRIdhan 28: For the short duration HYV, farmers widely use BRRIdhan 28 to escape early flash flood. However, due to long exposure of the variety in the area, it has become susceptible to rice Blast disease. For last few years Blast disease has emerged as havoc causing serious yield loss of Boro rice.

Labor Crisis at Planting and Harvesting Time: Due to ecological condition, farmers have to transplant and harvest boro rice within a short time due to absence of mechanization of planting and harvesting. Accordingly, farmers are dependent of hired labor coming from adjacent districts to carry out these vital operations. Labor shortage also a cause of inefficiency of other cultural practices.

Suggested Measures:

- ✓ Short duration boro rice varieties (maturing in < 150 days) such as BRRIdhan 81, BRRIdhan 84 and BRRIdhan 86, BRRI Hybrid 5, maturing in 143, 141, and 140 days, respectively with 6.5 t/ha yield may be used by replacing long duration BRRIdhan 29 and other similar varieties.
- ✓ The scarcity of irrigation water may be addressed by (a) developing surface water reservoirs by digging at suitable locations; (b) Developing necessary water pumping, conveyance and distribution infrastructure; (c) Developing both surface and groundwater resources to achieve full irrigation coverage; (d) Growing less water requiring upland crops in the upper position of catena by replacing Boro rice; and (e) Adopting more water efficient irrigation technologies such as Alternate Wetting and Drying (AWD) method of irrigation.
- ✓ To improve farmers' knowledge and skills, modern packages of crop production and management technologies should be demonstrated with farmer participation and providing technology training to as many farmers as possible within shortest possible time to mitigate knowledge and skill gaps.
- ✓ It is high time to replace BRRIdhan-28 by newly developed Blast resistant short duration (< 150 days or less) like BRRIdhan 81, BRRIdhan 84 and BRRIdhan 86, BRRI Hybrid Dhan 5 and other introduced hybrid varieties introduced by different seed companies. Farmers need to be supported in adopting the new varieties.
- ✓ Adequate support is needed to develop suitable mechanical devices for transplanting (transplanter) and harvesting (harvester/reaper) suitable for use in wet (often submerged) season.

North Central Region: Borobila Beel

Issues:

Late recession of monsoon water

- Siltation of Existing River named Banar which is linked with the beel through Boro Khal (Big canal).
- Siltation of the Boro khal also to carry water from the beel.
- Regular puddling deteriorates the soil properties
- The production process suffers from being late and the harvest faces rainy day related complications
- Tough to manage huge rice crop at the onset of monsoon (May-June)
- Labor crises and high wages due to mono cropping

- High production cost and no or very low profit

Sudden flood in Boro season

- Unprecedented High rainfall during April- May;
- Water flow from upper streams.
- Partial to heavy damage of Boro rice, the major livelihood of farmers;
- Crop quality and market price deteriorate;
- Farmer's economic loss constrains livelihoods.

Eutrophication seriously deteriorates water quality

- Fertile soil eroded to basin of the Beel;
- Huge growth of protected aquatic plants- Water lily, Lotus and other weeds;
- Very dense aquatic plants and weeds dies and rot before maturity resulting water pollution.
- Causes etching, skin diseases and unknown effects to fishery resources and aquifer.
- Difficult for cultivation due to higher labor cost and time is unsustainable.
- Higher production cost.
- Lower family income of Beel farmers.

High Labor cost and poor availability

- Monocrop of Boro rice needs high number of labor in peak season.
- Monocropping also discourage the labor force to settle around due to lack of year round labor demand.
- Manual cultivation specially, transplanting and harvesting demands more labor.
- Delays transplanting causing late harvest and exposure to more hazards due to advancing monsoon weather.
- Product quality deteriorates.
- Labor wages goes as high as BDT 800 a day.
- High production costs causing lower income.

Suggested Measures:

✓ The canal connecting the Beel and Banar river need to be re-excavated to maintain continuous/ long–term flow of water from the beel.

- ✓ The Beel may be excavated at Government (KHASH) part of its basin and put the soil on croplands and thus elevating the same providing facilities i) for multiple crops, ii) early Boro crop, iii) accommodate early monsoon flood and save the crops, iv) promote more fish culture, v) to maintain a deeper part as fish sanctuary to protect and regenerate fish species and breeding, vi) protect the eutrophication and water quality, vii) attract tourists with maintained beauties with different suitable aquatic plants, local and guest birds, plants, fish species, fish catches, boat fairs and so on.
- ✓ The beel may be protected from inflow of soil and extra nutrients by constructing embankments and making a walkway with beautiful hedge and locally adopted extinct plants species to attract tourists. This can add to family income from tourists.
- ✓ A fish sanctuary may be maintained for enriching aquatic production and farmer's income.
- ✓ Construction of sluice gates needed at Golaper Bandh (Embankment) and Boro Khal (canal) point to control water pressure of the beel.
- ✓ The management of the beel needs to be with the concerned farmers and fishermen instead of leasing to businessmen who exploit the water body without considering its' sustainability and biodiversity;
- ✓ Use of rice transplanter and reaper in muddy lands (with plastic wheels) would reduce labor cost, ease and shorten the time for both the operations;
- ✓ Rotting of aquatic weeds, seemingly the main cause of degradation of water quality may otherwise be used for composting and/or preparing beds for floating agriculture.

North West Region: Beel Halti

Issues:

- Almost no organic recycling is there as generally found in other water bodies.
- Water holding capacity of soils, specially, at the upper catena is less, needing frequent irrigation almost every day or each alternate days for Boro rice cultivation.
- The fertilizers applied are also leached down resulting to a poor rice yield with high fertilizer use.
- The profit margin is low or negative.
- The soils, especially of upper catena are seemingly, degraded into de-structured, heavy, metallic biomass locally called KHAGRAI MATI.
- This soil is characterized with quickly shrinking when dry and become very sharp for walking and handling and make giant cracks for long.
- The cracks promotes quick seepage losses of irrigation water and nutrients.
- The Bro crop requires frequent irrigation in every day or alternate days.

- Frequent (60-70 times) irrigation makes the cost too high to be profitable.
- The rivers Atrai and Barnoi are silted restricting outflow of off-season water. During winter, Barnoi flows slowly but the Atrai is totally dried up in winter.
- Construction of barrier ponds (locally called KUA) on the existing outlet/drainage canal.
- Closed weaved net locally called SHUTI JAL, put against the draining out current for fishing with other nets and fishing structures. These also kills huge young fish fingerlings and broods reducing the amount of fish production and extinction of some species from the water body.
- Dumping garbage by residents alongside drainage canal restricting the flow of water.
- The canal itself has been silted up as excavated long before about four decades back.
- The road constructed across the bell is a barrier as it consists very poor number of culverts required to ease the flow of water.

Suggested Measures:

- ✓ Cultivation of deep water rice at possible catena to protect fish netting and check wave severity.
- ✓ Plantation of aquatic plants like Hijol, Koroch, Bhati besides the roads and ails to shelter local and guest birds, reptiles, frog, and other minor plants and animals.
- ✓ Protect some areas as non-fishing zone and allow aquatic weeds with natural beauties to grow.
- ✓ Establishment of tourist spots with facilities to gather, organize conferences, occasions of amusements like traditional boat racing, racing with rowing boats, water polo, swimming races, swimming pools, training of swimming, safer overnighting, fair with traditional natural fish and so on.
- ✓ Establishment of a fish sanctuary and maintaining the breeding and nurturing diversified species under the threat of extinction.
- ✓ Massive dryland culture to allow heavy biomass production, using roots and stable as recycled organic matters. This can be possible through early recession of water.
- ✓ Increase aquatic plant biomass production and decomposing them in cropped lands of the beel.
- ✓ Check washing out of the biomass from soils through creating life barriers against waves and netting.
- ✓ Re-excavation of existing drainage canal.
- ✓ Connecting both ends with upstream and down streams to ease the continuous drainage of beel water

- ✓ Re-excavation of dead Atrai and Barnoi rivers to drain water to down steams – ultimately to the Jamuna river.
- ✓ Remove all barriers like ponds, Shuti jal (fishing nets), and other structures from drainage canals. This needs political commitment and policy decisions.
- ✓ Construction of more culverts (10-12) on the existing road across the beel.
- ✓ Excavation of a new north-south cross drainage canal along Patul-Khajura road to facilitate quick recession monsoon water.
- ✓ Construction and maintenance of sluice gates at upper and lower streams for controlling unwanted inflow and out flow of water to and from the beel.

The details of the stakeholder’s consultations of agricultural study has been given in Volume-II: Appendix-H.

7.10.6 Socio-Economic Findings

Focus Group Discussion (FGD)

Consultations have been conducted regarding the project goals and objective, potential social impacts on them and their suggestion about mitigation measures. The discussions were held with special focus on their impact and or livelihood. People were brought together in groups based on homogeneity and or nearness. Total 8 focused group meetings were held. The brief of FGD with respect to socio – economic condition is prescribed below whereas the details are given in Volume-II: Appendix-J.

Recommendations from FGD Participants for Tanguar Haor:

- Construction of embankment to protect flash flood;
- Prohibited duck rearing in the open water;
- Stop catching fish throughout the year specially during the breeding season of fishes;
- Ensure financial support for the actual fishermen for certain (nonproductive) period;
- Lease the haor to the actual fishermen in and around the area;
- Building awareness among the people of haor area;
- Develop communication for haor area, for easy movement inside the haor and other urban area;
- Arrange and conduct training on haor resource management;
- Initiative for eco-tourism development in the haor area and
- Develop fish and bird sanctuary in the haor;

Participatory Rural Appraisal (PRA)

A total 8 nos. of Participatory Rural Appraisal (PRA) followed FGDs throughout the period of field level data collection purpose to gather information regarding on social and resource in the haor area. The PRA participants prepare 6 social maps and 2 resource maps covering entire Tanguar haor area after that the consultant converted the information into 2 sheets, one is social map and another one is resources map showing all information indicated by the PRA participants as shown in Figure 7-29 to Figure 7-30.

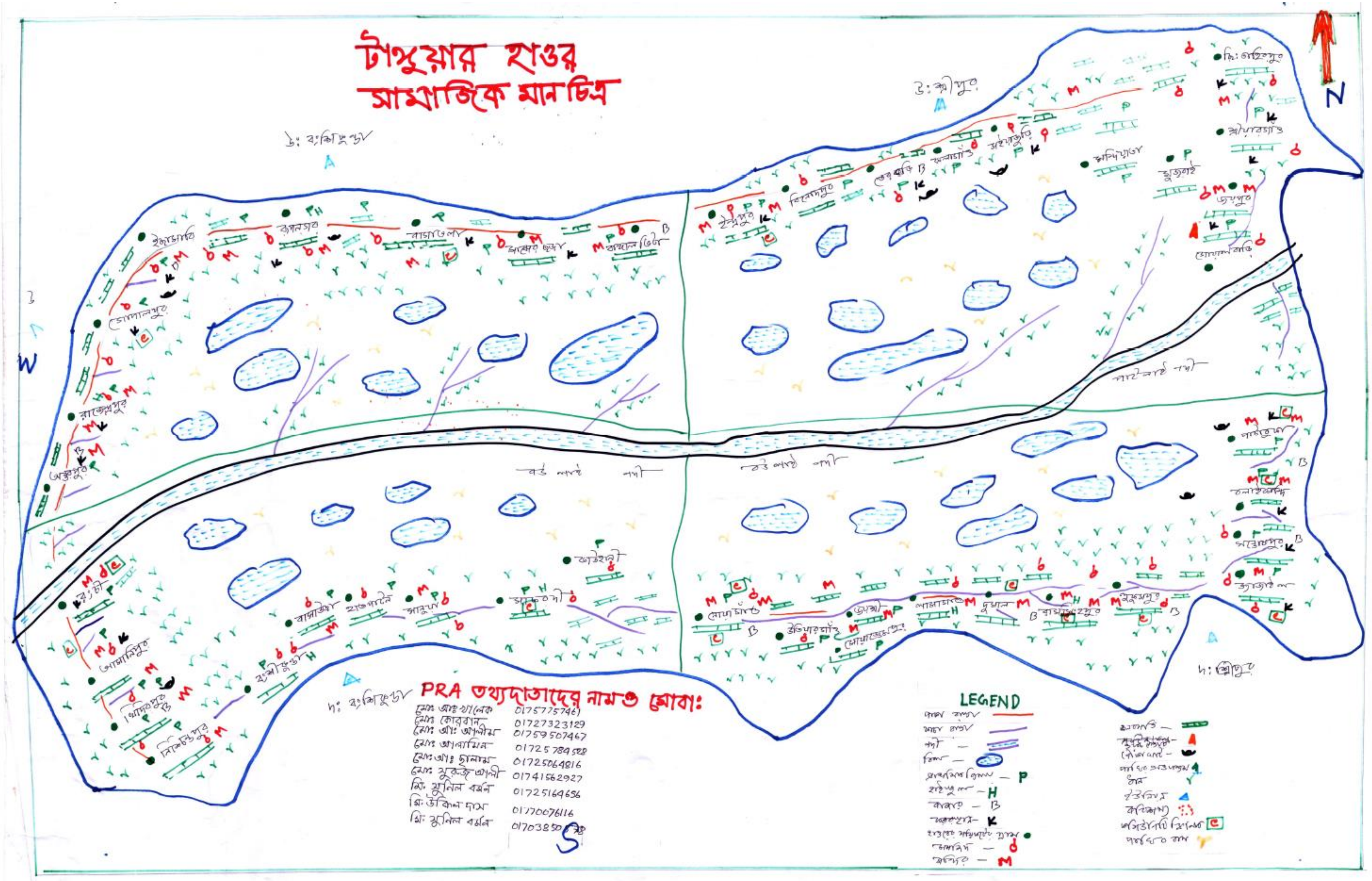


Figure 7-29: Social Map for Tanguar Haor Area

Figure 7-30: Resources Map for Tanguar Haor Area

Focus Group Discussion of Hakaluki Haor

Total 10 focused group meetings were held with 112 participants. The consultant sought opinion from people about potential adverse impacts and their suggested mitigation measures.

Recommendations from FGD Participants for Hakaluki Haor

Like Tanguar haor, FGD participants recommended the following for the Hakaluki haor development:

- Construction of embankment to protect flash flood;
- Prohibited duck rearing in the open water;
- Stop catching fish throughout the year specially during the breeding season of fishes;
- Ensure financial support for the actual fishermen for certain (nonproductive) period;
- Lease the haor to the actual fishermen in and around the area;
- Building awareness among the people of haor area;
- Develop communication for haor area, for easy movement inside the haor and other urban area;
- Arrange and conduct training on haor resource management;
- Initiative for eco-tourism development in the haor area and
- Develop fish and bird sanctuary in the haor;

Participatory Rural Appraisal (PRA)

The consultant conducted 6 Participatory Rural Appraisal (PRA) followed FGDs throughout the period of field level data collection purpose to gather information regarding on social and resource in the haor area. The PRA participants prepared 8 social maps and 8 resource maps covering entire haor area after that the consultant converted this information into 2 sheets one is resource map and another one is social map showing all information indicated by the PRA participants as shown in Figure 7-31 to Figure 7-32.

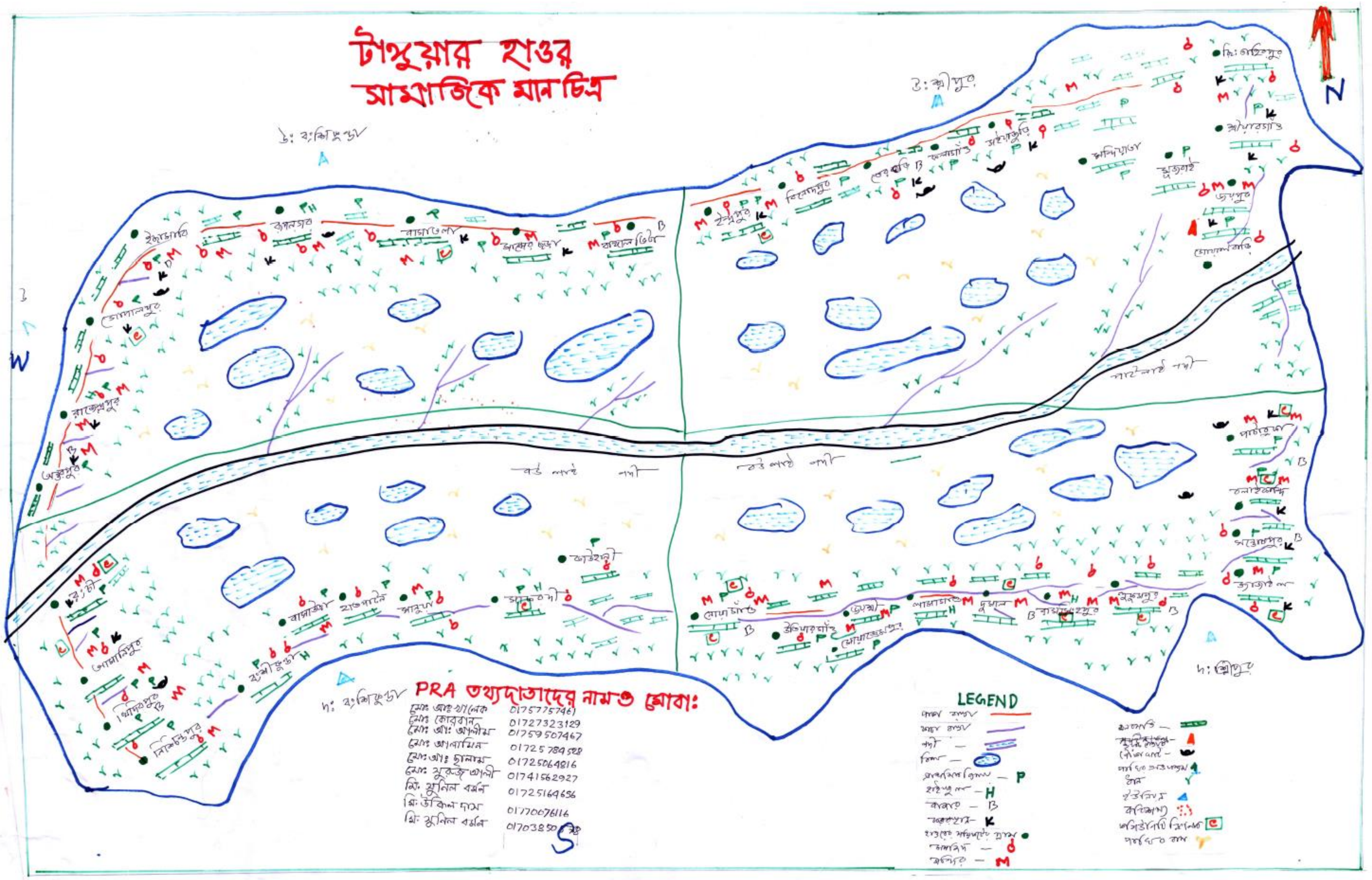


Figure 7-31: Social Map for Hakaluki Haor Area

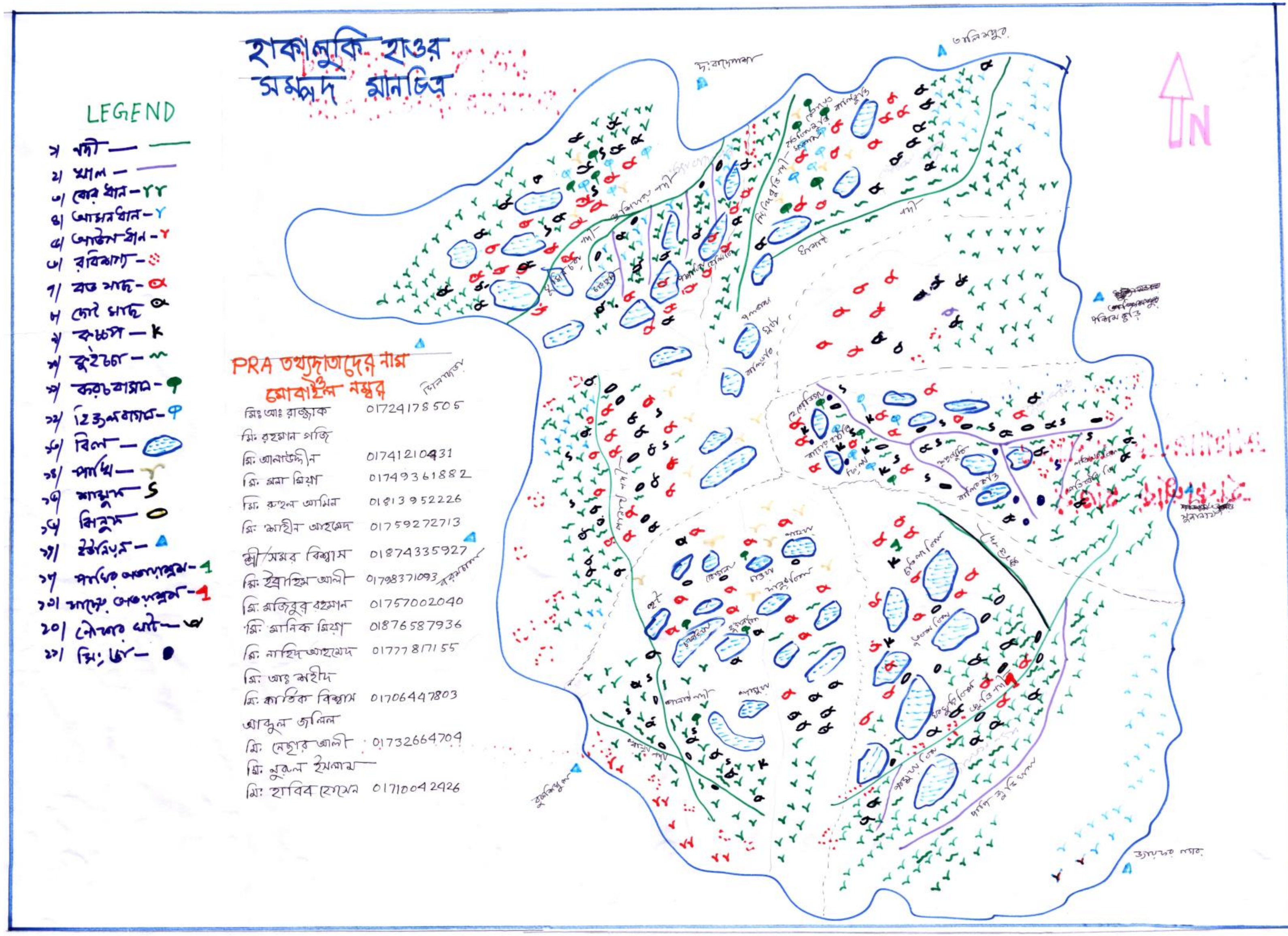


Figure 7-32: Resources Map for Hakaluki Haor Area

7.10.7 Meeting

Science its inception of the project, a Project Steering Committee (PSC) and a Project Implementation Committee (PIC) has been formed for better implementation of the project and regular planning and monitoring of the project activities. The Secretary, Ministry of Water Resources was the chairperson of PSC whereas the PIC was headed by the Director General, DBHWD. Accordingly, 10 nos. of PIC meeting and 5 nos. of PSC meetings were held during the project implementation period. All the decisions taken from PIC meeting was vetted by PSC as such the decisions of PSC meeting and its compliance has been illustrated below:

1st PSC meeting, Date: 07.06.2016		
Sl. No.	**Comments and Suggestions**	**IWM Compliance**
১.	বাংলাদেশ হাওর ও জলাভূমি উন্নয়ন অধিদপ্তর কর্তৃক বাস্তবায়নাধীন " Study on Interaction between Haor and River Ecosystem including Development of Wetland Inventory and Wetland Management Framework" প্রকল্পের কাজ বাংলাদেশ নৌবাহিনীর ডকইয়ার্ড এন্ড ইঞ্জিনিয়ারিং ওয়ার্কস লি: কে প্রদানের লক্ষ্যে ডিপিএম (DPM) পদ্ধতিতে সম্পন্ন করার জন্য প্রয়োজনীয় উদ্যোগ গ্রহণ করতে হবে;	CCEA এর সিদ্ধান্ত মোতাবেক প্রকল্পের ক্রয়কার্য QCBS পদ্ধতিতে সম্পাদন করা হয়।
২.	বাংলাদেশ হাওর ও জলাভূমি উন্নয়ন অধিদপ্তর কর্তৃক বাস্তবায়নাধীন " Impact Assessment of Structural Intervention in Haor Eco System and Innovation for Solution " প্রকল্পের কাজ চলমান নিয়মে পরিচালিত হবে।	--------

2nd PSC meeting, Date: 12.07.2017		
Sl. No.	**Comments and Suggestions**	**IWM Compliance**
১.	ইমেজ ক্রয়সহ প্রকল্পের সকল কার্যক্রম গতিশীল করার বিষয়ে প্রকল্পে নিয়োজিত ফার্ম ব্যবস্থা গ্রহণ করবেন।	পরামর্শক প্রতিষ্ঠান কর্তৃক ইমেজ ক্রয় (৩৩৯ টি) ও প্রক্রিয়াকরণ করা হয়েছে যাহা Volume-I: Section-6.4.1 এ বর্ণিত করা হয়েছে ।
২.	পিআইসি সভার সিদ্ধান্ত অবহিতকরণ । ১। প্রকল্পের অনুমোদিত ToR অনুসারে জলাভূমির মানচিত্র প্রণয়নসহ প্রকল্পের সকল ক্ষেত্রে ToR এর প্রতিফলন ঘটাতে নিয়োগকৃত ফার্ম ব্যবস্থা গ্রহণ করবেন। ২। নির্দিষ্ট জলাভূমি (বাংলাদেশের Ramsar sites সমূহের) বিশদ তথ্য ও উপাত্ত সংগ্রহ করে বিস্তারিত Inventory প্রণয়ন, জলাভূমির দূষনের উৎস এবং কারণসমূহ চিহ্নিতকরণ, Pilot এলাকা নির্দিষ্টকরণ এবং Wetland Management Framework চুড়ান্ত করার বিষয়ে নিয়োগকৃত ফার্ম ব্যবস্থা গ্রহণ করবেন।	প্রকল্পের অনুমোদিত ToR এবং PIC ও PSC কমিটির সুপারিশ মোতাবেক জলাভূমির মানচিত্রসমূহ ১: ১০০০০ স্কেলে প্রণয়ন করে সর্বমোট ৪৪৪৩ টি মানচিত্র প্রস্তুত করা হয়েছে যাহা Volume-I: Section-7.2 এ বর্ণিত করা হয়েছে । পরামর্শক প্রতিষ্ঠান বিশদ তথ্য ও উপাত্ত সংগ্রহ করে বিস্তারিত Inventory প্রণয়ন, জলাভূমির দূষনের উৎস এবং কারণসমূহ চিহ্নিতকরণ, Pilot এলাকা নির্দিষ্টকরণ এবং Wetland Management Framework চুড়ান্তকরণ সম্পন্ন করেছে যাহা যথাক্রমে Volume-I: Section-7.2, Section-

2nd PSC meeting, Date: 12.07.2017		
Sl. No.	**Comments and Suggestions**	**IWM Compliance**
		7.7, Section - 7.11 ও Section-7.12 এ বর্ণিত করা হয়েছে ।
	৩। মানচিত্র প্রণয়নের ক্ষেত্রে সার্ভে অফ বাংলাদেশ (SoB) কর্তৃক নির্ধারিত Projection System এবং Datum ব্যবহার করার বিষয়ে প্রকল্প সংশ্লিষ্টগণ ব্যবস্থা গ্রহণ করবেন।	মানচিত্র প্রণয়নের ক্ষেত্রে সার্ভে অফ বাংলাদেশ (SoB) কর্তৃক নির্ধারিত Projection System এবং Datum ব্যবহার করা হয়েছে যাহা Volume-I: Section-7.2 এ বর্ণিত করা হয়েছে ।
	৪। প্রকল্পের অনুমোদিত ToR অনুসারে নির্দিষ্ট জলাভূমি সমূহের ecosystem এর উপর বিশদ পর্যালোচনা করে Final Report সহ সকল প্রতিবেদনে অন্তর্ভুক্ত করতে হবে।	জলাভূমি সমূহের ecosystem এর উপর বিশদ পর্যালোচনা করে Draft Final Report প্রস্তুত করা হয়েছে যাহা Volume-I: Section-6.6.1, Section-7.6.1, Section-7.6.2, Section - 7.10.1 ও Volume-II: Appendix-E এ বর্ণিত করা হয়েছে ।
	৫। PIC কমিটিতে কো-অপ্ট সদস্য হিসেবে সার্ভে অব বাংলাদেশ, স্পারসো, বাংলাদেশ পরিসংখ্যান ব্যুরো (বিবিএস), ঢাকা বিশ্ববিদ্যালয়ের সহকারী অধ্যাপক জনাব গোলাম দস্তগীর আলম খাদেম, মৎস্য অধিদপ্তর, কৃষি সম্প্রসারন অধিদপ্তর এবং বন ও পরিবেশ অধিদপ্তরের প্রতিনিধি অন্তর্ভুক্ত করা হলো।	PSC কমিটির সিদ্ধান্ত মোতাবেক PIC কমিটিতে কো-অপ্ট সদস্য হিসেবে সার্ভে অব বাংলাদেশ, স্পারসো, বাংলাদেশ পরিসংখ্যান ব্যুরো (বিবিএস), ঢাকা বিশ্ববিদ্যালয়ের সহকারী অধ্যাপক জনাব গোলাম দস্তগীর আলম খাদেম, মৎস্য অধিদপ্তর, কৃষি সম্প্রসারন অধিদপ্তর এবং বন ও পরিবেশ অধিদপ্তরের প্রতিনিধি অন্তর্ভুক্ত করা হয়েছে।
	৬। পরামর্শক প্রতিষ্ঠানকর্তৃক দাখিলকৃত Inception Report (IR) এ উল্লিখিত Approach and Methodology এর ভিত্তিতে Inception Report (IR) টি সর্বসম্মতিক্রমে গ্রহন করা হলো। **সিদ্ধান্ত: পিআইসি সভায় গৃহীত সিদ্ধান্তসমূহ বাস্তবায়নে প্রকল্প পরিচালকসহ প্রকল্পের সাথে সংশ্লিষ্ট সকলেই প্রয়োজনীয় ব্যবস্থা গ্রহন করবেন।**	Inception Report (IR) এ উল্লিখিত Approach and Methodology এর ভিত্তিতে Draft Final Report প্রস্তুত করা হয়েছে।
৩.	প্রকল্প পরিচালক প্রয়োজনীয় অর্থ সংস্থানের ব্যবস্থা গ্রহন করত: বরাদ্দকৃত অর্থের সর্ব্বোচ্চ ব্যবহার নিশ্চিত করবেন।	প্রয়োজনীয় ব্যবস্থা গ্রহন করা হয়েছে।
৪.	প্রকল্প পরিচালক ভ্যাট ও আইটি খাতের যাবতীয় সংশোধনী সহকারে প্রকল্পের মেয়াদ বৃদ্ধি করার প্রয়োজনীয় ব্যবস্থা গ্রহন করবেন।	প্রয়োজনীয় ব্যবস্থা গ্রহন করা হয়েছে।
৫.	JV of Megatech GNBD and IWM (Institute of Water Modelling) কে জরুরি ভিত্তিতে ইমেজ ক্রয় ও প্রক্রিয়াকরণ করতে হবে এবং প্রকল্প পরিচালক ফার্মকে যথাসময়ে যথাযথ প্রক্রিয়ায় বিল পরিশোধ করবেন।	পরামর্শক প্রতিষ্ঠান কর্তৃক ইমেজ ক্রয় (৩৩৯ টি) ও প্রক্রিয়াকরণ করা হয়েছে যাহা Volume-I: Section-6.4.1 এ বর্ণিত করা হয়েছে ।

3rd PSC meeting, Date: 30.05.2018		
Sl. No.	**Comments and Suggestions**	**IWM Compliance**
১.	বিগত সভার কার্যবিবরণীর বিষয়ে কারো কোন আপত্তি না থাকায় তা নিশ্চিতকরণ করা হয়।	

3rd PSC meeting, Date: 30.05.2018		
Sl. No.	**Comments and Suggestions**	**IWM Compliance**
২.	Image প্রসেসিং এর জন্যে average year condition (1 in 2.33 year) বিবেচনা করে dry এবং wet season অনুযায়ী জলাভূমি ও নদীসমূহের আন্ত:সম্পর্ক চিহ্নিতকরণসহ মানচিত্র প্রণয়ন করতে হবে।	Image প্রসেসিং এর জন্যে average year condition (1 in 2.33 year) বিবেচনা করে dry এবং wet season অনুযায়ী জলাভূমি ও নদীসমূহের আন্ত:সম্পর্ক চিহ্নিতকরণসহ মানচিত্র প্রণয়ন করা হয়েছে যাহা Volume-I: Section-7.5 এ বর্ণিত করা হয়েছে ।
৩.	Sentinel-I (SAR) সেটেলাইট ইমেজ ক্লাসিফাই করে বর্ষা মৌসুমের জলাশয়ের সীমানা নির্ধারণ করা এবং Sentinel-II অথবা LandSat 8 (মেঘমুক্ত) সেটেলাইট ইমেজ ক্লাসিফাই করে শুষ্ক মৌসুমের জলাশয়ের সীমানা নির্ধারণ করতে হবে।	Sentinel-I (SAR) সেটেলাইট ইমেজ ক্লাসিফাই করে বর্ষা মৌসুমের জলাশয়ের সীমানা নির্ধারণ করা এবং Sentinel-II অথবা LandSat 8 (মেঘমুক্ত) সেটেলাইট ইমেজ ক্লাসিফাই করে শুষ্ক মৌসুমের জলাশয়ের সীমানা নির্ধারণ করা হয়েছে যাহা Volume-I: Section-7.2 এ বর্ণিত করা হয়েছে ।
৪.	সমগ্র টাঙ্গুয়ার হাওর (১২০ বর্গ কিমি) এলাকায় LiDAR survey করতে হবে। এ বিষয়ে বাংলাদেশ হাওর ও জলাভূমি উন্নয়ন অধিদপ্তর পানি সম্পদ মন্ত্রনালয়ের মাধ্যমে হাওরের নো ফ্লাই জোনে বিমান চলাচলের বিষয় ভারত সরকাররক অবহিত করার পদক্ষেপ গ্রহন করবে ।	টাঙ্গুয়ার হাওর ও পার্শ্ববর্তী এলাকার ১৫৪ বর্গ কিমি এলাকায় LiDAR survey করা হয়েছে যাহা Volume-I: Section-7.3 ও Volume-II: Appendix-B এ বর্ণিত করা হয়েছে ।
৫.	পরামর্শক প্রতিষ্ঠান পরবর্তী PIC সভায় একটি Sample work উপস্থাপন করবে।	PIC সভায় একটি Sample work উপস্থাপন করা হয়েছে।
৬.	প্রকল্পের PIC কমিটিতে জনাব মোঃ নুরুল আমিন, পরিচালক (প্রশাসন ও অর্থ), বাহাজউঅ কে কো-অপ্ট করার সিদ্ধান্ত গৃহীত হয়।	প্রকল্পের PIC কমিটিতে জনাব মোঃ নুরুল আমিন, পরিচালক (প্রশাসন ও অর্থ), বাহাজউঅ কে কো-অপ্ট করা হয়।
৭.	আগামী ২০১৮-১৯ অর্থ বছরে ১৫৮৫.৪২ লক্ষ টাকা (প্রস্তাবিত ২য় সংশোধনী মোতাবেক) বা প্রয়োজনীয় অর্থ সংস্থানের ব্যবস্থা গ্রহন করতে হবে।	প্রয়োজনীয় ব্যবস্থা গ্রহন করা হয়েছে।
৮.	প্রকল্প পরিচালক প্রকল্পের ২য় সংশোধন অনুমোদন বিষয়ে প্রয়োজনীয় ব্যবস্থা গ্রহন করবে।	প্রয়োজনীয় ব্যবস্থা গ্রহন করা হয়েছে।
৯.	পরামর্শক প্রতিষ্ঠান টাঙ্গুয়ার হাওর ও হাকালুকি হাওরের বিস্তারিত তথ্য সংগ্রহ করতে হবে এবং প্রাকৃতিক মৎস্য প্রজনন স্থানসমূহ চিহ্নিত করবে।	পরামর্শক প্রতিষ্ঠান টাঙ্গুয়ার হাওর ও হাকালুকি হাওরের বিস্তারিত তথ্য সংগ্রহ করেছে যাহা Volume-I: Section-6.5 ও Volume-II: Appendix-E to Appendix-J এ বর্ণিত করা হয়েছে ।
১০.	পরামর্শক প্রতিষ্ঠান আগামী তিন মাসের মধ্যে প্রত্যেক বিভাগ/জেলায় উল্লেখযোগ্য দুইটি জলাভূমির যাবতীয় তথ্যাদি সংগ্রহ করে বাংলাদেশ হাওর ও জলাভূমি উন্নয়ন অধিদপ্তরের মাধ্যমে পানি সম্পদ মন্ত্রণালয়ে দাখিল করবে।	প্রত্যেক বিভাগ/জেলায় দুইটি জলাভূমির যাবতীয় তথ্যাদি সংগ্রহ করে বাংলাদেশ হাওর ও জলাভূমি উন্নয়ন অধিদপ্তরে প্রেরন করা হয়েছে।
১১.	জলাভূমি ও নদীর মধ্যে সংযোগ স্থাপনের ক্ষেত্রে প্রয়োজনীয় দিকনির্দেশনা উল্লেখপূর্বক প্রতিবেদন দিতে হবে ।	জলাভূমি ও নদীর মধ্যে সংযোগ স্থাপনের ক্ষেত্রে প্রয়োজনীয় দিকনির্দেশনা উল্লেখপূর্বক প্রতিবেদন প্রস্তুত করা হয়েছে যাহা Volume-I: Section-7.5 এ বর্ণিত করা হয়েছে ।

4th PSC meeting, Date: 15.01.2019		
Sl. No.	**Comments and Suggestions**	**IWM Compliance**
১.	স্টিয়ারিং কমিটির পূর্ববর্তী ১ম, ২য় ও ৩য় সভার সিদ্ধান্তের বাস্তবায়ন নিশ্চিত করতে হবে	
২.	ভারত সরকারের অনুমতি না পাওয়া গেলে বাংলাদেশ-ভারত সীমান্তে No Fly Zone বহির্ভূত টাঙগুয়ার হাওর ও তদসংলগ্ন মোট ১২০ বর্গ কি.মি. এলাকায় বিমানের সাহায্যে LiDAR survey সম্পন্ন করতে হবে। এক্ষেত্রে কেবল বেসামরিক বিমান চলাচল কর্তৃপক্ষের অনুমতি গ্রহণপূর্বক জরিপ কাজ সম্পন্ন করতে হবে।	টাঙ্গুয়ার হাওর ও পার্শ্ববর্তী এলাকার ১৫৪ বর্গ কিমি এলাকায় LiDAR survey করা হয়েছে যাহা Volume-I: Section-7.3 ও Volume-II: Appendix-B এ বর্ণিত করা হয়েছে ।
৩.	সমীক্ষা প্রকল্পটির ডিপিপির ToR অনুযায়ী শুষ্ক মৌসুমে একবার লাইডার সার্ভে সম্পন্ন করতে হবে।	টাঙ্গুয়ার হাওর ও পার্শ্ববর্তী এলাকার ১৫৪ বর্গ কিমি এলাকায় একবার LiDAR survey করা হয়েছে।
৪.	বিদেশী বিমানের পরিবর্তে বাংলাদেশ বিমান বাহিনীর হেলিকপ্টার ব্যবহারের কারিগরী সুবিধা/অসুবিধা, জরীপ কাজে ব্যয় সাশ্রয়ের পরিমান ও ব্যয় পরিশোধের ধরণ সম্পর্কে জরুরীভিত্তিতে প্রকল্প পরিচালক মন্ত্রণালয়ে প্রতিবেদন দাখিল করবে।	পরামর্শক প্রতিষ্ঠান SKM GIS Air এর মাধ্যমে LiDAR survey সম্পন্ন করেছে।

5th PSC meeting, Date: 13.11.2019		
Sl. No.	**Comments and Suggestions**	**IWM Compliance**
১.	বর্ষা ও শুষ্ক মৌসুমে দেশের জলাভূমি, নদী/খাল ও পুকুরের আয়তন চিহ্নিত করে প্রকল্প বাস্তবায়ন কমিটির সিদ্ধান্ত মোতাবেক নমুনা মানচিত্র অনুমোদন করা যেতে পারে।	বর্ষা ও শুষ্ক মৌসুমে দেশের জলাভূমি, নদী/খাল ও পুকুরের আয়তন চিহ্নিত করে প্রকল্প বাস্তবায়ন কমিটির সিদ্ধান্ত মোতাবেক জলাশয়ের মানচিত্র প্রস্তুত করা হয়েছে।
২.	জলাভূমির Inventory তে জলাভূমির অবস্থান (জেলা, উপজেলা, ইউনিয়ন ও মৌজা) ও আয়তন সন্নিবেশ করতে হবে এবং কেবল হাকালুকি ও টাঙ্গুয়ার হাওরের Historical background সংক্রান্ত তথ্য সংগ্রহ করতে হবে।	জলাভূমির Inventory তে জলাভূমির অবস্থান (জেলা, উপজেলা, ইউনিয়ন ও মৌজা) ও আয়তন সন্নিবেশ করে চূড়ান্ত করা হয়েছে যাহা Volume-I: Section-7.2 এ বর্ণিত করা হয়েছে ।
৩.	Wetland management piloting পূর্বক Best Wetland Management Practice নির্ণয় এবং Cluster ভিত্তিক Wetland management framework তৈরী করতে হবে।	Wetland management piloting পূর্বক Best Wetland Management Practice নির্ণয় এবং Cluster ভিত্তিক Wetland management framework তৈরী করা হয়েছে যাহা Volume-I: Section-7.11 ও Section-7.12 এ বর্ণিত করা হয়েছে ।
৪.	LiDAR Survey মাধ্যমে সংগৃহীত ও প্রক্রিয়াকৃত ডাটাসমৃদ্ধ Survey report টি কার্যাদেশের শর্তাদিপূরন বিষয়ে কার্যাদেশ প্রদানকারী কর্তৃপক্ষের সন্তুষ্টিসাপেক্ষে গ্রহন করা যেতে পারে।	LiDAR Survey মাধ্যমে সংগৃহীত ও প্রক্রিয়াকৃত ডাটাসমৃদ্ধ Survey report টি Volume-I: Section-7.3 ও Volume-II: Appendix-B এ বর্ণিত করা হয়েছে ।
৫.	চলমান ও ভবিষ্যত প্রকল্পের মাধ্যমে সংগৃহীত তথ্যাদি সংরক্ষন ও ব্যবহারের জন্যে বাহাজউঅ সংক্রান্ত সক্ষমতা বৃদ্ধির ব্যবস্থা গ্রহণ করবে।	বাহাজউঅ প্রয়োজনীয় ব্যবস্থা গ্রহন করবে।
৬.	এ প্রকল্পের মাধ্যমে চিহ্নিত জলাভূমিসমূহের বিস্তারিত তথ্য সংগ্রহ করা এবং জলাশয় Restoration এবং Protection এর জন্যে এবং সারা দেশে LiDAR survey এর মাধ্যমে তথ্য সংগ্রহের জন্য চলমান প্রকল্পটির দ্বিতীয় পর্যায়ের প্রকল্প প্রস্তাব তৈরী করা যেতে পারে; প্রয়োজনে প্রকল্প প্রণয়ন কমিটিও তৈরী করা যেতে পারে।	চলমান প্রকল্পটির দ্বিতীয় পর্যায়ের প্রকল্প প্রস্তাব তৈরী করার লক্ষ্যে প্রকল্প প্রণয়ন কমিটি তৈরী করা হয়েছে এবং প্রকল্প প্রস্তাব তৈরীকরণ প্রক্রিয়াধীন আছে ।

7.11 Piloting Site Selection, Monitoring and Evaluation of Piloting

Depending on various local (resource depletion) and global (donor funding) factors, the state often intervenes to protect its bio-diversity. Such intervention is often essential because, on the one hand, the state does not want its citizens to remain overly dependent on a natural resource, thereby causing its depletion, while on the other hand, intervention helps to maintain the delicate ecological balance of the country. Baikka Beel (the first and only permanent wetland sanctuary in Bangladesh) is one such case where the Government of Bangladesh (GoB) intervened, because an excessive dependency on and misuse of the wetland had been causing large-scale bio-diversity extinctions since the 1990s (Mukul 2007).

This conservation project evolved from the Bangladesh Ministry of Land's (MoL) realization that a multi-party conservation approach in small areas has the potential to sustain the ecology and bio-diversity while at the same time protecting the livelihood of hundreds of people living in the vicinity. In 2003, the Government of Bangladesh declared Baikka Beel, a 100-hectare wetland as a permanent wetland sanctuary conservation project intended to preserve its fish breeding and bio-diversity. Since 2003, when the Baikka Beel area was declared as a sanctuary zone, it has been considered a safe haven for birds, reptiles, mammals and fish and from 2004 onwards all fishing, hunting and aquatic plant collection was banned (although limited fishing rights were given to selected people, who were awarded lease by the local government). Consequently, it was observed that the wetland sanctuary declaration resulted in increased fish size and abundance (Dev 2011).

During the dry season, the haors tend to dry up significantly, but Baikka Beel retains water throughout the entire year. Therefore, it is an important breeding ground for numerous aquatic and fish species, of which many are categorized as rare and endangered. It is also a premier birding destination in Bangladesh. The aquatic species that mostly shelter and breed at Baikka Beel also disperse to Hail Hoar to re-populate the region during the rainy season, thus safeguarding the availability and sustainability of natural resources.

The GoB's approach to the management of Baikka Beel is based on a multi-party participatory model in which USAID, the US-based funding agency, is the principal project donor; it supports the project through its Management of Aquatic Resources through Community Husbandry (MACH) programme. MACH began in 1998 and is implemented jointly by Winrock International, the Bangladesh Centre for Advanced Studies (BCAS), Caritas Bangladesh and the Center for Natural Resource Studies (CNRS). The major purpose of MACH is to demonstrate to communities, local government and policy makers the viability of community approaches to sustainable natural resource conservation and management in aquatic ecosystems, with the ultimate goal of ensuring food security to those dependent on wetland aquatic resources. Besides MACH, the United States Agency for International Development (USAID), Borogangina Resource Management Organization (BRMO), Ministry of Land (MoL), Social Welfare Development, Center for

Natural Resource Studies (CNRS), Integrated Protected Area Co-Management (IPAC), Chevron Bangladesh and other Resource Management Organisations (RMOs) are the stakeholders in this project.

As a part of the study, a pilot site has been selected based on four criterions such as, Physical and Hydrological Criteria, Social Criteria, Biological Criteria, Management/ General Criteria. To select a new site for piloting, it needs a longer period of monitoring as well as investments in the field for maintaining the bio-ecological ecosystem. Considering the limitation of time and financial support, Baikka beel has been selected as a pilot site as because it has been operated by Management of Aquatic Resources through Community Husbandry (MACH) program since 2003. Under this study, the impact of MACH project has been conducted in comparison between the baseline data and data collected under this study. Also, the gaps and limitations of the management approach has been evaluated in this study. For field data a collection a team comprising of fisheries expert, ecologist, forest expert, sociologist have been visited the Baikka beel area for the duration of December 10 to December 14, 2019.

The fisheries survey team applied Focus Group Discussion (FGD) and direct interviews of different stake holders viz. Key Informant Interview (KII), Personal Interview (PI) of individual fishermen and local inhabitants and as well as interviews with fish traders in a fish lending center for collection of data. For estimating fuel wood consumption, tourism impact on species and to list endangered species, vegetation survey was conducted by semi-structured questionnaire within the associate’s village and local dwellers by the forest survey team. The biodiversity survey team has conducted stakeholder consultation and field visit for identifying the faunal diversity with their abundance and distribution within and periphery of Baikka Beel as well as their biological status in Bangladesh.

Findings from the Field Survey

Since the commissioning of the BRMO, which was developed under MACH and CNRS in 2004, a number of bio – ecological, social, economic and cultural conditions have changed, impacting the lives of the people living at Baikka Beel.

Unfortunately, presently co-management organizations in the Baikka Beel of Hail haor area face a number of problems and challenges in wetland management. Presently, the government does not provide any financial support to the RMOs, so it is difficult to manage the haor efficiently and monitor it properly, concerned government officials from fishery department do not monitor regularly although they are assigned to do so (Mazumder et al, 2016).

Along with other sanctuary sites of MACH project, fish species diversity has been assessed as base line survey in most of the beels including Baikka Beel at Hail Haor area during 1999 – 2004. Within those periods the number of fish species recorded in those wetlands from minimum 71 nos. of species and maximum 85 nos. of species (MACH, 2003; Haque, 2013). Kabeer (2013) reported that Baikka Beel once was famous for it's rich fisheries and as a spawning and nursery grounds of indigenous fish species. Present study also reveals these facts that as a sanctuary, which has been well managed by a local beel management committee but in practical the scenario of fisheries resources and biological diversity conditions of Baikka Beel was little bit different. According to the opinion of all the stakeholders consulted at FGD and interviews of PI and KII, a total of 46 nos. of fish species is available, although there was no scope of estimating available fish species directly from a number of fish catching efforts in the beel due to dry season, no such fishermen were found to fish over there. Among the available 46 nos. of indigenous fish species, 22 nos. of less available species (48%), 07 nos. of rarely available species (15%), total 63% species as shown in Figure 7-33 are categorised as vulnerable species, which could be threatened and endangered within a few years of time if better wetland management practices as well as conservation effort of biodiversity of these species are ascertained at Baikka beel and other adjacent beel and action taken accordingly.

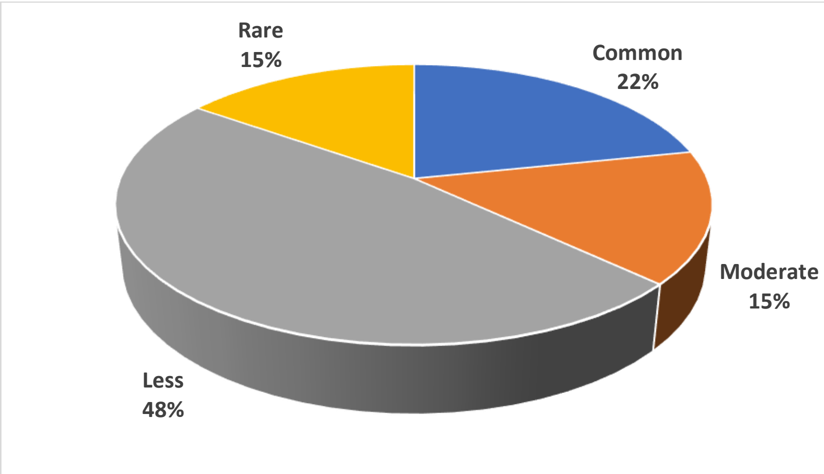


Figure 7-33: Comparison of Presently Available Fish Species of Baikka Beel

The main reasons of such vulnerability of good number of fish species in this water body are i) heavy growth of aquatic weeds like water hyacinth, water lily, lotus etc. inside the beel area; ii) siltation and sedimentation reduced drastically the water level during dry season; iii) insufficient number of brush shelters inside the beel; although the water body is under sanctuary but occurring of undesirable poaching of fish during that season etc., all those are severely hindering fish breeding and spawning habitat to recruit enough number of indigenous fish species in Baikka beel and other adjacent wetland of Hail Haor area. The list of fish species that are not presently available in Baikka Beel is shown in Table 7-22 which reveals that a total of 7 nos. of species are not available at Baikka Beel as well at some other adjacent beels of Hail Haor area.

Table 7-22: List of Fish Species not Presently Available in Baikka Beel

Sl. No.	Local/Common Name	Species	Fish Type	Availability Status
1	Chang	*Channa orientalis*	Medium	NA
2	Ekthuta	*Hyporamphus limbatus*	Medium	NA
3	Dhela	*Osteobrama cotio*	Small	NA
4	Chapila	*Gaduasia chapra*	Small	NA
5	Bata	*Labeo bata*	Medium	NA
6	Batashi	*Pseudeutropius atherinoides*	small	NA
7	Kajuli	*Ailia coila*	small	NA

Note: Not Available: NA

The fishermen group reported that drastic environmental changes such as incidences of flash floods, which had a negative impact on the fish and prevented these participants from working as fishermen throughout the years. Some of the small-scale commercial and subsistence fishermen in the area observed that despite an increase in the quantity of fish in the beel (due to the conservation regulation), they were not able to catch fish freely because they couldn't gain fishing rights under the regulation. On the other hand, the BRMO allowed business people coming from outside the area to lease a portion of the sanctuary and harvest fish in a regulated way. Such a dual practice fuelled animosity among the direct stakeholders, although BRMO stakeholders tried to negotiate between business people and fishermen.

The tree vegetation diversity of Baikka beel were analysed using the quantitative indexing approaches, the Shannon- Wiener index indicate the diversity status of the site where as Magalef index is showing the richness and Simpson is showing the dominance. The study found the tree vegetation diversity is quite good as the Shannon index is around 0.68 in range of (0 to 1). The tree vegetation diversity of Baikka beel has been given in the Table 7-23. List of floral species and their status in the Baikka beel area has been shown in Table 7-24.

Table 7-23: Total Species Recorded and Studied with Values of Shannon-Wiener Index (Diversity), Margalef Index (Richness) and Simpson Index (Dominance)

Season	No. Species	Shannon Index (Diversity)	Margalef Index (Richness)	Simpson Index
Dry	19	0.68	0.55	0.42

Table 7-24: List of Floral Species and their Status at the Baikka Beel Area

Abundantly Found Trees	Trees Sparsely Found (becoming rare)	Trees Lost from Ecosystem
Acacia auriculiformis (Akashmoni)	*Anthocephalus indicus* (Kadam)	*Anthocephalus indicus* (Kadam)
Albizia lebbeck (Koroi)	*Barringtonia acutangula* (Hijol)	*Schumannianthus dichotomus (Murta)*
Barringtonia acutangula (Hijol)	*Ficus bengalensis* (Bot)	
Bombax ceiba (Shimul)	*Lagerstroemia speciosa* (Jarul)	
Elaeocarpus serratus (Jolpai)	*Millettia pinnata* (Koroch)	
Ficus bengalensis (Bot)	*Terminalia arjuna* (Arjun)	
Lagerstroemia speciosa (Jarul)	*Trewia polycarpa* (Pitali)	
Millettia pinnata (Koroch)	*Bombax ceiba* (Shimul)	
Samanea saman (Raintree)		
Spondias mombin (Amra)		
Syzygium cerasoides (Kalo Jam)		
Terminalia arjuna (Arjun)		
Trewia polycarpa (Pitali)		
*Arundo donax (*Nal Khagra) shrub		
Typha elephantiana		
Nymphaea nouchali (water lily)		

Though a management approach exists there, the Table 7-24 shows that about 8 nos. of tree species are becoming rare whereas 2 nos. of tree species totally lost from the ecosystem of Baikka beel.

The biodiversity team organized local stakeholder's consultation for assessing the present conditions of biodiversity. Multi-dimensional comments or opinions have been received from the local stakeholders. However, major findings of those consultation sessions are summarized below in brief:

- Baikka Beel biodiversity seems to be reducing due to various reasons; most faunal biodiversity exists within and periphery of beel and peripheral villages. In past, Baikka Beel was rich with faunal diversity, especially for the migratory avian species. Short stay duration of migratory bird inside the beel occurs now, due to various reasons such as disturbance of migratory bird habitats, illegal wildlife / bird hunting & fish collection - especially at night, etc. Suggested to ensure active monitoring program on the issues by strengthen the local resource management organization (RMO) via GoB.
- Peripheral villagers have some knowledge on local biodiversity that exists within and outside of their villages. Some peripheral village fauna uses the peripheral beel land and water-bodies as their habitat (seasonal and/ or permanent). Faunal population are

decreasing continuously due to over exploitation of natural resource (legal & illegal), habitat disturbance, illegal hunting, etc. Suggested to ensure regular awareness program to the peripheral villagers on faunal diversity conservation and its importance to nature and human society.

- Precise boundary of Baikka Beel is not yet well defined; peripheral villagers and other powerful people sometime use the Beel land as per their need and also for their economic benefit by ignoring Baikka Beel's contribution to the natural environment and the nearby human society. Outer boundary of Baikka Beel area needs to be ensured exactly, and people interference and resource collection needs to be restricted by the GoB.
- Current management on Baikka Beel is weak in comparison to that of past by local RMO. Some illegal fish collection and fishery related activities occur inside the beel, occasionally, and the RMO can't handle those issues timely due to lack of resources.
- Faunal diversity is decreasing due to weak management on Baikka Beel by local RMO. Few avian diversity is noticeable mainly in winter season including few migratory birds, but many other types of biodiversity always exist there, and play vital roles in the existing natural environment. Suggested to ensure strengthen of local RMO via GoB.
- Pesticides use for agriculture and herbicide use in tea garden also pollutes the beel land and its water-bodies, both in dry and rainy season. Suggested to ensure banning of pesticide use for agricultural activities and herbicide in the tea garden.
- The number & type of migratory birds as well as other wild life species are decreasing due to the multifarious disturbances, habitat destruction, hunting, food scarcity, pesticide use, etc. Suggested to expand more restricted areas for wild life and fish species, create more public awareness for non-use of agro-pesticide or tea garden herbicide, etc.
- All sorts of fish, fish fry, fish egg and other natural resources are harvesting from the beel, indiscriminately at all nights, and some of these are use as food by specific wetland dependent wild life species; weak monitoring exists on it by RMO. Suggested to ensure effective monitoring program on it throughout the year from GoB as well as ensure punishment for violation of management rules.
- Tourism activities are increasing at Baikka Beel that also disturbs the faunal habitat, their movement, breeding places, etc. It is suggested to restrict the tourism aspects under direct GoB supervision, not through RMOs.

7.12 Wetland Management Framework and Best Management Practice

The study proposes a participatory collaborative management regime for the wetland's management in Bangladesh. A bottom up approach has been proposed in the decision-making process regarding wetland management. The study proposes a five tier organizational structure from local level to national level for wetland management. Relevant stakeholders i.e. governmental agencies (Department of Bangladesh Haor and Wetlands Development, Department of fisheries, Forest department, Department of agriculture, civil administration), elected representatives (local government), users of the wetlands, local elites (religious leader, teachers etc.), relevant entrepreneur, civil society representative, journalist and NGO representative will be the participating actors in different tiers of the Co-management/ collaborative management organizations. The Figure 7-34 gives a schematic diagram of the proposed wetland management regime.

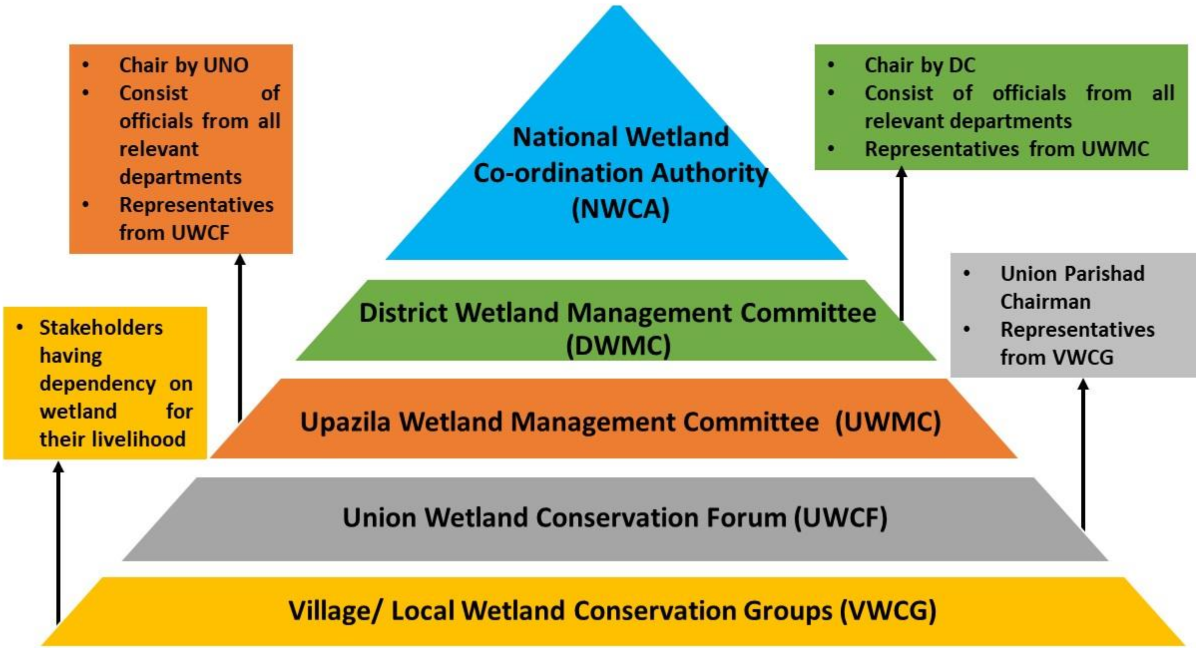


Figure 7-34: Proposed Wetland Co-management Regime

Terms of Reference (ToR) for Community Wetland Management Organization (CWMO) and National Wetland Coordination Authority (NWCA) are given in the Table 7-25.

Table 7-25: ToR of CWMO and NWCA

Organization	Terms of reference
Village/ Local Wetland Conservation Groups (VWCG)	• Organize community groups, which will act as the local management committee. • Develop a management plan with the local community. • Provide training to groups on conservation and sustainable uses.
Union Wetland Conservation Forum (UWCF)	• Endorse, coordinate and oversee the management plan developed by Village Level Committee.

	• Conduct training programs on wetland and floodplain resource management for local committee groups, fisher-folks, farmers, nursery owner and others.
Upazila Wetland Management Committee (UWMC)	• Identify the problems and recommend the potential solutions to overcome the wetland degradation, • Plans for habitat restoration, • Find out the problems and issues encountered by the community organizations and provide solutions accordingly.
District Wetland Management Committee (DWMC)	• Coordination among different user groups such as UWMC, UWCF and VWCG. • Distribution of benefit among the stakeholders. • Enforcement of rules and regulation for wetland management in line with Government principles. • Regular communications with NWCA or higher authorities if necessary.
National Wetland Co-ordination Authority (NWCA)	• Improve institutional and organizational arrangements; • Address legislative and policy needs; • Increase knowledge and awareness of wetland values; • Establish a participatory monitoring and evaluation system with the involvement of local government representatives; and • Identify programme priorities and develop action plans for specific sites.

Wetland Management Strategy:

The Management of wetlands ecosystem consists of the following, inter alia, (i) Regulated fishing: Commercial and non-Commercial; (ii) Controlling illegal fishing, and (iii) Ecosystem Restoration.

(i) *Regulated Fishing:* Benefit sharing formula has been notified in a central government gazette. The Ministry of Environment and Forest, Government of Bangladesh on 13 March, 2008 through a circular determined the ratio of share of fishery for the three stakeholders, namely fishermen (harvester) 40%; Community 36% and the Government 24%. The above ratio of share was determined through community level consultation discussion at the THMC, National Steering Committee and the Ministry. There has been a good income for fishers as well as for the community organization.

(ii) *Controlling Illegal Fishing:* Establishment of a magistrate and ansar system is needed. Magistrate should hold a weekly meeting with UWMC and UWCF leaders. Ansars jointly patrol with community guards, renting a boat.

(iii) *Ecosystem Restoration:* Several activities should be undertaken for ecosystem restoration, including establishment of fish and bird sanctuaries; fish nurseries; plantation of large number of Hijal and Koroch saplings.

The wetland management strategy/activity should take up the following measures:

- *Water Management*
  a. Plan on water demand for wetland ecosystem management
  b. Allocate water to meet the specific user requirement
  c. Establish operation tools for droughts, flood,
  d. Rapid and effective action to stop pollution, etc.
- *Habitat Management*
  a. Conserve quality habitat for wildlife & fish
     - ✓ Beel, swamp forest, reed bed, etc.
     - ✓ Reintroduction of tree species like Hijal, Borun, karoch
  b. Manage invasive species
     - ✓ Prevention / illumination / control, etc.
- *Species Management*
  a. Species management (threatened & interested species)
  b. Rapid action to stop illegal hunting
- *Vegetation Management*
  a. Reintroduction of tree species like Hijal, Borun, karoch along the kanda.
  b. Establish plantation of indigenous species early in dry season.
  c. Use of taller saplings for plantation to protect from ground trolling damage.
  d. Engaging VWCG and UWCF in protection of plantation.
  e. Management of grazing.
- *Fisheries Management*
  a. Establishment of haor management committee.
  b. Need co-management systems to implement in total haor area.
  c. Implement dredging of rivers, canals and beel areas for increasing water flow and depth.
  d. Establishment of effective sanctuaries in entire haor area.
  e. Creation of alternative income source during ban period for decreasing fishing pressure.
  f. Construction of eco-friendly sluice gates in in coming rivers and canals.

g. Increasing public awareness for aquatic ecosystem and conservation of fish biodiversity.

- *Management of Socio-economic Values and Uses*

a. water storage & flow regulation, drought relief, etc.

b. food, fuel & fiber (e.g. fish, agriculture, etc.)

Proposed Interventions for Wetland Management Framework:

- Establishment of effective sanctuaries for fish and birds in entire haor area
- Implement dredging of rivers, canals and beel areas for increasing water flow and depth
- Construction of eco-friendly water control structure
- Tree plantation in haor dyke areas like hijol and koros trees
- Lease collection after fish harvesting
- Alternative income generation for the fishermen during breeding season

7.13 Workshops

Workshops has been organized to disseminate the concept of the wetland inventory and cluster-wise wetland management framework to obtain national recognition of the sustainable wetland management framework of Bangladesh.

Workshops has been arranged at field level to disseminate and share the study findings with clients, beneficiaries and decision makers as shown in Figure 7-35 to Figure 7-36. The present report has been prepared incorporating the comments and suggestions of the workshops. The comments and suggestions as well as the compliance from the consultants have been illustrated in Table 7-26.

Figure 7-35: Guest Presented in the Workshop at Sylhet

Figure 7-36: Participants in the Workshop at Sylhet

Table 7-26: Comments and Compliance of Workshops

Sl. No.	Comments and Suggestions	IWM Compliance
Akhil Podder, Farmer, Taherpur		
1	Dredging of haor is needed for ecosystem restoration	Agreed and mentioned in Section – 8.2.
2	Number of security guard needs to be increased for safeguard of the haor resources.	Agreed and mentioned in Section – 8.2.
3	Alternate income sources have to be introduced to reduce the dependency on fisheries resources.	Agreed and mentioned in Section – 8.2.
4	Sufficient tree has to be planted and the catching of birds has to be prohibited.	Agreed and mentioned in Section – 8.2.
Ahmed Kabir, General Secretary, Haor Rokkha Committee, Tanguar Haor		
1	Provision of sustainable eco-tourism has to be recommended with a view to introduce the alternate sources of income for the stakeholders	Agreed and mentioned in Section – 8.2.
2	Manually driven boat rather than engine boat can be recommended to keep the ecosystem undisturbed.	Agreed and mentioned in Section – 8.2
3	Current net has to be strictly prohibited and grazing of cattle’s / bufellows has to be controlled.	Agreed and mentioned in Section – 8.2.
S4ukhlal Biswas, fisherman, Hakaluki Haor		
1	Net catching of fish has to be stopped immediately.	Agreed and mentioned in Section – 8.2.
2	Embankment at horekrishnapur and sonai char to poschim kakrai has to be constructed	This can be recommended through a detailed a feasibility study. This is beyond the ToR of the present study.
Khaled Ahmed, Farmer, Golapganj		
1	Proper monitoring has to be ensured	Agreed and mentioned in Section – 8.2.
2	Subsidy for the mechanized cultivation of agricultural sector has to be proposed.	Agreed and mentioned in Section – 7.10.5.
Md. Mokhlesur Rahman Talukder, SDE, BWDB, Moulovibazar		
1	Project has to be formulated based on the opinion of stakeholders and field data.	Agreed and mentioned in Section – 8.2.
2	Re-excavation of river/canal and construction of embankments with adequate drainage structure will be helpful for the local people.	Agreed and mentioned in Section – 8.2.
3	Rectification of govt. wetlands and lease it with a condition of protection of it and culture of fish/duck and increment of plantation can be established.	Agreed and mentioned in Section – 8.2.

4	Artificial water reservoir in the tea garden has to be established to facilitate the plantation, fish culture, duck culture etc. for remedial measures due to climate change.	This is beyond the ToR of the present study and can be conducted a separate study for the conservation of surface water in tea garden area.
5	Nursery for Hijal, Koroch etc. has to be established.	Agreed and mentioned in Section – 8.2.
Md. Sultan Mahmud, Senior Upazila Fisheries Officer, Moulovibazar		
1	LiDAR survey is highly appreciated but needs to disseminate the data among the stakeholders.	DBHWD may formulate a guideline for handing over the LiDAR data supplied by the consultant.
2	Number of available fish species should be cleared.	The number of available fish species as mentioned in this report is from a field visit, stakeholder consultations, Focus Group Discussion (FGD), Key Informant Interview (KI) and visit of fish market and landing stations. The duration of survey is only for a short time and data collected from the survey is presented in this report. A comprehensive data collection in this regard is recommended to get the actual scenario of fish species in the field.
3	Recommendation has to be detailed regarding the management of fish breeding, fish sanctuary and others.	Agreed and mentioned in Section – 8.2.
4	The road network constructed by LGED destroy the environment of haor ecosystem and a recommendation regarding this issue is needed in the report.	A separate study for environmental impact assessment may be conducted to make such a recommendation.
5	Support to fisherman during banning time of catching fishes should be promoted.	Agreed and mentioned in Section – 8.2.
Koruna Shindhu Chowdhury, Upazila Chairman, Tahirpur		
1	Production, distribution and sales of current net has to be strictly prohibited.	Agreed and mentioned in Section – 8.2.
2	Steps has to be taken to conserve the forest and plantation of trees.	Agreed and mentioned in Section – 8.2.
3	Large scale dredging through technical study and monitoring is necessary in haor area.	Agreed and mentioned in Section – 8.2.
4	The catching of fish for the duration of June to August has to be banned and incentives has to be given to fishermen.	Agreed and mentioned in Section – 8.2.
5	Natural environment has been worst due to 'Haor Utsab' in each year which needs to be stopped.	Agreed and mentioned in Section – 8.2.
Prof. Dr. Nirmal Roy, Faculty of Fishereis, Sylhet Agricultural University		
1	DBHWD has to be the apex body for the wetland management and has to take all the	Agreed and mentioned in Section – 8.2.

	programs in coordination with all other beneficiaries and stakeholders	
2	Fish catching can be banned in reserve area rather than the whole fish sanctuary.	Agreed and mentioned in Section – 8.2.
3	Pollution from different sources has to be stopped.	Agreed and mentioned in Section – 8.2.
Ashfaq Ahmed, Upazila Chairman, Sylhet Sadar, Sylhet		
1	Bodies of local government has to be promoted in the wetland management framework	Agreed and mentioned in Section – 7.12.
2	Tourism should be discouraged as it detoriate the ecosystem of wetlands.	Agreed and mentioned in Section – 8.2.
A.K.M Sofi Ahmed Solman, Upazila Chairman , Kulaura		
1	Fish sanctuary has to be protected.	Agreed and mentioned in Section – 8.2.
2	Necessary guards and their logistic support has to be ensured.	Agreed and mentioned in Section – 8.2.
Md. Nurul Islam, Upazila Chairman , Fenchuganj		
1	Juri river has to be dredged.	Not only Juri river, all the river connected to the haor is recommended for dredging as mentioned in section – 8.2.
2	Hakaluki haor has to be protected from flash flood.	Agreed and mentioned in Section – 8.2.
Mr. Bijen Benerjee, UNO, Tahirpur		
1	Vocational education has to be promoted	Agreed
2	Incentives has to be proposed for the fishermen.	Agreed and mentioned in Section – 8.2.
Mohammad Emdadul Haque, DFO, Moulovibazar		
1	The fish sanctuary in Hakaluki haor has to be restored and conserved permanently.	Agreed and mentioned in Section – 8.2.
2	Fish catching can be banned in reserve area rather than the whole fish sanctuary for one month.	Agreed and mentioned in Section – 8.2.
Mr. Soriful Islam, UNO, Moulovibazar		
1	Development projects have been lunched without considering the environmental issues.	Agreed
2	The data of wetland inventory should be disseminated to the stakeholders.	DBHWD may formulate a guideline for handing over the LiDAR data supplied by the consultant.
Mohammad Suhel Mahmud, ADM, DC office, Sunamganj		
1	Logistic support has to be provided for the close monitoring of wetlands.	Agreed and mentioned in Section – 8.2.
2	Wetland Management Framework has to be implemented by DBHWD.	Agreed

Prof. Dr. M Rashed Hasnath, Dean, Faculty of Veternery Animal and Biomedical Science, Sylhet Agricultural University		
1	Facilities for migratory bird has to be established.	Agreed and mentioned in Section – 8.2.
2	Alternate income sources have to be generated for the affected stakeholders during the implementation of wetland management framework.	Agreed and mentioned in Section – 8.2.
Prof. Dr. Mohammad Abu Syed, Dean, Faculty of Fisheries, Sylhet Agricultural University		
1	Connectivity between wetland and river has to be maintained round the year to increase the production of fish.	Agreed and mentioned in Section – 8.2.
2	A collaborative research among different institutes, universities and stakeholders should be proposed for monitoring of impacts of wetland management framework.	Agreed and mentioned in Section – 8.2.
Mr. Debjit Singha, Chief Executive Officer, Zila Porishad, Sylhet		
1	A 2nd phase of the project for detail data collection of the identified wetlands should be suggested under this study.	Agreed and mentioned in Section – 8.2.
2	Copy of the Final Reports and data should be delivered to the stakeholders.	The consultant will delivered the Final Report as per the agreement and DBHWD will take the initiatives to deliver the report to the concerned authority.
Muhammad Shahed Kabir, Director, Department of Bangladesh Haor & Wetlands Development		
3	Development project has to be taken considering the issues of nature.	Aggreged
Md. Moshiur Rahman, NDC, Divisional Commissioner, Sylhet		
1	Awareness among the different stakeholders has to be increased.	Aggreged
2	A research based on satellite observations for birds can be proposed.	Agreed and mentioned in Section – 8.2.
3	Zoning map for different uses should be established for the haor region.	A separate study for Zoning map for different uses should be established for the haor region can be conducted.
4	A combined research of different users should be proposed.	Agreed and mentioned in Section – 8.2.

7.14 Training and Technology Transfer

Technology transfer is an essential element for successful completion of a project. Training and capacity building ensure the boosting up of the capabilities of the staffs and officials from the concerned agencies/ departments. In this regard since the project is being carried out by DBHWD hence it is imperative that technology transfer through on-the-job trainings of various activities in the project, interaction meetings and study tour to the concerned officials is important.

According to the ToR the consultants have addressed this very important task through in-formal trainings which was held on the following issues:

- Application and use of wetland inventory for DBHWD/GoB officials and community peoples.
- Community based livelihoods & value chain training for community peoples.
- Study tour to Asia for DBHWD/GoB officials (DBHWD-5 persons, MoWR-5 persons, PC-2 person and WARPO – 1 person)
- In-country learning visits for DBHWD/GoB officials and community peoples

Training on application and use of wetland inventory for DBHWD/GoB officials and community peoples

The main objective of this training component was to share the DBHWD/GoB officials and community peoples on application and use of wetland inventory and wetland classification, proposed wetland management framework and other important components of the study. A several number of meetings and discussion regarding this issue was held to formulate the wetland inventory as well as proposed wetland management framework among GoB officials from different organaizations/institutes and DBHWD officials. Basically the Project Implementation Committee (PIC) which was formed with the representative from different organaizations/institutes such as MoWR, SoB, BBS, DU, BUET, GSB, BWDB, DAE, IMED, PC, DoE, SARSO, BFD, DoF, BADC, BARC and DBHWD officials are the main stakeholder of the project and took part in the knowledge sharing for wetland inventory and its application. Also, a discussion among the community people around the wetlands were conducted to aware of them about the importance of wetland and application of wetland inventory. The picture of such discussion meetings is presented in the Figure 7-37. The decisions from the above mentioned stakeholders has been incorporated into the wetland inventory to make it more convenient and user friendly. Feedback from the community peoples also used for the finalization of wetland inventory.

Figure 7-37: PIC Committee Meeting (Left) and Consultation (Right)

Community based livelihoods & value chain training for community peoples

During field data collection program, a number of discussion session was held among the different community group to disseminate the importance of wetlands, its restoration and protection, wetlands based livelihood importance and others as shown in Figure 7-38. The community people are mostly aware of the importance of wetlands and shared their knowledge on livelihood improvements. The knowledge of these sessions is presented in the consultation part of this report.

Figure 7-38: Community Consultation and Training session

Study tour to Asia for DBHWD/GoB officials (DBHWD-5 persons, MoWR-5 persons, PC-2 persons and WARPO – 1 person)

In accordance with the provision of ToR, a study tour to Indonesia and Malaysia has been conducted in two groups for the duration of 30th November 2018 to 07th December 2018 and 02nd March 2019 to 08th March 2019 for 12 persons from DBHWD, MoWR, PC and WARPO. The teams visited Tegalang Rice Terrace and wetlands, Kintamani wetland and Lake Bratan in the Bedugul Highlands in Indonesia as shown in Figure 7-39.

Figure 7-39: Study Tour to Indonesia

The teams also attended a Lecture on Wetland Hydrology at IIUM, Malaysia as shown in Figure 7-40. Team also visited to Putrajaya lake, Paya Indah Wetland and Hybrid Off-river Augmentation System (HORAS) in Bestari Jaya, Kuala Selangor, Malaysia.

Figure 7-40: Study Tour to Malaysia

The learning from the study tour can be presented as follows:

- Knowledge on wetland management without disturbing the biodiversity and natural resources.
- Idea about the restoration and protection of wetlands.
- Familiarity with the role of different institutions in the management and conservation of wetlands.
- Indication of ecosystem management of different type of wetlands.
- Knowledge about the hydrological and ecological characteristics of wetlands.
- Institutional capacity building.

<u>In-country learning visits for DBHWD/GoB officials and community peoples</u>

The consultant has conducted several field visits with project officials during field data collection program and validation of maps in the field. The project officials have received on – the –job training on field data collection such as hydrological measurement, water quality measurement, ground truthing of maps in the field, collection on agriculture, fisheries, forest, biodiversity and socio-economic data in the field as shown in the Figure 7-41 to Figure 7-43. Also, an official from IMED, Planning commission has visited the project area. The list of the visits of project officials and others are listed in Table 7-27 and Table 7-28.

Figure 7-41: In-Situ Water Quality Measurement

Figure 7-42: Bio-Diversity Consultation with Local Stakeholders at Balouhar Baor

Figure 7-43: Vegetation Survey Consultation with Local Stakeholders

Table 7-27: List of Field Visits by Project Director

Sl. No.	Duration	Location	Purpose of Visit
01	September 17, 2018 to	Tanguar Haor	• Site visit around Tanguar Haor (Sunamganj) and consultation with stakeholders,

	September 22, 2018		• Inspection of Geo-referencing survey spot. • Visit the LiDAR Survey area.
02	February 11, 2019 to February 15, 2019	Tanguar Haor and Hakaluki Haor	• Monitoring of collection of agricultural and vegetation survey • Consultation with local stakeholders
03	July 27, 2019 to July 30, 2019	Tanguar Haor and Hakaluki Haor	• Monitoring for biodiversity related data collection • Consultation with local stakeholders
04	August 27, 2019 to August 30, 2019	Hakaluki Haor	• Monitoring of collection of fisheries survey • Monitoring of water quality sampling • Consultation with local stakeholders
05	November 13, 2019 to November 15, 2019	Borobila Beel at Fulbaria, Mymensingh	• Monitoring of collection of agricultural, bio-diversity, fisheries and vegetation survey • Monitoring of water quality sampling • Consultation with local stakeholders
06	November 28, 2019 to December 04, 2019	Baluhar Baor at Kotchandpur, Jhenaidah and Borni Baor at Tungipara, Gopalganj	• Monitoring of collection of bio-diversity, fisheries and vegetation survey • Monitoring of water quality sampling • Consultation with local stakeholders
07	December 10, 2019 to December 13, 2019	Baikka Beel at Srimangal, Moulvibazar	• Monitoring of collection of bio-diversity, fisheries and vegetation survey • Monitoring of water quality sampling • Consultation with local stakeholders
08	December 24, 2019 to December 28, 2019	Beel Halti at Natore Sadar, Natore	• Monitoring of collection of agricultural, bio-diversity, fisheries, vegetation and social survey • Monitoring of water quality sampling • Consultation with local stakeholders

Table 7-28: List of Field Visits by Project Officials

Sl. No.	Name of Officials, Designation and Organaization	Objectives of field visits	Duration of visits
01.	শেখ মোঃ আব্দুর রহমান, উপ-পরিচালক, আইএমইডি	Visited sunamganj to monitor the field data collection.	১৪-১৫ নভেম্বর, ২০১৭ খ্রিঃ

8 CONCLUSION AND RECOMMENDATION

The study aims at (i) preparation of an inventory of the wetlands through classification of satellite images, (ii) assessment of interaction between haor and river ecosystems, (iii) LiDAR survey of Tanguar haor and (ii) development of region/cluster-wise wetland management framework. For fulfilment of the study objectives, the major activities that have been carried out are:

- Collection of currently available remotely sensed images of recent years, georeferenced the images and ground truthing by field survey and classification of the satellite images to identify the exact locations and boundaries of wetlands.
- LiDAR survey of Tanguar haor for an area of approximately 152 sq. km. for empirical data collection.
- Classification of wetlands of Bangladesh according to their hydrological functions, important ecosystem, ecosystem services, physiographic characteristics and demography.
- Identification of connectivity of haors and wetlands with adjacent river system.
- Development of an inventory of wetlands along with different categorical contour maps.
- Comprehensive stakeholder consultations to find out gap(s), and incorporating their suggestions for successful completion of the wetland inventory;
- Monitoring and evaluation of piloting sites to find out gap in selected best management practices.
- Finalization of wetland management framework based on their (wetlands) cluster-wise best management practices and piloting results.

8.1 Conclusions

The major findings from the study can be summarized as follows:

Findings from Delineation and Inventory of Wetland

- ➢ The total number of wetlands during wet season is about 61,150 with an area of about 1,687,312 ha whereas in dry season the number of wetlands is about 30,942 with an area of about 284,835 ha.
- ➢ The inventory has been prepared based on hydrological region of Bangladesh and the map-based output is in 1:10000 scale. A total 4443 nos. of maps have been produced to cover the whole country. The inventory is developed tabular format including the location (districts, upazila, union and mouza), area and other physical features such as geology, agro- ecological zone and bio-ecological zone and others.

- The study reveals that in average year hydrological condition, the North West (NW) region loses about 64% area of the rivers and canals in dry season with respect to the wet season water area. In terms of length the reduction of the extent of the rivers and canals in dry season is 46.69% (5,721 km) with respect to the wet season extent. In wet season the rivers and canals are connected to the closed water bodies in 725 locations whereas in dry season the connecting points reduced to 30 locations.
- The North Central (NC) region loses about 65% area of the rivers and canals in dry season with respect to the wet season water area for average year hydrological condition. In terms of length, the reduction of the extent of the rivers and canals in dry season is 49.5% (3,003 km) with respect to the wet season extent. In wet season the rivers and canals are connected to the closed water bodies in 485 locations whereas in dry season the connecting points reduced to 47 locations.
- The statistic on dry and wet season extents of the rivers and canals reveals that the North East (NE) region loses about 47% area of the rivers and canals in dry season with respect to the wet season water area and in terms of length the reduction of the extent of the rivers and canals in dry season is 55% (5,916 km) with respect to the wet season extent. The rivers and canals are connected to the closed water bodies in 1315 and 56 points in wet and dry season respectively.
- The South East (SE), South Central (SC) and South West (SW) regions loses about 52.71%, 11.36% and 7.44% area of the rivers and canals in dry season with respect to the wet season water area respectively. In terms of length, the reduction of the extent of the rivers and canals in dry season is 62% (2,880 km), 18.47% (1,356 km) and 20.65% (3,720 km) with respect to the wet season extent for SE, SC and SW region respectively.
- The Eastern Hill (EH) region loses about 17.33% area of the rivers and canals in dry season with respect to the wet season water area for average year hydrological condition. In terms of length, the reduction of the extent of the rivers and canals in dry season is 36.21% (2,882 km) with respect to the wet season extent. In wet season the rivers and canals are connected to the closed water bodies in 778 locations whereas in dry season the connecting points reduced to 79 locations.
- The number of ponds having an area greater than 0.17 ha has been digitized for capturing the complete picture of the closed water body in the country. The number of ponds found to be 184346 for North – western hydrological region whereas 102196 nos. of ponds belongs to North – central region. The North – eastern region has 72657 nos. of ponds whereas South – eastern, Eastern hill, South – central and South – western has 6886, 38087, 61412 and 89197 nos. of ponds respectively.
- Most of the area of wetlands in Bangladesh falls under the category of Ganges tidal floodplain (41.37%) which is followed by high Ganges river floodplain (12.87%) and then Northern and Eastern hills (10.86%). The minimum area of wetland covers

Akhaura terrace (0,01% of the total wetland area). It can also be concluded that about 65.45% area of wetlands is under three dominant agro-ecologiical zones namely Ganges tidal floodplain, Ganges river floodplain and Northern and Eastern hills.

- The study reveals that Saline Tidal Floodplain covers about 38% of the total wetland area in Bangladesh. The Chittagong Hills and CHTs is the 2nd highest bio-ecological zone which covers about 37322 ha (13%) of total wetland area which is followed by Ganges Floodplain (10%). The study also indicates that Chakaria Sundarban zone contains the minimum wetland area (only 17 ha).

Findings from the Study of Interaction between Haor and River Ecosystem

Three major river systems govern in the haor area inside Bangladesh: the Surma-Baulai, the Kalni- Kushiyara and the Kangsa-Dhanu. The Surma is the main river of this system which fed by Barak River. The Baulai is another important river of this system which flows entirely within Bangladesh. Major tributaries of Surma-Baulai river system are Sarigowain, Piyan, Dhalagang, Chela, Jalukhali, Jadukata and Someswari rivres. This river system meets the Kalni-Kushiyara system at Bajitpur upazila of Kishoreganj district. The main left tributaries of Kushiyara river are Sonai-Bardal river, Juri river and Manu river. The combined flow of the Dhanu River and Baulai River forms the Ghora-Utra River.

The faunal biodiversity prefers to utilize some components of haor ecosystem, rather than river ecosystem, because resources collection from haor is quite easy, especially in winter season. It has been observed that native faunal species prefer to use the connecting areas of haor and river ecosystem in compare to migratory faunal species; this happened due to tolerance behavior of native fauna on presence of anthropogenic activities.

Backwater from the Surma- Jadukata-Baulai River system intrudes the haor in pre-monsoon. Simultaneously, rainwater from the Meghalayan hilly areas flows into the haor through a good number of small streams. Its morphological shape, topography, inter-connectivity among the water bodies, shallow and deep levees/ridges, emergent vegetation, reed lands and swamp forest serve as the most prolific ground for breeding, nursing, grazing and sheltering place for fish species. Its low sediment, less turbid and transparent water facilitates photosynthesis process that promotes huge phytoplankton growth. The rich nutrient content with good water quality of this wetland promotes the growth of zooplankton, bentho-zooplankton and periphyton. The reeds, grass, and emergent vegetation, rivers and streams facilitate breeding and hatching process of the fish species.

Tanguar and Hakaluki Haor falls under freshwater wetland and have a unique freshwater ecosystem where biotic [living (e.g. flora, fauna. microbes, etc.)] and abiotic [e.g. non-living (physical & chemical components)] community interact with each other at various trophic level. The interactions within communities of organisms at population and community level play a key role in determining the stability and resilience of the ecosystem as a whole. Communities are structured by multiple biotic processes, and external conditions may strongly influence the outcome.

Tanguar Haor has lentic (still) water and its associated rivers have lotic (flowing) water. Three rivers such as Jadukata River, Boulai River and Patnai River have been identified that have direct connection with Tanguar Haor. It has known from stakeholder consultations that upstream water, from more than 30 streams of Meghalaya Hills of India, also enters into the Tanguar Haor in the rainy season and enriches its ecosystem.

Like Tanguar Haor, Hakaluki Haor has also lentic (still) water and its associated rivers have lotic (flowing) water. A total of five rivers namely (i) Juri / Kantinala River, (ii) Sonai / Bordol River, (iii) Damai River, (iv) Fanai River and (v) Kuiachara River, have direct connection with the Hakaluki Haor.

The fish population dynamics of Tanguar Haor is intensively influenced with the hydrological regime of this wetland. Fish movement occurs beel to beel and migration occurs beel to river or vice-versa. In Tanguar Haor, migration takes place beel to beel through a river, Tanguar Haor to the Surma River, Tanguar Haor to the Jadukata River or vice-versa.

In Tanguar haor, in the pre-monsoon, major carps like Rui, Catla and Mrigel go long distances to find suitable place and environment for breeding. The fertilized eggs roll down with river current and within 4 days' time they enter into the floodplain adjacent to the river (Ahmed, 2015). Minor carps, catfishes and barbed fish species move to the flowing rivers/streams/ canals and breed in the shrubs/grasses of the adjacent levees/ridges in the early monsoon.

From the river Kushiyara, there are frequent upstream movement of fish towards the beels and tributaries of Hakaluki haor. The beels in Hakaluki haor provide winter shelter for the mother fisheries. In early monsoon these mother fisheries produce millions of fries for the entire downstream fishing communities.

Findings from Piloting Study

As a part of the study, a pilot site has been selected based on four criterions such as, Physical and Hydrological Criteria, Social Criteria, Biological Criteria, Management/ General Criteria. To select a new site for piloting, it needs a longer period of monitoring as well as investments in the field for maintaining the bio-ecological ecosystem. Considering the limitation of time and financial support, Baikka beel has been selected as a pilot site as because it has been operated by Management of Aquatic Resources through Community Husbandry (MACH) program since 2003. Under this study, the impact of MACH project has been conducted in comparison between the baseline data and data collected under this study. Also, the gaps and limitations of the management approach have been evaluated in this study.

Findings from the Field Survey of Pilot Site

- ✓ Since the commissioning of the BRMO, which was developed under MACH and CNRS in 2004, a number of bio – ecological, social, economic and cultural conditions have changed, impacting the lives of the people living at Baikka Beel.
- ✓ Unfortunately, presently co-management organizations in the Baikka Beel of Hail haor area face several problems and challenges in wetland management. Presently, the government does not provide any financial support to the RMOs, so it is difficult to manage the haor efficiently and monitor it properly,
- ✓ During 1999 – 2004, the number of fish species recorded in Baikka beel varies from minimum 71 nos. of species and maximum 85 nos. of species (MACH, 2003; Haque, 2013). Present study also reveals these facts that as a sanctuary, which has been well managed by a local beel management committee, but in practical the scenario of fisheries resources and biological diversity conditions of Baikka Beel was little bit different. A total of 46 nos. of fish species is available. Among the available 46 nos. of indigenous fish species, 22 nos. of less available species (48%), 07 nos. of rarely available species (15%), i.e. total 63% species are categorised as vulnerable species, which could be threatened and endangered within a few years of time if better wetland management practices as well as conservation effort of biodiversity of these species are ascertained at Baikka Beel and other adjacent beel and action taken accordingly.
- ✓ The main reasons of such vulnerability of good number of fish species in this water body are:
  - i) Heavy growth of aquatic weeds like water hyacinth, water lily, lotus etc. inside the beel area;
  - ii) Siltation and sedimentation reduced drastically the water level during dry season;
  - iii) Insufficient number of brush shelters inside the beel; although the water body is under sanctuary but occurring of undesirable poaching of fish during that season etc., all those are severely hindering fish breeding and spawning habitat to recruit enough number of indigenous fish species in Baikka beel and other adjacent wetland of Hail Haor area.
- ✓ The fishermen group reported that drastic environmental changes such as incidences of flash floods, which had a negative impact on the fish and prevented these participants from working as fishermen throughout the years. Some of the small-scale commercial and subsistence fishermen in the area observed that despite an increase in the quantity of fish in the beel (due to the conservation regulation), they were not able to catch fish freely because they couldn’t gain fishing rights under the regulation. On the other hand, the BRMO allowed business people coming from outside the area to lease a portion of the sanctuary and harvest fish in

a regulated way. Such a dual practice fueled animosity among the direct stakeholders, although BRMO stakeholders tried to negotiate between business people and fishermen.

- ✓ The tree vegetation diversity of Baikka beel were analyzed using the quantitative indexing approaches, the Shannon- Wiener index indicate the diversity status of the site where as Magalef index is showing the richness and Simpson is showing the dominance. The study found the tree vegetation diversity is quite good as the Shannon index is around 0.68 in range of (0 to 1).
- ✓ Though a management approach exists there, the study reveals that about 8 nos. of tree species are becoming rare, whereas 2 nos. of tree species totally lost from the ecosystem of Baikka beel.
- ✓ Baikka Beel biodiversity seems to be reducing due to various reasons; most faunal biodiversity exists within and periphery of beel and peripheral villages. In past, Baikka Beel was rich with faunal diversity, especially for the migratory avian species. Short stay duration of migratory bird inside the beel occurs now, due to various reasons such as disturbance of migratory bird habitats, illegal wildlife / bird hunting & fish collection - especially at night, etc. Suggested to ensure active monitoring program on the issues by strengthen the local resource management organization (RMO) via GoB.
- ✓ Peripheral villagers have some knowledge on local biodiversity that exists within and outside of their villages. Some peripheral village fauna uses the peripheral beel land and water-bodies as their habitat (seasonal and/ or permanent). Faunal population is decreasing continuously due to over exploitation of natural resource (legal & illegal), habitat disturbance, illegal hunting, etc. It is recommended to ensure regular awareness program to the peripheral villagers on faunal diversity conservation and its importance to nature and human society.
- ✓ Precise boundary of Baikka Beel is not yet well defined; peripheral villagers and other powerful people sometime use the Beel land as per their need and also for their economic benefit by ignoring Baikka Beel’s contribution to the natural environment and the nearby human society. Outer boundary of Baikka Beel area needs to be ensured exactly, and people interference and resource collection needs to be restricted by the GoB.
- ✓ Current management on Baikka Beel is weak in comparison to that of past by local RMO. Some illegal fish collection and fishery related activities occur inside the beel, occasionally, and the RMO can’t handle those issues timely due to lack of resources.
- ✓ Faunal diversity is decreasing due to weak management on Baikka Beel by local RMO. Few avian diversities are noticeable mainly in winter season including few migratory birds, but many other types of biodiversity always exist there, and play

vital roles in the existing natural environment. Suggested to ensure strengthen of local RMO via GoB.

- ✓ Pesticides use for agriculture and herbicide use in tea garden also pollutes the beel land and its water-bodies, both in dry and rainy season. Suggested to ensure banning of pesticide use for agricultural activities and herbicide in the tea garden.
- ✓ The number & type of migratory birds as well as other wild life species are decreasing due to the multifarious disturbances, habitat destruction, hunting, food scarcity, pesticide use, etc. Suggested to expand more restricted areas for wild life and fish species, create more public awareness for non-use of agro-pesticide or tea garden herbicide, etc.
- ✓ All sorts of fish, fish fry, fish egg and other natural resources are harvesting from the beel, indiscriminately at all nights, and some of these are use as food by specific wetland dependent wild life species; weak monitoring exists on it by RMO. Suggested to ensure effective monitoring program on it throughout the year from GoB as well as ensure punishment for violation of management rules.
- ✓ Tourism activities are increasing at Baikka Beel that also disturbs the faunal habitat, their movement, breeding places, etc. Suggested to restrict the tourism aspects via direct GoB supervision, not through RMOs.

Findings of Ecosystem Boundary Delineation

The probable faunal ecosystem boundary at different wetlands has been delineated in general-way, based on macro-scale assessment via field observation and literature review.

The major eco-components of faunal biodiversity are (i) Amphibia, (ii) Reptile, (iii) Aves and (iv) Mammal.

Amphibia: The amphibian species require both water and land for their survival. The travel distance varies among the amphibian species, and in general, maximum travel distances of some amphibian species (terrestrial & aquatic) are in between 300 to 500 meter from the wetlands. So, this distance could be the probable home range / ecosystem boundary for the amphibian species.

Reptile: Reptilian species vary among themselves, and most species require both water and land for their survival. The travel distance varies among the reptilian species, and in general, maximum travel distance of few reptilian species could be in between 0.5 to 1.0 km from the wetland. So, this distance could be the probable ecosystem boundary for the reptilian species.

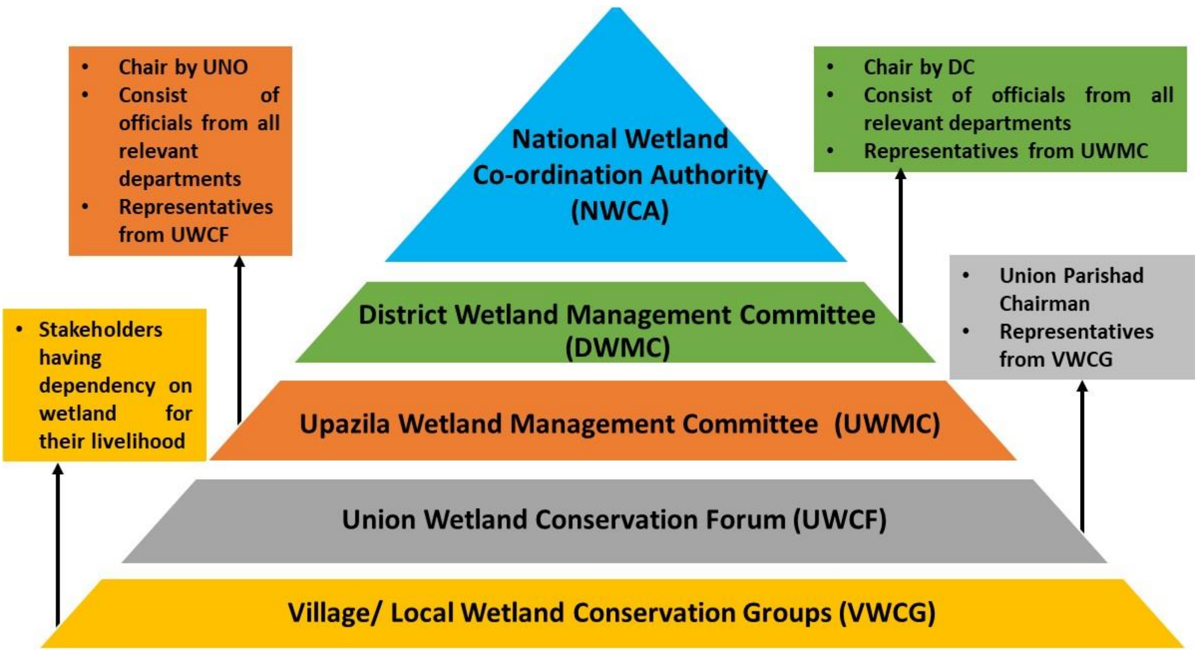
Aves: Avian species are diversified, and some species require both water and land for their survival. The travel distance varies among the avian species, and in general, maximum travel distance of few avian species could be in between 2.0 to 4.0 km from the wetlands.

So, this distance could be the probable home range / ecosystem boundary for the avian species.

Mammal: Mammalian species vary among themselves, and few species require both water and land for their survival. The travel distance varies among the mammalian species, and in general, maximum travel distance of few mammalian species could be in between 2.0 to 5.0 km from the wetland. So, this distance could be the probable home range / ecosystem boundary for the mammalian species.

Wetland Management Framework and Best Management Practice

- The study proposes a participatory collaborative management regime for the wetlands of Bangladesh. A bottom up approach has been proposed in the decision-making process regarding wetland management as shown below. The study proposes a five-tier organizational structure from local level to national level for wetland management such as i) Village/Local Wetland Conservation Groups (VWCG), ii) Union Wetland Conservation Forum (UWCF), iii) Upazila Wetland Management Committee (UWMC), iv) District Wetland Management Committee (DWMC) and v) National Wetland Co-ordination Authority (NWCA).



- Relevant stakeholders i.e. governmental agencies (Department of Bangladesh Haor and Wetlands Development, Department of fisheries, Forest department, Department of agriculture, civil administration), elected representatives (local government), users of the wetlands, local elites (religious leader, teachers etc.), relevant entrepreneur, civil society representative, journalist and NGO representative has been proposed as the participating actors in different tiers of the Co-management/ collaborative management organizations.

Proposed Interventions for Wetland Management Framework:

- Establishment of effective sanctuaries for fish and birds in entire haor area
- Implement dredging of rivers, canals and beel areas for increasing water flow and depth
- Construction of eco-friendly water control structure
- Tree plantation in haor dyke areas like hijol and koros trees
- Lease collection after fish harvesting
- Alternative income generation for the fishermen during breeding season

Findings from the field survey

- The surveyed LiDAR data used to delineate the boundaries of the wetlands very accurately in the project area which have been found highly validated by the wetlands separated from the high-resolution satellite image analysis.
- The bathymetric survey results reveal that the minimum elevation of the Tanguar and Hakaluki haor is -3.164 mMSL and -0.914 mMSL respectively.
- The discharge varies from 3.02 to 33.91 m^3/s for Tanguar haor and 4.12 to 261.22 m^3/s for Hakaluki haor whereas the velocity ranges from 0.005 to 0.057 m/s for Tanguar haor and 0.028 to 0.67 m/s for Hakaluki haor.
- pH value of collected surface water samples varies from 6.4 to 8.62 in the Tanguar haor area where as for Hakaluki haor area it ranges from 6.63 to 7.4. In most of the cases the values are within the range of Bangladesh drinking water standard.
- The Dissolved Oxygen (DO) content value of the collected samples ranges from 7.68 to 8.8 mg/l for Tanguar haor whereas it varies from 5.27 to 8.28 mg/l for Hakaluki haor areas. In context of Bangladesh drinking water standard, the DO value of Tanguar haor and Hakaluki haor exceed the limit except in 1 location of Hakaluki haor area.
- The laboratory analysis of collected water sample reveals that Total Hardness as $CaCO_3$ varies from 27 to 48 mg/l for Tanguar haor and 14.9 to 19 mg/l for Hakaluki haor and all the values are below Bangladesh drinking water standard.
- Biochemical Oxygen Demand (BOD5) ranges between 2.8 to 6 mg/l for Tanguar haor and 3 to 4.2 mg/l for Hakaluki haor whereas Chemical Oxygen Demand (COD) varies from 6 to 20 mg/l for Tanguar haor and 5 to 8 mg/l for Hakaluki Haor. The turbidity values range from 1.43 to 5.25 NTU for Tanguar haor and 1.54 to 59.4 NTU for Hakaluki haor area.

Findings from data Collection on Biodiversity, Fisheries Resources, Vegetation Survey, Agricultural Development and Socio – economic Study

Biodiversity

The identified faunal species at different wetland have been divided into four biological classes namely amphibia, reptilia, aves and mammalia. All identified faunal species play a vital role for balancing the existing ecosystem via intra-ecological and inter-ecological niches. Some species use the areas as their permanent habitat, while others use as temporary habitat. Finding of inventory on faunal biodiversity is presented below:

Wetland	Species Present Study			
	Amphibia	Reptilia	Aves	Mammalia
Tanguar haor	8	16	76	12
Hakaluki haor	8	23	131	16
Kaptai Lake	12	32	104	39
Baluhor Baor	7	12	59	12
Borni Baor	7	18	65	11
Borobila Beel	9	15	52	12
Baikka Beel	6	11	69	9
Beel Halti	5	12	54	9

Fisheries

- In case of Tanguar haor, commonly numbers of available, moderately available, less available, rarely available and not available species are respectively 14, 16, 17, 16 and 8. Similarly at Hakaluki haor, the numbers of species of commonly available, moderately available, less available, rarely available and not available respectively are 17, 17, 21, 12 and 11. In both haors, the less available and rarely available species can be considered as vulnerable species, will be threatened and endangered within a couple years. IUCN Bangladesh (2003) found 32 nationally threatened freshwater fish species in the Hakaluki haor, which was a positive indicator of declining fish biodiversity in that aquatic ecosystem.

- About 8 nos. of fish species are not available during dry season in Tanguar Haor such as Nanid (*Labeo nandina*), Mohashaol (*Tor tor*), Gangmagur (*Plotosus caniu*), Chittal (*Notopterus chitala*), Shilon (*Silonia silondia*), Deshi Pangus (*Pangasius pangasius*), Baghair (*Bagarius yarrellii*) and Rita (*Rita rita*). During wet season, 8 nos. of fish species are not available in Tanguar Haor such as Nanid (*Labeo nandina*), Mohashaoal (*Tor tor*), Deahi Pangus (*Pangasius pangasius*), Gangmagur (*Plotosus caniu*), Shilon (*Silonia silondia*), Along (*Megarasbora elanga*), Ilish (*Tenualosa ilisha*) and Baghair (*Bagarius yarrellii*).

- In Hakaluki haor, 14 nos. of fish species are not available in dry season such as Nanid (*Labeo nandina*), Mohashal (*Tor tor*), Gangmagur (*Plotosus caniu*), Chittal

(*Notopterus chitala*), Shilon (*Silonia silondia*), Deahi Pangus (*Pangasius pangasius*), Baghair (*Bagarius yarrellii*), Rita (*Rita rita*), Ilish (*Tenualosa ilisha*), Borali (*Barilius barila*), Fasha, Along (*Megarasbora elanga*), Posuti Punti (*Oreichthys cosuatis*), Baspata (*Paramugil parmatus*). In wet season, 14 nos. of fish species are not available in Hakaluki haor such as Nanid (*Labeo nandina*), Mohashoal (*Tor tor*), Deshi Pangus (*Pangasius pangasius*), Gangmagur (*Plotosus caniu*), Shilon (*Silonia silondia*), Along (*Megarasbora elanga*), Borali (*Barilius barila*), Kosuti punti (*Oreichthys cosuatis*).

- In Kaptai Lake, numbers of commonly available, moderately available, less available, rarely available and not available species respectively are 10, 14, 21, 9 and 4. Both less available and rarely available species can be categorized as vulnerable species, which is sharing 56% of species (both 39% less available + 17% rarely available species) are in alarming stage; those are on the way to be endangered within few years of time.
- Category wise availability of fishes at both Baluhar Baor and Borni Baor shows that, in both cases there are major proportions of these fish species become vulnerable, which are in the line of critically threatened or endangered soon or later.
- The trend of availability of vulnerable species (both less available + rarely species) and declining species biological diversity are very close between Baikka Beel and Beel Halti. Although at Borobila Beel number of vulnerable species having lower trend but huge vegetative growth at shallow water depth of the beel ecosystem during dry/winter season occurred huge mortality of the existing fish stocks due to deterioration of water quality parameters viz. dissolved oxygen, pH, alkalinity and hardness etc.
- No visible haor management practice exists either from any side of GoB or NGOs except Baikka beel. Local people do not get easy access to collect haor resources. Powerful people take advantage and take its resources unprofessionally, and thus, destroy its resources. Peripheral villagers and outside peoples are collecting natural resources from haor indiscriminately that ultimately damage the haor entity and its fisheries resources.
- At least 4 nos, of breeding spots have been identified in Tanguar haor such as Nazarkhali Khalerbak/ Bhanga, Bagmara Kanda, near the right bank where bend and deeper part is there- Alamer Duar, Shoshan Kanda, Chhara beel- Koraibari stream.
- A total of five fish sanctuaries is identified in Tanguar haor such as Rupaboi beel Fish Sanctuary, Rowa beel Fish Sanctuary, Tekunna beel Fish Sanctuary, Ballardubi beel Fish Sanctuary and Alamer Duar River Fish Sanctuary.
- Hakaluki haor are identified as important for fish sanctuaries such as Takuni beel, Moishar Dhak beel, Ronchi beel, Bhuterkona beel, Lampang beel and the confluence of Juri River.

Vegetation Survey

- A total of 52 species under 30 families were found in the Tanguar haor sites from 61 plots and of total 24400 m^2 area during the first survey period (dry season) and 54 species were found from 51 plots of wet season. Amid of them, Moraceae switched 4 species, Fabaceae clicked 10 species and Meliaceae family carried out 3 species respectively, rest of the species had gone to several families.
- A total of 28 species were found in the Hakaluki haor sites from 50 plots and of total 20000 m^2 area during dry season and 34 species were found in wet season from 53 plots. Amid of them, Moraceae switched 4 species, Fabaceae clicked 5 species and Meliaceae family carried out 2 species respectively, rest of the species had gone to several families.
- The study found the tree vegetation diversity is in the mid-range as the Shannon index is around 0.54 in range of (0 to 1) for both the Tanguar haor and Hakaluki haor.
- The Mean above-ground, below-ground and Total Biomass Carbon (TBC) of the Tanguar haor areas were 21.37913 Ton per ha, 4.55077 Ton per ha and 25.92991 Ton per ha respectively and 28.01954 Ton per ha, 5.56763 Ton per ha and 33.58718 Ton per ha respectively for Hakaluki haor area.
- The study found 6 trees species and 4 shrub species in the sample plots of the Ratargul swamp forest. The forest is mostly dominated by *Barringtonia acutangula* (Hijol), *Millettia pinnata* (Koroch) and *Crataeva magna* (Barun). Among the shrub Murta is the most common plant found in the forest, which also have great importance for cottage industry in the region.
- The study found the tree vegetation diversity is not rich as the Shannon index is around 0.27 in range of (0 to 1) and Mean above-ground, below-ground and Total Biomass Carbon (TBC) were 26.20 Ton per ha, 5.34 Ton per ha and 31.54 Ton per ha respectively for Ratargul swamp forest.
- The vegetation study of Baikka beel reveals that 16 trees species and 3 shrub species were present in the sample plots of the area. The forest is mostly dominated by *Barringtonia acutangula* (Hijol), *Millettia pinnata* (Koroch), *Terminalia arjuna* (Arjun), *Ficus bengalensis* (Bot), *Trewia polycarpa* (Pitali), *Albizia lebbeck* (Koroi) and *Lagerstroemia speciosa* (Jarul). Among the herbs and shrubs *Typha elephantiana* (Hogal) and *Arundo donax* (Nal Khagra) are the most common plant found in the wetland. However, it is recorded that Murta was present there but now no longer exist.
- The tree vegetation diversity is quite good as the Shannon index is around 0.68 in range of (0 to 1) and Mean above-ground, below-ground and Total Biomass Carbon (TBC) were 23.83 Ton per ha, 4.94 Ton per ha and 28.77 Ton per ha respectively for Baikka beel.

- The study found 23 trees species and 2 shrub species in the sample plots of Borobila beel area. The forest is mostly dominated by *Psidium guajava* (Peyara), *Samanea saman* (Raintree), *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot) *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Albizia lebbeck* (Koroi) and *Lagerstroemia speciosa* (Jarul). Among the herbs and shrubs *Typha elephantiana* (Hogal) and *Saccharum spontaneum* (kash ful) are the most common plant found in the Borobila beel.

- The study found 23 trees species and 2 shrub species in the in the sample plots of the Beel Halti area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot), *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), and *Borassus flabellifer* (Tal). Among the herbs and shrubs Motmote, Chitki and *Ipomoea carnea* (Dhol kolmi) are the most common plant found in the Beel Halti area.

- The tree vegetation diversity is quite good as the Shannon index is around 0.53 in range of (0 to 1) for Beel Halti area. The study also shows that the mean above-ground, below-ground and Total Biomass Carbon (TBC) of the Beel Halti area were 42.67 Ton per ha, 8.07 Ton per ha and 50.74 Ton per ha respectively

- The vegetation around the Baluhor Baor is classified under village homestead forest and are mostly privately owned. The study found 32 trees species and 2 shrub species in the sample plots of the area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Ficus bengalensis* (Bot) *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Acacia auriculiformis* (Akashmoni) and *Acacia catechu* (Khoi Babla). Among the herbs and shrubs *Typha elephantiana* (hogla), and *Ipomoea carnea* (Dhol kolmi) are the most common plant found in the wetland.

- The study found the tree vegetation diversity very rich as the Shannon index is around 0.90 in range of (0 to 1) for Baluhor baor. Mean above-ground, below-ground, and Total Biomass Carbon (TBC) of the Baluhor baor areas were 44.12 Ton per ha, 7.86 Ton per ha and 51.97 Ton per ha respectively.

- The study found 29 trees species and 2 shrub species in the selected plots of the Borni baor area. The vegetation is mostly dominated by *Swietenia mahagoni* (Mahogany), *Trewia polycarpa* (Pitali), *Artocarpus heterophyllus* (Kanthal), *Mangifera indica* (Aam), *Acacia auriculiformis* (Akashmoni) and *Albizia procera*. Among the herbs and shrubs *Saccharum spontaneum* (kash ful), *Typha elephantiana* (hogla), and *Ipomoea carnea* (Dhol kolmi) are the most common plant found in the wetland.

- The study found the tree vegetation diversity rich as the Shannon index is around 0.69 in range of (0 to 1) for Borni baor area. Mean above-ground, below-ground, and Total Biomass Carbon (TBC) of the Borni baor area were 27.43 Ton per ha, 5.13 Ton per ha and 32.56 Ton per ha respectively.

- The study has recorded 52 species and 487 woody individuals along with 4 species of bamboos in the sampling plot of Kaptai lake. The vegetation is mostly dominated by *Gmelina arborea* (Gamar), *Dipterocarpus turbinatus* (Garjan), *Artocarpus chaplasha* (Chapalish), *Albizia lebbeck* (Koroi), *Hopea odorata* (Telsur), and *Syzygium grande (dhaki Jam).* Out of the 4 bamboo species, *Melocanna baccifera (*Muli Bansh) is the most common species. *Byttneria aspera, Sterculia balanghas, Physalis angulate* and *Macaranga peltata* are among the climbers, shrubs found in the sample plots.
- The study found the tree vegetation diversity rich as the Shannon index is around 0.78 in range of (0 to 1) for Kaptai lake. Mean above-ground, below-ground, and Total Biomass Carbon (TBC) of the Kaptai lake areas were 50.72517Ton per ha, 8.48571Ton per ha and 59.21089 Ton per ha respectively.
- The study findings indicate that the vegetation structure and diversity is changing over the time. Though the species diversity in different site is still healthy but the distribution or spread of different tree species is not healthy, i.e. a number of species are found abundantly but many indigenous species are sporadically found.
- Another important finding is that local people are replacing the indigenous multipurpose tree species (like Palash, Shimul) by high yielding timber producing tree species (like, Mahaguni and Akash moni). This replenish of vegetation around the wetlands like Baor and Beels is hampering the balance of the microclimate and habitat of wildlife especially indigenous and migratory birds. Additionally, removal of trees from large wetland like Tanguar and Hakaluki haor is also a major issue for health wetland management.

Agriculture

Tanguar and Hakaluki Haor

The following issues have been observed at Tanguar Haor and Hakaluki haor during the RRA/FGD exercises with the farmers:

i. *Vulnerability to Early Flash Flood:* Boro rice, being the only crop grown in haor basin is vulnerable to early flash floods due to sudden heavy rainfall within and outside haor basin as well in upstream beyond the boarder. In case early onset of monsoon, early flash flood is almost inevitable causing total crop damage.

ii. *Scarcity of Irrigation Water:* Though haors remains submerged for about a half the year, Boro rice is exposed to water stress in the reproductive and grain growth stages due to lack of adequate irrigable water and infrastructure facilities for water conveyance and distribution. In fact, only 19-20 percent of Boro land is irrigated in Hakaluki and Tanguar haor area. This adds to the uncertainty of the crop and discourages desired investment due to risk of crop failure.

iii. *Poor Technical Knowhow:* Due to inaccessibility of the area for lack of communication facilities, farmers have minimal access to modern technological massages and extension services making farmers dependent on traditional practices of crop production and management.

iv. *Low Input Use in Boro Production:* Boro rice is the only crop for livelihood for most of farming community of the area. Accordingly, farmers make efforts to cover all their land with boro rice even beyond their capacity to manage it well in terms resource use to increase yield and productivity.

v. *Blast Disease in BRRIdhan 28:* Being the short duration HYV, farmers widely use BRRIdhan 28 to escape early flash flood. However, due to long exposure of the variety in the area, it has become susceptible to Rice Blast disease. For last few years Blast disease has emerged as havoc causing serious yield loss of Boro rice.

vi. *Labor Crisis at Planting and Harvesting Time:* Due to ecological condition, farmers have to transplant and harvest boro rice within a short time due to absence of mechanization of planting and harvesting. Accordingly, farmers are dependent of hired labor coming from adjacent districts to carry out these vital operations. Labor shortage also a cause of inefficiency of other cultural practices.

Borobila Beel

- Over a long period, gradual siltation has significantly raised the bed resulting reduced water depth at peak time. Re-excavation, at the bottom would increase the depth and duration of water, help maintain water quality, increase fish productivity as well as other aquatic agricultural production practices;
- Use of rice transplanter and reaper in muddy lands (with plastic wheels) would reduce labor cost, ease and shorten the time for both the operations.
- The aquatic weeds seem to be main cause of degradation of water quality due to rotting may otherwise be used for composting and/or preparing beds for floating agriculture;
- Constructing sluice gates at Golaper Embankment and Boro Khal point would help regulate water to control flooding and drainage to minimize crop damage and facilitate timely planting of Boro rice.
- The management of the beel, especially the Khash land at the bottom is traditionally leased out to businessmen who exploit the water body without considering its sustainability and biodiversity. Vesting the management of Khash water body to concerned farmers and fishermen would help improve productivity of aquatic resources, improve water quality and sustainability of biodiversity.

Beel Halti

- The canal connecting the beel with Banar river need to be re-excavated to maintain continued/ long–term flow of water from the beel;

- The river Banar need to be excavated to maintain the stream flow towards larger flowing rivers and thus allowing quicker recession of the monsoon water from beel;
- The beel may be excavated at Government (KHASH) part of its basin and put the soil on croplands and thus elevating the same providing facilities i) for multiple crops, ii) early Boro crop, iii) accommodate early monsoon flood and save the crops, iv) promote more fishery wealth, v) to maintain a deeper part as fish sanctuary to protect and regenerate fish species and breeding, vi) protect the eutrophication and water quality, vii) attract tourists with maintained beauties with different suitable aquatic plants, local and guest birds, plants, fish species, fish catches, boat fairs and so on;
- The beel may be protected from inflow of soil and extra nutrients by constructing embankments and making a walkway with beautiful hedge and locally adopted extinct plants species to attract tourists. This can add to family income from tourists;
- A fish sanctuary may be maintained for enriching aquatic production and farmer's income;
- Construction of sluice gates needed at Golaper Bandh (Embankment) and Boro Khal (canal) point to control water pressure of the beel;
- The management of the beel needs to be with the concerned farmers and fishermen instead of leasing to businessmen who exploit the water body without considering its' sustainability and biodiversity;
- Use of rice transplanter and reaper in muddy lands (with plastic wheels) would reduce labor cost, ease and shorten the time for both the operations;
- Rotting of aquatic weeds, seemingly the main cause of degradation of water quality may otherwise be used for composting and/or preparing beds for floating agriculture.

Social Study

Tanguar and Hakaluki Haor

- Construction of embankment to protect flash flood;
- Prohibited duck rearing in the open water;
- Stop catching fish throughout the year specially during the breeding season of fishes;
- Ensure financial support for the actual fishermen for certain (nonproductive) period;
- Lease the haor to the actual fishermen in and around the area;
- Building awareness among the people of haor area;
- Develop communication for haor area, for easy movement inside the haor and other urban area;
- Arrange and conduct training on haor resource management;

- Initiative for eco-tourism development in the haor area and
- Develop fish and bird sanctuary in the haor;

8.2 Recommendations

The major focus of the study was to prepare an inventory of the wetlands through classification of satellite images, delineations of wetlands, study of interaction between haor and river ecosystems and LiDAR survey of Tanguar haor for an area of approximately 120 sq. km. for empirical data collection. Accordingly, the extent of wetlands of Bangladesh for both the dry and wet seasons has been identified through the classifications of high-resolution images collected under this study. An inventory of wetlands has also been developed and presented in Volume-IV. The classifications of wetlands with respect to Bangladesh standard as developed earlier by DBHWD has been applied in classifying of all the identified wetlands. The map of the wetlands for the whole country has been presented in 1:10000 scale. DBHWD has also implemented a new approach of surveying wetlands through LiDAR survey and this type of approach is first in Bangladesh. The study also proposed a five-tier general management framework for wetlands. The major recommendation that has been made under this study can be summarized as below:

- The vulnerability assessment has been done as per guidelines of Ramsar Convention (1971) & Convention on Biological Diversity (CBD, 2006) as well as Millennium Ecosystem Assessment (MEA, 2005) which has to be replicated for the major and critical wetlands in Bangladesh through detailed data collection.
- All sorts of fish fry, fish egg and other natural resources are harvesting from the wetlands, indiscriminately, and some of these are used as food by specific wetland dependent wild life species; no monitoring exists on it either from any side of GoB or Local Community. It is suggested to ensure effective monitoring program on it throughout the year from GoB as well as to ensure punishment for violation of management rules.
- Faunal diversity is decreasing due to non-visible management of wetlands. Few avian diversities are noticeable mainly in winter season including few migratory birds, but many other types of biodiversity always exist there and play a vital role in the existing natural environment. It is suggested to ensure the best management practice on wetlands & its resources by involving peripheral villagers, i.e. villagers could play a vital role to stop over harvesting of natural resources, illegal hunting of wild life species, over harvesting of fishes and other aquatic resources, etc.
- It is strongly recommended that the co-management systems should be continued, enhanced and re-adopted as the integrated Best Wetland Management Practices (BWMPs) by GoB and concerned departments and ministries in coordinated way to restore threatened natural ecosystem habitat and conserve fish biological diversity at Tanguar and Hakaluki haor ecosystem.

- Dredging is extremely recommended for depleted rivers, canals and beel areas for increasing water flow and depth for proper migration and better survival of gravid and juvenile stocks throughout the year.
- Banning of wild fish catch need to be restored during June – July months, during that time the fishermen should be provided alternative/supportive income opportunities like Govt. Hilsa Fisheries conservation and management program.
- Manually driven boat rather than engine boat is recommended to keep the ecosystem undisturbed.
- The scarcity of irrigation water may be addressed by (a) developing surface water reservoirs by digging suitable locations; (b) Developing necessary water pumping, conveyance and distribution infrastructure; (c) Developing both surface and groundwater resources to achieve full irrigation coverage; (d) Growing less water requiring upland crops in the upper position of catena by replacing Boro rice; and (e) Adopting more water efficient irrigation technologies such as Alternate Wetting and Drying (AWD) method of irrigation.
- To improve farmers' knowledge and skills; modern packages of crop production and management technologies should be demonstrated with farmer participation and providing technology training to as many farmers as possible within shortest possible time to mitigate knowledge and skill gaps.
- The wetlands may be excavated at its Government part (KHASH) and put the soil on croplands and thus elevating the same providing facilities i) for multiple crops, ii) early Boro crop, iii) accommodate early monsoon flood and save the crops, iv) promote more fish culture, v) to maintain a deeper part as fish sanctuary to protect and regenerate fish species and breeding, vi) protect the eutrophication and water quality, vii) attract tourists with maintained beauties with different suitable aquatic plants, local and guest birds, plants, fish species, fish catches, boat fairs and so on.
- The management of the wetlands needs to be activated with the concerned farmers and fishermen instead of leasing to businessmen who exploit the water body without considering its' sustainability and biodiversity;
- Radio-telemetry technique is a common method which frequently is used to delineate the faunal biodiversity home range / ecosystem boundary. However, the cost as well as time was not sufficient to conduct such type of survey. So, for delineation of site-specific ecosystem boundary, a Radio-telemetry technique is highly recommended.
- Adequate support is recommended to develop suitable mechanical devices for transplanting (transplanter) and harvesting (harvester/reaper) suitable for use in wet (often submerged) season.
- From the perspective of Hakaluki Haor & Tanguar Haor, the stakeholder has suggested to plant Hijol, Koroch and Barun. The stakeholders have also suggested to reintroduce Kadam, Shimul, Raintree, Bot, Pitali because these plants were there in

the recent past & they can be grown & survived in such environment. The stakeholders have mentioned some causes for which they have selected these species. The causes are;

a) These are the native plants of haor areas and it is wise to plant native plants under any plantation program. Native plants are crucial in habitat restoration and help to restore plant diversity, stabilization and replenish soil.

b) Fresh water swamp forest consists of flood-tolerant evergreen trees & they are adapted to monsoon flooding for three to four months to depths of 0.5 to 2.5 m

c) The swamp plants provide habitat for fishes & birds & thus increase the number of fishes & birds.

d) The suggested plants can also give protection against wave action, storm action, erosion

e) Hijol is used to make Kathha for fishery purpose.

f) Capable of withstanding the flood, these particular trees may be conserved and protected as seed trees for future propagation.

- Enrichment of plantation with Hijol, Koroch, Barun and Murta in the ratargul swamp forest is recommended by the stakeholders. During field survey and stakeholder consultations, the strip plantation beside the road from patul- Naldanga is suggested for Beel Halti area. Preferred species are kodom, shimul and hijol.
- Reintroduction of Hijol tree is suggested for Borni baor as it provides habitat for fish and birds. Also, koroi, kadam and shimul may be the second options for tree plantation.
- The study proposes a co-management system of the wetlands. Effectiveness of the management would depend on the strength of the implementing agency. If the real stakeholders are well represented and the decision-making structure is a democratic one, only then the system will function and succeed. During initial years of such management, active support of the project should be there, and financial rules and norms must be clearly worked out and implement in an integrated way.

In the stakeholder’s consultations, PIC and PSC meetings and field workshops several study projects have been suggested to take for the sake the improvement of wetlands and associated livelihood. As such, a 2nd phase of the study considering the following issues is highly recommended under this study:

1. Investigation of the status of fish, vegetation, forests, birds, livelihoods, navigation and farming pattern and develop a framework to use the natural resources of the wetlands in an equitable way and support the livelihoods of all stakeholders;
2. Establish the level of function and condition of wetlands to detect changes and stressors and to characterize trends over time.

3. Establish and or restore the connectivity between the rivers and wetlands, migration opportunity of fish, status of biodiversity, environmental health of the eco-system, socio-economic status and water availability.
4. Detailed cross – section survey/topographic survey of major wetlands and collection of hydrological data.
5. Development of water balance model to represent the key hydrological processes in the wetland.
6. Development of hydrodynamic river model to simulate the flow and water level along regional rivers and development of flood inundation map of wetlands for identifications of monthly variation of water level which will helps the decision makers to wise use of wetlands.
7. Development of system linkage model to represent qualitative and quantitative relationships among the physical, ecological and socio-economic variables and to identify the potential impacts of climate change on ecology and livelihoods.
8. Identifications of wetlands that need to be dredged/ re-excavated to meet up the future water demand in an equitable manner.
9. Determination of long – term impacts of dredging/ re-excavation of wetlands on groundwater recharge through the development of regional groundwater flow model.
10. Cluster wise piloting of the recommended wetland management framework and monitoring the same and come up with updated recommendations.
11. Development of a comprehensive and user-friendly data and information management system for the identified wetlands.

8.3 Assumption and Limitation of the Study

The study identifies the wetlands of Bangladesh as well as ponds of greater than 25 decimal areas through the classification of high-resolution images and prepared an inventory of identified wetlands. This is a huge task and first-time inventory of wetlands in Bangladesh. During the study, the consultant has tried their level best to fulfill the study objectives with a few limitations as mentioned below:

a. There is a limited scope of field data collection for biodiversity, fisheries resources, forest, agriculture and social perspective. These types of data should be collected continuously in every month for the duration of at least two years, but the scope of man – month and cost for field data collection was not sufficient to complete such comprehensive data collection.
b. As per the decision of PSC meeting, the inventory should include the mouza name. But at present there is no such soft copy of authentic mouza maps. The digitization and georeferencing of mouza maps for the whole country is time consuming and a very costly works. As such, the mouza name collected from secondary sources has

been used in inventory which may vary to some extent and requires future verification in the recommended 2nd phase of the study.

c. As per the ToR, the consultant has to do the piloting of wetlands for effective management. But unfortunately, there was no any provision of funding as well as time for this work. As such, the consultant has collected the data for a selected beel (where a management approach exists) and compared it with the base condition to find out the effectiveness of management approach and identifies the gaps as well.

However, for the national interest and to make the study more fruitful, the consultant has completed additional works beyond ToR, such as identifications of ponds (having area greater than 25 decimal) for the whole country, bathemetric survey of Tanguar and Hakaluki haor, discharge measurement of the connected rivers of Tanguar and Hakaluki haor and finally printed out of maps (two copies) in 1:10000 scale for the whole Bangladesh.

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