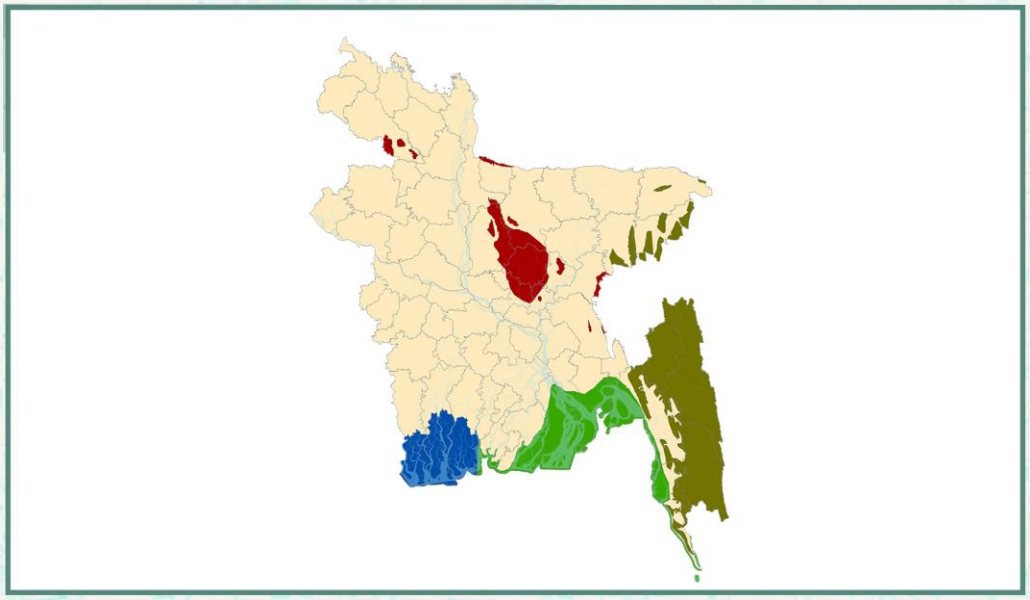
Zoning for Tree and Forest Assessment in Bangladesh



Bangladesh Forest Department

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Food and Agriculture Organization of the United Nations

The Forest Department of Bangladesh leads actions to improve forest management and conservation, adopting forward thinking, innovative approaches in its management of approximately 1.55 million hectares of land across the country.

In 2015, the Forest Department began a process to establish a National Forest Inventory and Satellite Land Monitoring System for improved forest and natural resource management. The process supports national objectives related to climate change mitigation and provides information in support of the UN REDD programme aimed at Reducing Emissions from Deforestation and Forest Degradation (REDD+). The process also addresses domestic information needs and supports national policy processes related to forests and the multitude of interconnected human and environmental systems that forests support.

The activities implemented under the Bangladesh Forest Inventory process are a collaboration between several national and international institutions and stakeholders. National partners from multiple government departments and agencies assist in providing a nationally coordinated approach to land management. International partners, including the United Stated Agency for International Development (USAID), the Food and Agriculture Organization of the United Nations (FAO) and SilvaCarbon are supporting the development of technical and financial resources that will assist in institutionalising the process.

The results will allow the Forest Department to provide regular, updated information about the status of trees and forests for a multitude of purposes including for assessment of role of trees for firewood, medicines, timber, climate change mitigation.

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Executive Summary

The stratification of the tree population in Bangladesh has been identified as one option to ensure the Bangladesh Forest Inventory provides the necessary information to the different forests of interests, mainly for management purpose. In addition, it is one option to reduce the uncertainty of estimates and reduce measurement costs. Several maps can be considered for the stratification process. The maps have been developed for different objectives (ecology, climate, carbon cycling, physio-geography, agriculture, etc.) and use different data sources. Some of them are global maps, others are national maps. Their use contributes to the overall aim which is to delineate homogenous sub-populations that will remain constant, in terms of their defining physiographic attributes, over time.

The objectives of this document are to analyse the various available maps for Bangladesh for delineation of ecological features; to present the data used for defining selection criteria; and to propose two options for the delineation of sub-populations for the Bangladesh forest inventory.

The analysis reveals three factors: (i) most of the global maps[1] used do not capture the distribution of the vegetation and soil types, (ii) two global maps have been compared considering national datasets such as forest cover map and they are considered as not appropriate to capture the distribution of forest types, (explained in section 4) (iii) it is preferable to develop new zoning map for two main objectives that are: ecological zoning, and management zoning.

In consequence, two maps have been developed using available datasets: a zoning map and a forest management area map (areas under management of the forest department).

The zoning map was primarily derived from four datasets: (1) soil types (1988), (2) digital elevation model 2013, (3) climate types and (4) salinity map. The zoning map aims to define the climatic and edaphic factors influencing the distribution of five vegetation types, namely: Hill, Sal, Costal, Sundarbans and Village zones. In this way, the boundaries of the zoning map will not change over time.

The forest management area map is based on existing legal boundaries, predominantly areas currently under management of the forest department. The following datasets were used: (1) forest reserve boundary, (2) protected forest boundary, (3) forest division map 2013 and (4) mauza map. The same five zones were defined namely: hill, Sal, mangrove plantations, Sundarbans and Villages. Existing reserved and protected forest boundaries, as well as mauza boundaries for the territorial forest administration divisions, were used to delineate the Hill and Sal. The Mangrove plantation zone was based on the forest division map of 2013; while the map does not cover the national scale, it is the latest forest boundary delimitation prepared by FD-RIMS.

The two proposed maps aim at supporting the stratification for the Bangladesh Forest Inventory. Both have strengths and weaknesses. On one hand, the zone map may be more appropriate for assessing the status of the resources on an ecological point of view. Furthermore, its boundaries will remain constant on account of its defining geophysical attributes. On the other hand, the forest management area map may be more appropriate from a management point of view as more samples will be placed in areas physically managed by

[1] Global maps include: FAO (map 1), Holdridge (map 3), Olson (map 4), Udvardy (map 5), Bailey (map 6), Koeppen (map 7).

the Forest Department, however its boundaries may be modified depending on changes of the land tenure and forest management plans.

Contents

1. Introduction

Data collection, analysis, interpretation, and reporting on natural resources are time and scale dependent processes. Reporting data at a national scale provides a broad overview of landscape characteristics and temporal trends that are useful for ecosystem health assessments, however, they can be too coarse for operational planning purposes. Using such course scales can mask sub-national trends, amalgamate contradictory trends and convey misinformation. While the NFA 2005-7 reflects the status of trees and forests at national scale, it failed to capture information about forest types such as Sal forests and mangrove plantations (Table 1). Defining sub-populations within the national boundaries is one way to more accurately provide information about the status of natural resources in specific areas of interest.

TABLE 1: FOREST TYPES CONSIDERED BY THE NFA 2005-7, DATA: (BANGLADESH FOREST DEPARTMENT 2007)

Zones	Area (ha)	No of tracts (in and outside forests) in 2005-7
Hill	1641503	30
Mangrove plantation	61497	
Sal	285338	6
Sundarbans Reserved Forest	580708	9
Village	11872366	254
Total		299

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Zoning or stratification is a process of creating sub-populations to assist survey design optimisation. The process involves dividing a population into non-overlapping subpopulations called 'strata' that together comprise the entire population. An independent sample can then be drawn from each individual stratum (Czaplewski 2004).

This process is otherwise known as stratified sampling. Numerous justifications can be made in promotion of stratified sampling (Cochran 1977, Schreuder 1993).

Stratification is used to increase the precision of population estimates may contribute to avoiding estimation bias, depending on the estimator selected. To understand the potential for gain in precision achieved through stratification, some notation and formulae are necessary.

Another reason for stratification is to accommodate different sampling protocols or different estimation procedures for different subpopulations. For example, a substantial portion of sampling costs may be attributed to travel to and from plot locations. If data from remote sensors may be used to determine that some plots are located on non-forest land, then travel costs may be substantially reduced by not sending field crews to those plot locations. As a result, a different estimator may be required for those strata.

In the context of the preparation of a Greenhouse Gas Inventory, the IPCC (2003) proposes 6 land classes to report the impact of human activities for the Land use, land use change and forest (LULUCF) sector and those classes can be subdivided into different strata.

The IPCC mentions that stratification into homogeneous sub-categories, and if possible at regional or sub-regional level within a country (i) improves the accuracy of the estimate for the entire population; and (ii) ensures that adequate results are obtained for certain subpopulations, e.g., for certain administrative regions.

Further stratifications may refer to tree species composition, management regime, stand age, climatic region and soil type, etc. The IPCC also mentions that the data used for the activity data area totals should be summed across all land-use categories to ensure that total area involved in the inventory and its stratification across climate and soil types remains constant over time. National land classifications or stratification may change over time as national circumstances change. When changes to the stratification system occur, countries should recalculate the entire time-series of estimates using the new stratification if possible (IPCC 2003).

In the context of Bangladesh, several systems exist to represent the variability of ecosystems and natural resources depending on different objectives for which they have been produced. Some of them are global representations; others are national and local specific. Several national efforts aim at improving the natural and tree resources management in Bangladesh. At current status, the forest master plan is under revision and aims at improving forest management and conservation.

In parallel, the initiation of the national forest monitoring system and the national forest inventory implementation aims at providing information about the status of trees and forest to guide national and sub-national forest policies and measures. For this, several activities are being implemented in collaboration with several national institutions to map the various land cover/use types.

In this context, the development of a national stratification is crucial to ensure the implementation of a cost-effective national system and the integration of the various source of information to guide actions for improving the management of natural resources over time.

Mapped ecological units are usually defined by a combination of regional to sub-regional climatic, physiographic, aquatic/marine, and biotic characteristics that are delineated at various scales as entities that are more “homogeneous” within and across their boundaries. In this context the proposed stratification is an explicit, consistent method to support the monitoring and assessment of natural resources in Bangladesh, and, in particular, forests and trees outside forests.

The objectives of this document are to analyse the various available maps for Bangladesh for delineation of ecological features; to present the data used for defining selection criteria; and to propose two options for the delineation of sub-populations for the Bangladesh forest inventory.

The report has three parts: firstly, available global and national ecological zones are presented. Secondly, different datasets used for analysing the available maps are presented; and thirdly, the process for the development of two new maps for the purpose of delineating sub-populations for the Bangladesh Forest Inventory is presented.

1.1 Available global maps

A number of maps derived from global datasets were considered in this process. They have been developed for various purposes such as for conservation priority setting and planning purposes (WWF 2000), improving estimates of carbon content of soil and vegetation (Olson 1982), correlating world plant formations with simple climatic data (Leemans 1990), general conservation (Udvardy 1975), and biogeographic life form analysis (Bailey 1989). The maps vary in their level of detail and the context in which they can be used.

Global Ecological Zones assist in reporting on global forest resource (FAO 2012, Sayre 2014), while climate zones benefit climate monitoring and prediction (Kottek 2006). Detailed description on the maps can be found in Table 2 and the maps can be found in Appendix 1.

TABLE 2: DETAILS OF GLOBAL MAPS FOR ECOLOGICAL ZONING AVAILABLE FOR BANGLADESH

Map No.	Classification types	References	Description	Objective	Internet link	Suitable for i.e.	Number of classes
1	Global Ecological Zones	FAO (2012). Global ecological zones for FAO forest reporting: 2010 Update, Forest Resources Assessment Working Paper 179	The Global Forest Resources Assessment (FRA) of the Food and Agriculture Organization of the United Nations (FAO) presents global and regional forest data by global ecological zone (GEZ). The GEZ spatial dataset used by FAO has developed over the years from covering only the tropical areas (1990) to the globe (2000). Due to the developments in remote sensing and the compiling of many spatial products relating to climate and land cover between 2000 and 2010, an update to the map was commissioned and resulted in the available GEZ 2010 product	Global forest resource assessment	http://www.fao.org/geonetwork/srv/en/main.home?uuid=2fb209d0-fd34-4e5e-a3d8-a13c241eb61b	Forest resource assessment	5 domains and 20 classes
2	Biome-ecological zone	WWF, 2000. Terrestrial ecoregions of the world. Washington, DC.	They subivided the terrestrial world into 14 biomes and eight biogeographic realms. Nested within these are 867 ecoregions. White's (1983) phytogeographic regions serve as the basis for the ecoregions of the Afrotropics .	Global and regional conservation priority-setting and planning efforts, useful in priority setting and ecological analyses.	http://www.worldwildlife.org/science/ecoregions/item1267.html	biodiversity conservation project	12 biomes and 32 ecoregions
3	Biome-ecological zone	Leemans, R., 1990. Global data sets collected and compiled by the Biosphere Project. IIASA, Laxenburg, Austria.	The Holdridge Life Zones data set is from the International Institute for Applied Systems Analyses (IIASA) in Laxenburg, Austria. The data set shows the Holdridge Life Zones of the World, a combination of climate and vegetation (ecological) types, under current, so-called "normal" climate conditions, as well as under a presumed doubling of atmospheric CO2. The Life Zones were devised using three indicators: biotemperature (based on the growing season length and temperature); mean annual precipitation; and a potential evapotranspiration ratio, linking biotemperature with annual precipitation to define humidity provinces. The data set has a spatial resolution of one-half degree latitude/longitude, and a total of 38 life-zone classes.	to correlate world plant formations with simple climatic data.	http://www-cger.nies.go.jp/grid-e/griddoc/holdride.html	More appropriate to the complexities of tropical vegetation	27 classes
4	Biome-ecological zone	Olson, J.S., Watts, J.A., 1982. Major ecosystem complexes. Ranked by carbon in live vegetation. Oak Ridge National Laboratory, Tennessee, USA.	It represents the world's Major Ecosystem Complexes ranked by the amounts of carbon in live vegetation. The data set has a total of 44 land ecosystem classes. The data set was compiled from patterns of pre-agricultural vegetation, modern aerial surveys and intensive biomass data from research sites.	To interpret the role of vegetation in global CO2 cycling; a base for improved estimates of carbon content of soil and vegetation; and a means of correcting estimates of carbon released$	http://www-cger.nies.go.jp/grid-e/gridtxt/grid4.html	C stock estimates	9 classes

5	Biome-ecological zone	Udvardy, M.D.F., 1975. A classification of the biogeographical provinces of the world. IUCN, Morges, Switzerland.	To define geographic units for conservation purposes the following were considered: (a) the distribution of species and (b) the distribution of ecosystem units. Hierarchical Biogeographical entities were named Realms, Biomes and Provinces. (1) Realm: used the phylogenetic subdivisions of the world, unifying those for flora and fauna. (2) Biome: combine the features of a major vegetation type with climate. (3) Province: delimited on a faunal, floral and ecological basis.	To devise a satisfactory classification of the world's biotic areas for purposes of conservation	http://gcmd.nasa.gov/records/GCMD_GNVd0042_104.html // http://www.fao.org/geonetwork/srv/en/metadata.show?id=1008&currTab=simple	biogeographic life form analysis	3 realms, 29 provinces, 8 biomes
6	Biome-ecological zone	Bailey, R.G., 1989. Explanatory supplement to Ecoregions map of the continents. . Environmental Conservation 16, 307-309.	Ecoregions of the continents are based on macroclimate. The theory behind the approach is that macroclimates are among the most significant factors affecting the distribution of life on Earth. Four Domains were defined: Polar, Humid temperate, Humid tropical and Dry. The combination of temperature and rainfall to indicate major climatic zones was based on Köppen and Trewartha's work, where dry climates were treated as a separate entity from Tropical humid and Temperate humid.	To show how the national forests of the United States fit within the global ecoregional scheme. In this system an ecoregion is defined as any large portion of the Earth's surface over which the ecosystems have characteristics in common	http://ceos.cnes.fr:8100/cdrom-00b/ceos1/casestud/ecoreg/datasets/b03/bec.htm	biogeographic life form analysis	3 domains, 13 divisions, 34 provinces
7	Climate zone	Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of the Köppen-Geiger climate classification updated. Meteorol. Z., 15, 259-263. DOI: 10.1127/0941-2948/2006/0130.	The most frequently used climate classification map is that of Wladimir Köppen, presented in its latest version 1961 by Rudolf Geiger. A huge number of climate studies and subsequent publications adopted this or a former release of the Köppen-Geiger map. While the climate classification concept has been widely applied to a broad range of topics in climate and climate change research as well as in physical geography, hydrology, agriculture, biology and educational aspects, a well-documented update of the world climate classification map is still missing. Based on recent data sets from the Climatic Research Unit (CRU) of the University of East Anglia and the Global Precipitation Climatology Centre (GPCC) at the German Weather Service, we present here a new digital Köppen-Geiger world map on climate classification for the second half of the 20th century.	Climate monitoring and prediction	http://koeppen-geiger.vu-wien.ac.at/present.htm	climate	19 climate types
8	Ecological Land Units	Sayre, R., J. Dangermond, C. Frye, R. Vaughan, P. Aniello, S. Breyer, D. Cribbs, D. Hopkins, R. Nauman, W. Derrenbacher, D. Wright, C. Brown, C. Convis, J. Smith, L. Benson, D. Paco VanSistine, H. Warner, J. Cress, J. Danielson, S. Hamann, T. Cecere, A. Reddy, D. Burton, A. Grosse, D. True,	Land surface elements of global ecological pattern were characterized in an eco-physiographic stratification of the planet. The first step involved acquiring or developing four global raster data layers representing the primary components of ecosystem structure: bio climate, landform, lithology, and land cover. The second step involved a spatial combination of the four inputs into a single, new integrated raster dataset where every cell represents a combination of values from the bio climate, landforms, lithology, and land cover data layers. The third step involved an aggregation of the EFs into the 3,923 ELUs.	Global ecological zoning	http://www.arcgis.com/home/item.html?id=e55c8b1919854715a0d0ca5762c4dec9		The stratification produced 39 terrestrial ecological land units (ELUs) for Bangladesh at a base resolution of 250 meters

		M. Metzger, J. Hartmann, N. Moosdorf, H. Dürr, M. Paganini, P. DeFourny, O. Arino, S. Maynard, M. Anderson, and P. Comer. 2014. A New Map of Global Ecological Land Units — An Ecophysiographic Stratification Approach. Washington, DC: Association of American Geographers. 46 pages.					

2. Available maps for Bangladesh

Three national level ecological maps have been considered in this analysis.

Map 9: *Agro-Ecological map of Bangladesh*: Agro-Ecological Zones of Bangladesh determined on the basis of physiography, hydrology, cropping pattern, season, soil types and tidal activity. There are 30 Agro-Ecological Zones in Bangladesh. The agro ecological zone map of Bangladesh was developed to delineate the deferent agro-ecological zone and assess crop production potential for planning. The agro ecological zone map of Bangladesh was developed for national and local level production planning purposes (FAO 1988).

Map 10: *Physiographic map of Bangladesh*: Physiography is the description including form, substance, arrangement and changes of especially, natural features. In the context of physiography, Bangladesh may be classified into three distinct regions (a) floodplains, (b) terraces, and (c) hills each having distinguishing characteristics of its own. The physiography of the country has been divided into 20 sub-regions (FAO 1988).

Map 11: *Bio-ecological map of Bangladesh:* represents different bio-ecological zones for biodiversity protection (Reza 2002). The report on the bio-ecological zone produced an atlas on the biological diversity and ecological characteristics including biotic and abiotic at the national level. The focus was on the particular biological diversity in specific delineated areas.

Table 3 represents the detail information on the maps can be found in Appendix 2.

TABLE 3: AVAILABLE NATIONAL MAPS FOR ECOLOGICAL ZONING

ID	Classification types	References	Description	Objective	Internet link	Suitable for i.e.	Number of classes
9	Agro-ecological zones OF Bangladesh	FAO (1988). Land Resources Appraisal of Bangladesh for Agricultural Development BGD/81/035, Technical Report 1.	Land resource appraisal of Bangladesh was initiated in 1979 for the development of database of the natural resource using the soil survey data. These data is useful for planning and management of the natural resources.	To delineate deferent agro-ecological zone and assess crop production potential for planning, research and development	http://maps.barcapps.gov.bd/index.php?t=shape_file	Management and planning	30 classes
10	Physiographic units of Bangladesh	FAO (1988). Land Resources Appraisal of Bangladesh for Agricultural Development BGD/81/035, Technical Report 1.	physiographic units and subunits recognized	To identify the land form	http://maps.barcapps.gov.bd/index.php?t=shape_file	Planning	20 Classes
11	Bio-ecological zones of Bangladesh	2002, Reza, Ali. A. H. M.Barua, Shuvashish. P.Huq, S. M. ImamulKhan, A. S. MoniruzzamanNishat, Ainun, Bio-ecological zones of Bangladesh, ISBN: 984-31-1090-0	Bangladesh in 2002 classified the country into twenty five bio-ecological zones	To represent the different bio-ecological zones for biodiversity protection	https://portals.iucn.org/library/node/8177	Biodiversity conservation	12 zones

3. Available data to support the selection and description of the proposed zoning

Several maps and datasets are considered for the selection of the appropriate zoning map. Because the objective of the national forest inventory is to assess tree resources inside and outside forests, and tree structure and variability of the resources varies depending on various factors, the identification of the appropriate zoning map considers the following global, national and sub-national maps:

Map 12: Geographic location of forests according to Islam, J. (Islam 2007). This map was prepared by the forest department using the Landsat imagery of 2004-05 with the technical assistance of SPARRSO and FAO during the National Forest and Tree Sources Assessment. This map shows 14 land cover classes including forest areas in different region of the country. Forest areas are described as natural mangrove, mangrove plantation, hill and Sal forests.

Map 13: Forest Division map for forest types of Bangladesh (RIMS 2013a). Using the Ikonos and Rapid Eye imagery of 2011-12, maps were developed for the forest divisions of Bangladesh (RIMS 2013a). The Report provides the data descriptions, methodology for preparation of land cover map for the divisions, GIS Analysis and Maps. A separate appendix is attached (Appendix 4) to demonstrate the divisional maps.

Map 14: Soil types in Bangladesh: soil type database for Bangladesh was collected from BARC (FAO-UNDP 1988). Report can be found at http://www.fao.org/docrep/field/009/s7223e/s7223e.pdf.

Map 15: Digital Elevation Model: map for the country derived from SRTM data (http://srtm.csi.cgiar.org/). SRTM is an international research effort that obtained digital elevation models on a near-global scale to generate the most complete high-resolution digital topographic database of Earth.

Map 16 and 17: Temperature and precipitation map for Bangladesh (Hijmans 2005): One global map on temperature and precipitation was found available for the country. These information can be considered and aggregated with the ecological zone for better understanding of the zones.

Map 18: Salinity map of Bangladesh. Detail information can be found in

http://maps.barcapps.gov.bd/index.php?t=shape_file

Map 19. Map of Chittagong North and South Forest Division (RIMS 1998). Reserved and protected forest boundaries for the Chittagong forest division developed under FRMP (1994-1998(RIMS 1998)) Project based on the forest type map of FAO/UNDP project BGD/79/017.

Map 20. Map of Cox's Bazar Forest North and South Forest Division (RIMS 1998). Reserved and protected forest boundaries for the Coxsbazar forest division developed under FRMP (1994-1998 (RIMS 1998)) Project based on the forest type map of FAO/UNDP project BGD/79/017.

Map 21. Boundary of the Kassalong Reserved Forest (RIMS 2013b). Boundary of the Kassalong reserve is developed under Forestal Forestry (1958-60) project and digitised under FIGNSP project 2013.

Map 22. Boundary map of Rainkheong Reserve Forest (RIMS 2013c). Boundary of the Rainkheong reserve is developed under Forestal Forestry (1958-60) project and digitised under FIGNSP project 2013.

Map 23. Boundary of the of Sangu Matamuhuri Reserve Forest (RIMS 2013c). Boundary of the Sangu Matamuhuri reserve is developed under Forestal Forestry (1958-60) project and digitised under FIGNSP project 2013.

Map 24. Mouza Boundary of Rangamati, Bandarban and Khagrachari, (RIMS 2013a). Mauza boundaries for the CHT forest divisions (Rangamati, Bandarban, Khagrachari) were used to delineate the boundary of the forest of CHT.

Map 25. Best boundary for the Sylhet Region (RIMS 1998). Beat boundary for the hill forest of Sylhet region is digitised during FRMP Project (1994-1998) developed using Forest Cover and Beat Maps created by UNDP/FAO Project BGD/85/085).

Map 26. Map of Taingail Forest division (RIMS 2014). Division boundary prepared using the mauza boundary for Tangail, Mymensingh and Dhaka Forest division.

Map 27: Map of Mymensingh Forest division (RIMS 2014). Division boundary prepared using the mauza boundary for Tangail, Mymensingh and Dhaka Forest division.

Map 28. Map of Dhaka Forest division (RIMS 2014). Division boundary prepared using the mauza boundary for Tangail, Mymensingh and Dhaka Forest division.

Map 29. Map of Rajshahi social forest division (RIMS 2013a). Forest areas identified in the land cover data of forest type map of 2013 for Rajshahi, Rangpur, Dinajpur district were used to delineate the boundary of Sal forest. These maps can be found in Appendix 4.

Map 30. Compartment of the Sundarban Reserved Forest (RIMS 1998). FD use compartment boundaries for the management of Sundarban developed during Curtis 1930. Compartment boundaries have been digitised under FAO\UNDP Project BGD/84/056 that was refined under FRMP Project (1994-98) following the river courses is used as the boundary of the Sundarban.

Map 31. Map of the coastal plantation (RIMS 2013a). Mangrove plantation areas in newly accreted lands along the coast identified in the Land cover data of the coastal forest divisions of forest division map of 2013 was used to delineate the mangrove plantation boundary. These maps can be found in Appendix 4.

More detailed information about available global, national and sub-national datasets can be found in Table 4 and maps in Appendix 3.

TABLE 4: AVAILABLE DATA TO SUPPORT THE SELECTION AND DESCRIPTION OF THE PROPOSED ZONING

ID	Classification types	References	Description	Objective	Internet link	Suitable for i.e.	Number of classes
12	Forests In Bangladesh	Islam, J. (2007). Forest and other Land Uses of Bangladesh, A Technical Report on the Remote Sensing Monitoring Component of the Proiect Strengthening Capacity to Generate Quality Information on Forest Resources., Bangladesh Space Research and Remote Sensing Organization (SPARRSO) Agargaon, Dhaka Bangladesh, FAO Project TCP/BGD/3001: PP-31.	Land cover data of Bangladesh using Landsat imagery of 2004-05	For mapping the forest areas in the country	http://www.fao.org/forestry/17847/en/bgd/	Land cover Mapping	14 classes
13	Forest Division map for Bangladesh	RIMS (2013). Satellite Data Processing, GIS Analysis and Map Preparation. A separate appendix (Appendix 4) is added to show the maps.	Separate maps for all the existing forest types of 2011-12 of forest department were used to prepare a map to show all the types in a single map	To assess the legal forest areas of Bangladesh	-	Forest resource management	18 - 20 classes (based on the land cover identified in the areas of different forest types)
14	Soil type map of Bangladesh	FAO (1988). Land Resources Appraisal of Bangladesh for Agricultural Development **BGD/81/035, Technical Report 1**.	To provide soil information, from the global to the local scale,	Soil science and agriculture	http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html?sb=1	Agriculture	34 classes
15	Digital elevation model	Global SRTM data, (http://srtm.csi.cgiar.org/).	Digital elevation model at 30m resolution	to now the elevation, slope and aspect	http://srtm.csi.cgiar.org/	Planning	-
16	Mean temperature	Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.	Temperature	Spatial distribution of temperature	http://www.worldclim.org/current	Climate modelling	-
17	Annual precipitation	Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.	Precipitation	Spatial distribution of precipitation	http://www.worldclim.org/current	Climate modelling	-
18	Salinity map of Bangladesh	Bangladesh Agricultural Research Council, http://maps.barcapps.gov.bd/index.php?t=shape_file	Salinity	Presence of salinity	http://maps.barcapps.gov.bd/index.php?t=shape_file	Agriculture	-
19	Map of Chittagong North and South Forest Division	RIMS Unit, Forest Department	Boundary of the Chittagong North and South Forest Division	For forest management	-	Planning	-

20	Map of Cox'sBazar Forest North and South Forest Division	RIMS Unit, Forest Department	Boundary of the of Cox'sBazar Forest North and South Forest Division	For forest management	-	Planning	-
21	Boundary of the Kassalong Reserve Forest	RIMS Unit, Forest Department	Boundary of the of Kassalong Reserve Forest	For forest management	-	Planning	-
22	Boundary of the Rainkheong Reserve Forest	RIMS Unit, Forest Department	Boundary of the of Rainkheong Reserve Forest	For forest management	-	Planning	-
23	Boundary of the Sangu matamuhuri Reserve Forest	RIMS Unit, Forest Department	Boundary of the of Sangu matamuhuri Reserve Forest	For forest management	-	Planning	-
24	Mouza Boundary of Rangamati, Bandarban and Khagrachari	RIMS Unit, Forest Department	Mouza Boundary of the three districts	For forest management	-	Planning	-
25	Best boundary for the Sylhet Region	RIMS Unit, Forest Department	Beat boundaries of the Sylhet region	For forest management	-	Planning	-
26	Map of Tangail Forest division	RIMS Unit, Forest Department	Mauza boundaries for the Tangail Forest division	For forest management	-	Planning	-
27	Map of Mymensingh Forest division	RIMS Unit, Forest Department	Mauza boundaries for the Mymensingh Forest division	For forest management	-	Planning	-
28	Map of Dhaka Forest division	RIMS Unit, Forest Department	Mauza boundaries for the Dhaka Forest division	For forest management	-	Planning	-
29	Map of Rajshahi, Social Forest Division	RIMS Unit, Forest Department	forest areas identified in the land cover data of forest types map of 2013 for Rajshahi, social forest division	For forest management	-	Planning	-
30	Compartment of the Sundarban Reserved Forest	RIMS Unit, Forest Department	Compartment boundary of the Sundarbans reserved forest	For forest management	-	Planning	-
31	Map of the coastal plantation	RIMS Unit, Forest Department	Mangrove plantation areas of the coastal forest divisions of forest division maps of 2013 were used to delineate the mangrove plantation boundary.	For forest management	-	Planning	-

4. Comparison of available global and national maps

Available global and national ecological maps were compared. The following maps were considered as inappropriate because the delimitation of the boundary between the different zones was two coarse and did not reflect the national and subnational datasets boundaries: (FAO (map 1), Holdridge (map 3), Olson (map 4), Udvardy (map 5), Bailey (map 6), Koeppen (map 7). See Table 2 for details.

The analysis focused more on the available national maps (map 9, 10 and 12) and the map from WWF (map 2) and (map 8)). The selected maps developed by different institutions to meet different objectives of the country in different time have been analysed to select the proper maps for the delineation of ecological zones. Combining the maps of forest types, agro-ecological zone, ecological Land Units, physiographical zone and WWF ecoregion provides the opportunity for defining the zones for different forest type of the country (Table 5).

The forest division map of 2013 has been used to analyse the distribution of the forest types for the different classes within each proposed zone map. Table 6, Table 7, Table 8 and Table 9 present the distribution of forest types (e.g. Hill, Mangrove plantation, Sal, Sundarbans) into WWF ecoregions, Ecological Land Unit, Physiographic region and Agro-ecological Zone maps.

TABLE 5: DESCRIPTION OF THE ECOLOGICAL MAPS CONSIDERED FOR THE ANALYSIS

Maps	Results	Remark
WWF ecoregion map (WWF 2000)	Table 5	Includes only 8 classes with forest cover, therefore this combination should be considered as too general for use for stratification purposes.
Ecological Land Units (Sayre 2014)	Table 7	Includes 39 terrestrial ecological land units for Bangladesh
Physiographical map (FAO 1988)	Table 8	Is including the most information about all forest type distribution in 14 regions
Agro ecological map of Bangladesh (FAO 1988)	Table 9	Includes 18 classes representing forest distribution, but only describes 30% of mangrove forests

The analysis of the forest types with WWF ecoregion shows one eco-region is covering 97% of the Sal and 56% of the Hill forest (Table 6). Analysis with the Ecological Land Units also shows inconsistency among the ecological zone for the Hill and Sal forest (Table 7). Analysis of the forest types with respect to the national database of Physiographic Land Units shows difficulties to separate the Hill, Sal and Mangrove plantation areas in the physiographic units (Table 8). Agro-ecological units for the country also show the same problem for differentiating the Hill and Sal forest areas (Table 9). So far, none of the ecological zone database reflects properly the distribution of the forest types for the country.

In consequence, two options have been selected to improve defining the boundary of the zones. They are:

- Use the soil, altitude, salinity and climate database to define the best suitable boundary to represent the distribution of forest types. The idea for developing the zone map based on the above mentioned parameters is to use the ecological boundary for planning the inventory design that will not change over time for the forest types.
- Use the Forest management area map prepared using the data available at RIMS Unit of Forest Department to represent the forest areas throughout the country. This method uses existing reserved,

protected forest, protected area boundary of different forest divisions and mauza boundaries to define territorial forest administration divisions.

TABLE 6: PRESENTING THE DATA ABOUT FOREST TYPE DISTRIBUTION IN WWF ECOREGIONS (WWF 2000).

WWF Ecoregion	Total	Forest type							
		Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Assam hills moist deciduous forests	10944.39	33.94	0.00			843.84	2.17		
Bay of Bengal mangroves	72718.97	439.15	0.06	1845.17	3.00				
Lower Gangetic plain moist deciduous forests	10498856.87	435460.86	56.20	2467.00	4.01	37978.86	97.59		
Mizoram-Manipur-Kachin moist evergreen forest	711592.11	324842.55	41.92						
Myanmar Coastal forests	3022.64	1574.96	0.20	20.02	0.03				
Sunderbans mangrove	890594.04			6965.45	11.33			377745.22	95.34
Water	55796.70			122.73	0.20			1757.50	0.44
Brahmaputra Valley semi-evergreen moist forests	4651.88								
Terai-Duar savanna and grassland	12720.47								
No data		12557.24	1.62	49978.70	81.27	95.94	0.25	13958.01	3.52
Total	13703412	774908.7	100	61500	100	38918.63	100	396200	100

TABLE 7: PRESENTING THE DATA FOREST TYPE DISTRIBUTION IN ECOLOGICAL LAND UNITS (SAYRE 2014).

Ecological Land Unit	Total	Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Artificial or Urban Area	92145.95	3.06	0.00	18.08	0.03	15.07	0.04		
Hot Wet Hills on Mixed Sedimentary Rock with Grassland, Shrub, or Scrub	601.35	31.49	0.00						
Hot Wet Hills on Mixed Sedimentary Rock with Mostly Cropland	349.11	6.09	0.00						
Hot Wet Hills on Mixed Sedimentary Rock with Mostly Needleleaf/Evergreen Forest	227.95	1.35	0.00						
Hot Wet Hills on Non-Carbonate Sedimentary Rock with Grassland, Shrub, or Scrub	501402.97	254581.57	32.85			87.57	0.23		
Hot Wet Hills on Non-Carbonate Sedimentary Rock with Mostly Cropland	11552.93	3263.09	0.42			94.13	0.24		

Ecological Land Unit	Total	Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Hot Wet Hills on Non-Carbonate Sedimentary Rock with Mostly Deciduous Forest	13516.16	5615.51	0.72			25.73	0.07		
Hot Wet Hills on Non-Carbonate Sedimentary Rock with Mostly Needleleaf/Evergreen Forest	242482.85	152021.93	19.62			36.21	0.09		
Hot Wet Hills on Unconsolidated Sediment with Grassland, Shrub, or Scrub	6128.96	1340.34	0.17			11.57	0.03		
Hot Wet Hills on Unconsolidated Sediment with Mostly Cropland	841.59	61.01	0.01			11.27	0.03		
Hot Wet Hills on Unconsolidated Sediment with Mostly Deciduous Forest	394.97	46.63	0.01			2.44	0.01		
Hot Wet Hills on Unconsolidated Sediment with Mostly Needleleaf/Evergreen Forest	1452.15	480.16	0.06						
Hot Wet Mountains on Non-Carbonate Sedimentary Rock with Grassland, Shrub, or Scrub	59990.04	37844.67	4.88						
Hot Wet Mountains on Non-Carbonate Sedimentary Rock with Mostly Cropland	242.63	114.94	0.01						
Hot Wet Mountains on Non-Carbonate Sedimentary Rock with Mostly Deciduous Forest	1022.07	572.13	0.07						
Hot Wet Mountains on Non-Carbonate Sedimentary Rock with Mostly Needleleaf/Evergreen Forest	36423.06	24521.14	3.16						
Hot Wet Mountains on Unconsolidated Sediment with Grassland, Shrub, or Scrub	103.72	1.33	0.00						
Hot Wet Plains on Mixed Sedimentary Rock with Grassland, Shrub, or Scrub	1163.24	67.02	0.01						
Hot Wet Plains on Mixed Sedimentary Rock with Mostly Cropland	2942.16	21.81	0.00						
Hot Wet Plains on Non-Carbonate Sedimentary Rock with Grassland, Shrub, or Scrub	536874.41	180465.17	23.29	0.07	0.00	1771.87	4.55		
Hot Wet Plains on Non-Carbonate Sedimentary Rock with Mostly Cropland	1335618.51	23705.87	3.06			33159.56	85.20		
Hot Wet Plains on Non-Carbonate Sedimentary Rock with Mostly Deciduous Forest	18082.25	3617.24	0.47			594.86	1.53		
Hot Wet Plains on Non-Carbonate Sedimentary Rock with Mostly Needleleaf/Evergreen Forest	121676.40	60229.49	7.77			390.60	1.00		
Hot Wet Plains on Unconsolidated Sediment with Grassland, Shrub, or Scrub	886723.72	5702.65	0.74	488.09	0.79	4.44	0.01	5198.92	1.31

Ecological Land Unit	Total	Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Hot Wet Plains on Unconsolidated Sediment with Mostly Cropland	8560100.12	3118.85	0.40	690.30	1.12	2642.01	6.79	4966.95	1.25
Hot Wet Plains on Unconsolidated Sediment with Mostly Deciduous Forest	53935.94	295.07	0.04	40.50	0.07	5.99	0.02	22.21	0.01
Hot Wet Plains on Unconsolidated Sediment with Mostly Needleleaf/Evergreen Forest	80869.17	1988.31	0.26	28.88	0.05	0.89	0.00	219.27	0.06
Undefined	741540.32	390.57	0.05	39208.24	63.75			32495.72	8.20
Water body	584559.03	2274.44	0.29	2291.82	3.73	5.32	0.01	16148.89	4.08
Hot Wet Mountains on Unconsolidated Sediment with Mostly Cropland	9.88								
Hot Wet Mountains on Unconsolidated Sediment with Mostly Deciduous Forest	9.88								
Hot Wet Mountains on Unconsolidated Sediment with Mostly Needleleaf/Evergreen Forest	19.75								
Hot Wet Plains on Mixed Sedimentary Rock with Mostly Deciduous Forest	62.99								
Hot Wet Plains on Mixed Sedimentary Rock with Mostly Needleleaf/Evergreen Forest	140.67								
Hot Wet Plains on Non-Carbonate Sedimentary Rock with Bare Area	34.24								
Hot Wet Plains on Unconsolidated Sediment with Bare Area	37536.82								
No data		12440.08	1.61	16657.93	27.09	59.09	0.15	1000.04	0.25
Total	14295529.38	**774908.7**	**100**	**61500**	**100**	**38918.63**	**100**	**396200**	**100**

TABLE 8: PRESENTING THE DATA FOREST TYPE DISTRIBUTION IN PHYSIOGRAPHIC REGIONS (FAO 1988).

Physiography	Total	Forest type							
		Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%

Physiography	Total	Forest type							
		Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Chittagong Coastal Plain	373974.51	10115.65	1.31	7273.92	11.83				
Eastern Surma-Kusiyara Floodplain	486648.19	248.35	0.03						
Ganges Tidal Floodplain	1468314.8			5671.84	9.22			365705.72	92.30
High Barind Tract	165419.31					824.86	2.12		
Level Barind Tract	486518.84					51.39	0.13		
Lower Purnabhaba Floodplain	18185.504					63.13	0.16		
Madhupur Tract	412082.42					31007.21	79.67		
North-eastern Barind Tract	105883.04					1218.87	3.13		
Northern and Eastern Hills	1788575.9	752148.77	97.06	5.95	0.01	4376.13	11.24		
Northern and Eastern Piedmont Plains	417663.69	418.22	0.05			535.97	1.38		
Old Brahmaputra Floodplain	697163.88					135.52	0.35		
Old Himalayan Piedmont Plain	404948.86					570.07	1.46		
Teesta Meander Floodplain	952490.14					47.99	0.12		
Young Meghna Estuarine Floodplain	578208.22			34750.69	56.51				
Active Brahmaputra-Jamuna Floodplain	265290.66								
Active Ganges Floodplain	276054.25								
Active Tista Floodplain	63365.048								
Akhaura Terrace	8101.5964								
Arial Beel	15169.827								
Gopalganj-Khulna Beels	198357.61								
High Ganges River Floodplain	1297988.8								
Karatoya-Bangali Floodplain	253228.77								
Low Ganges River Floodplain	746780.05								
Lower Atrai Basin	79370.598								
Lower Meghna River Floodplain	83640.867								
Middle Meghna River Floodplain	125691.67								
Old Meghna Estuarine Floodplain	782551.91								
St. Martin's Coral Island	294.88971								

Physiography	Total	Forest type							
		Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sylhet Basin	412401.11								
Young Brahmaputra and Jamuna Floodplain	558312.23								
No data	102685.75	11977.70	1.55	13797.60	22.44	87.49	0.22	30494.28	7.70
Total	13625363	774908.7	100	61500	100	38918.63	100	396200	100

TABLE 9: PRESENTING THE DATA FOREST TYPE DISTRIBUTION IN AGRO-ECOLOGICAL UNITS (FAO 1988).

Agro-ecological Zone	Total	Forest type							
		Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Chittagong Coastal Plain	322709.47	2531	0	3542	6				
Eastern Surma-Kusiyara Floodplain	464483.65	253	0						
Ganges Tidal Floodplain	1482225			3155	5			357109	90
High Barind Tract	154159.32					520	1		
Kaptai Lake	49897.553	7917	1						
Level Barind Tract	500453.34					362	1		
Madhupur Tract	405346.7					31006	80		
North-Eastern Barind Tract	102723.63					1219	3		
Northern and Eastern Hills	1395223.6	528092	68	169	0	4383	11		
Northern and Eastern Piedmont Plains	387490.82	350	0			536	1		
Old Brahmaputra Floodplain	714580.45					136	0		
Old Himalayan Piedmont Plain	401919.47					570	1		
Reserved Forest	282174.65	160157	21						
Sylhet Basin	426937.52	128	0						
Tista Meander Floodplain	953727.69					137	0		
Urban	81318.971	174	0	6	0				
Waterbodies	15631.709	340	0			2	0		

Agro-ecological Zone	Total	Forest type							
		Hill forest		Mangrove plantation		Sal forest		Sundarban	
	Area (ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Young Meghna Estuarine Floodplain	544551.89			11342	18				
Active Brahmaputra-Jamuna Floodplain	242237.42								
Active Ganges Floodplain	228670.99								
Active Tista Floodplain	61767.943								
Akhaura Terrace	9747.2804								
Arial Bil	14370.623								
Gopalganj-Khulna Bils	222438.91								
High Ganges River Floodplain	1296413								
Karatoya-Bangali Floodplain	242558.63								
Low Ganges River Floodplain	779389.61								
Lower Atrai Basin	82802.276								
Lower Meghna River Floodplain	90596.281								
Lower Purnabhaba Floodplain	14484.966								
Middle Meghna River Floodplain	129738.51								
Old Meghna Estuarine Floodplain	776148.79								
St. Martin's Coral Island	840.66629								
Young Brahmaputra and Jamuna Floodplains	577085.11								
No data		74965.25	10	43286.48	70	48.29	0	39090.55	10
Total	13454846	774908.7	100	61500	100	38918.63	100	396200	90

5. Proposed Zoning for Forest Monitoring –Option 1

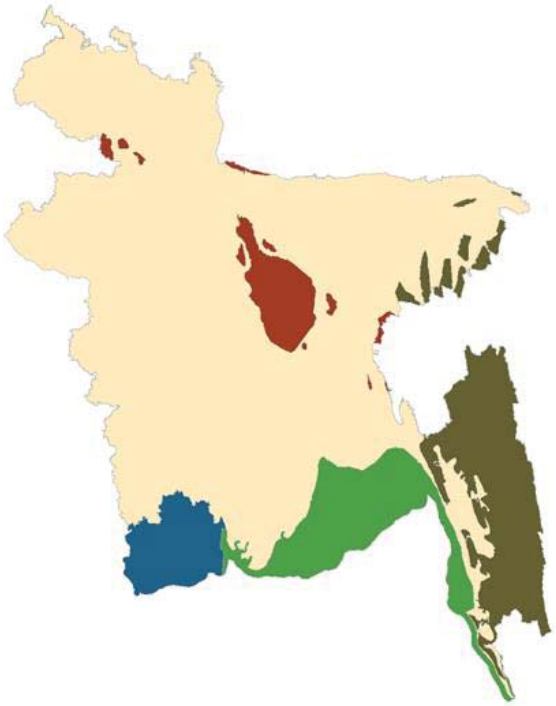


FIGURE 1: PROPOSED ZONES – OPTION 1

5.1 Methodology used to develop the zone – Option 1

The zoning map has been developed based on the analysis of the distribution of forest types (RIMS 2013) in different soil types, climate types, and altitude and salinity types. The results from the analysis used the rules outlined below for the delimitation of the forest zones based on edaphic and climate parameters.

TABLE 10: CLASSIFICATION BASED ON SOIL TYPES

Soil type	Description
Alluvium:	Includes three types of soil- Calcareous Alluvium (non-saline), Non-calcareous Alluvium, Non-calcareous Grey Floodplain (non-saline).
Sundarban	Dominant in the characteristics found in the Sundarban.
Terrace Soil and Brown Soil	Brown mottled Terrace soils, Deep Grey Terrace soils, Deep Red-Brown Terrace soils, Shallow Grey Terrace soils, Shallow Red Brown Terrace soils.
Other Soil	Acid basin clays, Acid sulphate soils, Calcareous Grey Floodplain soils, Grey Piedmont soils, Grey Valley soils, Non-calcareous Brown Floodplain soils, Non-calcareous Dark Grey Floodplain soils.

TABLE 11: CLASSIFICATION BASED ON SOIL SALINITY

Forest Type	Description
Mangrove	Includes dominantly two types of salinity- Very weakly saline (2-4 MMHOS/cm) and weakly saline (4-8 MMHOS/cm). Some small parts may also fall within Moderately saline (8-15 MMHOS/cm) and non-saline (<2 MMHOS/cm) areas.

TABLE 12: CLASSIFICATION BASED ON ALTITUDE/ ELEVATION

Forest Type	Description
Sundarban	Falls within the range of 1-50 meter above the sea level which is considered as the second lowest area.

TABLE 13: CLASSIFICATION BASED ON CLIMATE

Forest Type	Description
Hill Forest	Most of the areas fall within the Tropical Rainforest climatic category.
Sal Forest	Most of the areas fall within the Tropical Moist forest climatic category.
Village	Included both in the Tropical Moist and Tropical Rain forest climatic categories.

TABLE 14: OTHER TYPES

Forest Type	Description
Village	Includes most of the areas in of Bangladesh where 0.55% area is considered as forest according to BFD and 0.1% according to RIMS.

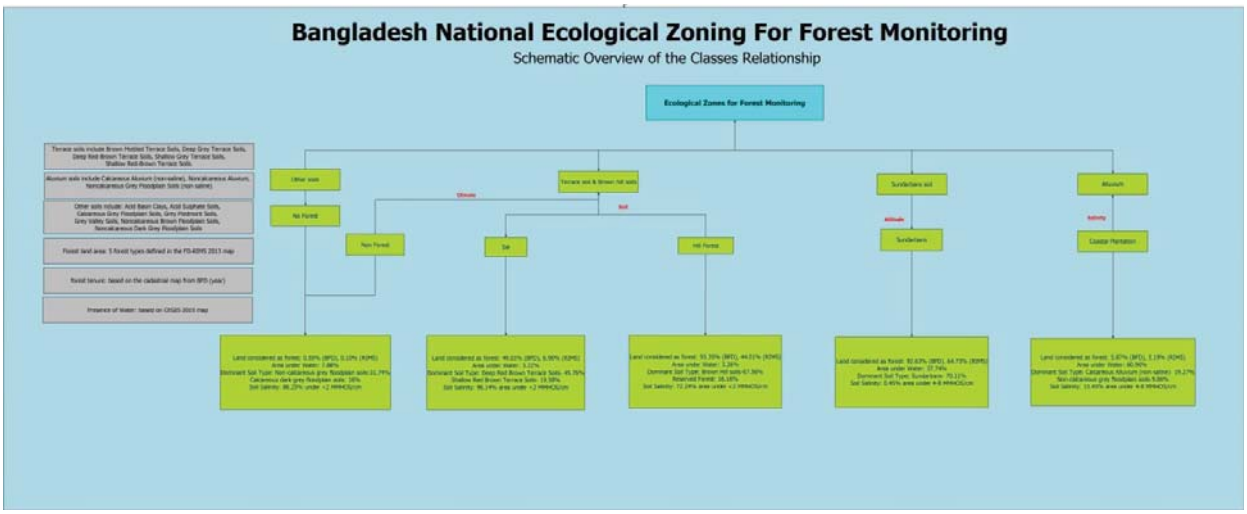
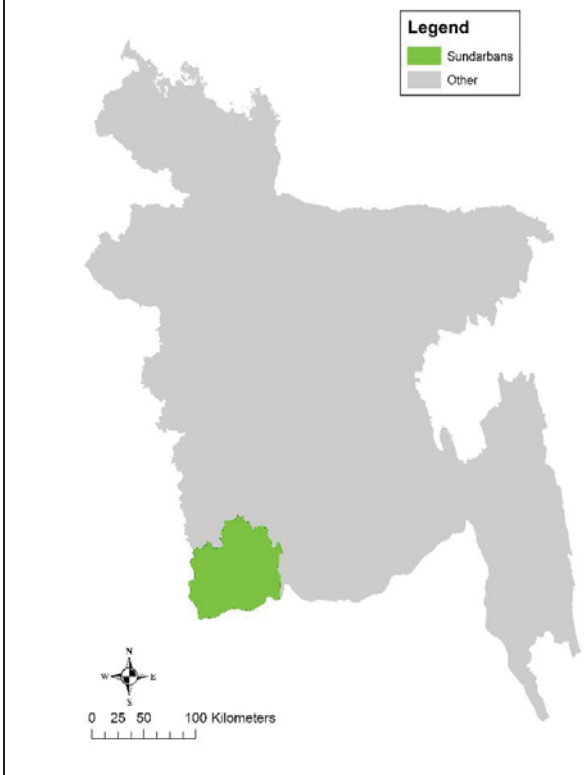


FIGURE 2: SCHEMATIC OVERVIEW OF THE FOREST AND ZONES RELATIONSHIP

TABLE 15: PERCENTAGE OF FOREST (RIMS 2013) IN EACH ZONE – OPTION 1

Zones	Forest land (FD-RIMS 2013)		Total Area (ha)
	Area (ha)	%	
Coastal plantation	62724.5	5.19	1,209,000
Hill	754414.7	44.01	1,714,000
Sal	36895.8	6.90	534,800
Sundarban	394355	64.73	609,200
Village	10849.46	0.10	10,890,000

5.2 Sundarbans zone



Presence of terrestrial land (%): 62.26
Presence of water (%): 37.74

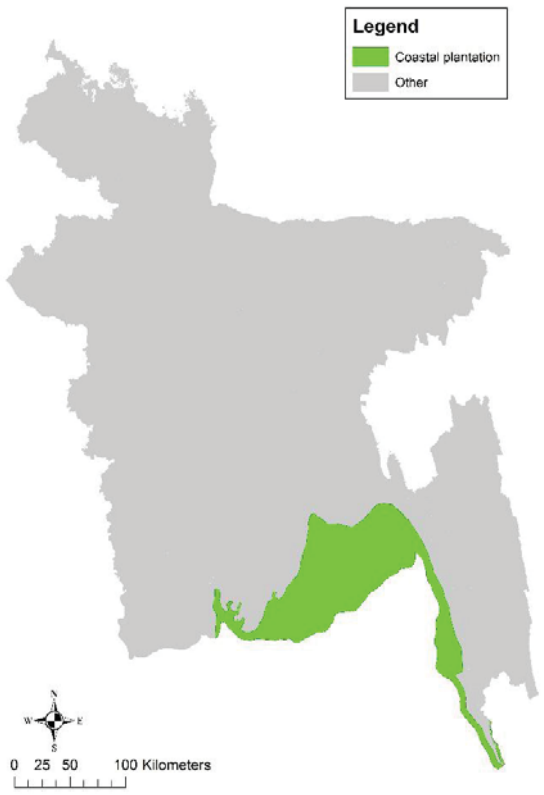
Soil types:
Noncalcareous Grey Floodplain Soils (non-saline) – 1923 ha and 0.32% of total land area
Acid Sulphate Soils – 333.1 ha and 0.05 % of total land area
Sundarban – 427100 ha and 70.11% of total land area
No data/- 179843.9 ha and 29.52% of total land area

Precipitation:
Min: 1783 mm, Max: 2343 mm, Average: 2004 mm

Accessibility (%):
Extreme HTR: 33.87, Very HTR: 0.04

Road length: 99993.07 m
Total Area: 609200 ha
Road density: 0.16 m/ha

5.3 Coastal zone



Presence of terrestrial land (%): 39.04
Presence of water (%): 60.96

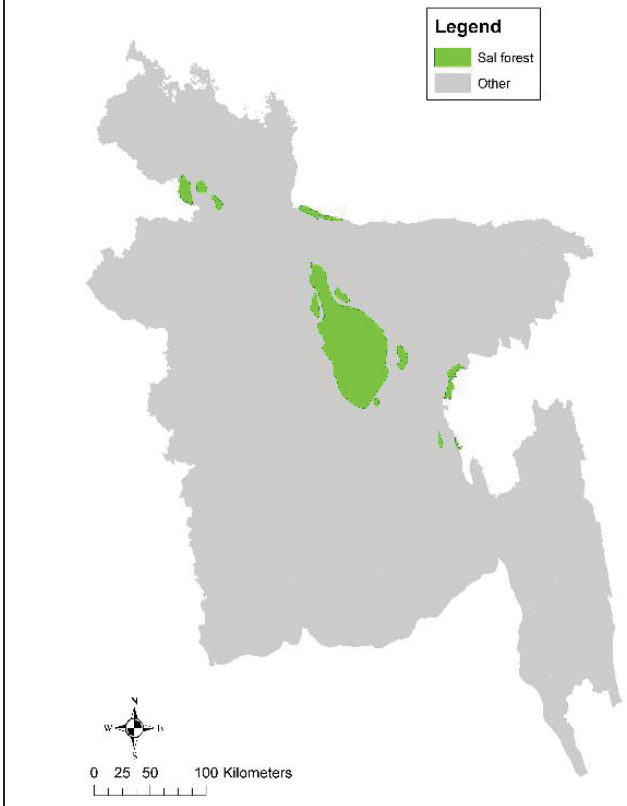
Soil types:
Brown Hill Soils– 16400 ha and 1.36% of total land area
Acid Sulphate Soils – 33060 ha and 2.73 % of total land area
Calcareous Aluvium (non-saline) – 233000 ha and 19.27% of total land area
Calcareous Grey Floodplain Soils- 75230 ha and 6.22% of total land area
Noncalcareous Aluvium- 31600 ha and 2.61% of total land area
Noncalcareous Grey Floodplain Soils (non-saline)- 109500 ha and 9.06% of total land area
No data - 709565.3 ha and 58.69% of total land area

Precipitation:
Min: 2267 mm, Max: 3698 mm, Average: 2870 mm

Accessibility (%):
Extreme HTR: 24.31, Very HTR: 1.42

Road length (m): 4110715.723
Total Area (ha): 1209000
Road density (m/ha): 3.40

5.4 Sal zone



Presence of terrestrial land (%): 96.78
Presence of water (%): 3.22

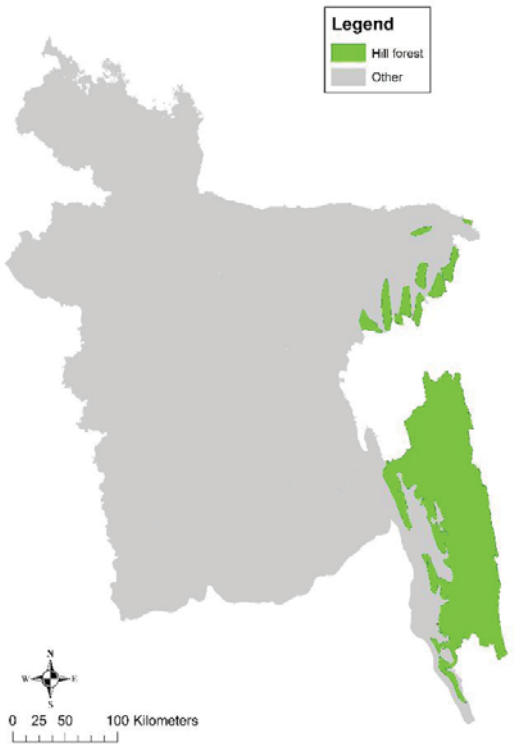
Soil types:
Acid Basin Clays- 16900 ha and 3.16% of total land area
Brown Hill Soils– 14980 ha and 2.8% of total land area
Brown Mottled Terrace Soils– 20310 ha and 3.8 % of total land area
Deep Red-Brown Terrace Soils- 244700 ha and 45.76% of total land area
Shallow Grey Terrace Soils- 34030 ha and 6.36% of total land area
Shallow Red-Brown Terrace Soils- 104700 ha and 19.58% of total land area

Precipitation:
Min: 1804 mm, Max: 2462 mm, Average: 2040 mm

Accessibility (%):
Extreme HTR:
12.01, Moderate HTR: 1.26, Very HTR: 6.26

Road length: 2484824.10 m
Total Area: 534800 ha
Road density: 4.65 m/ha

5.5 Hill zone



Presence of terrestrial land (%): 96.74
Presence of water (%): 3.26

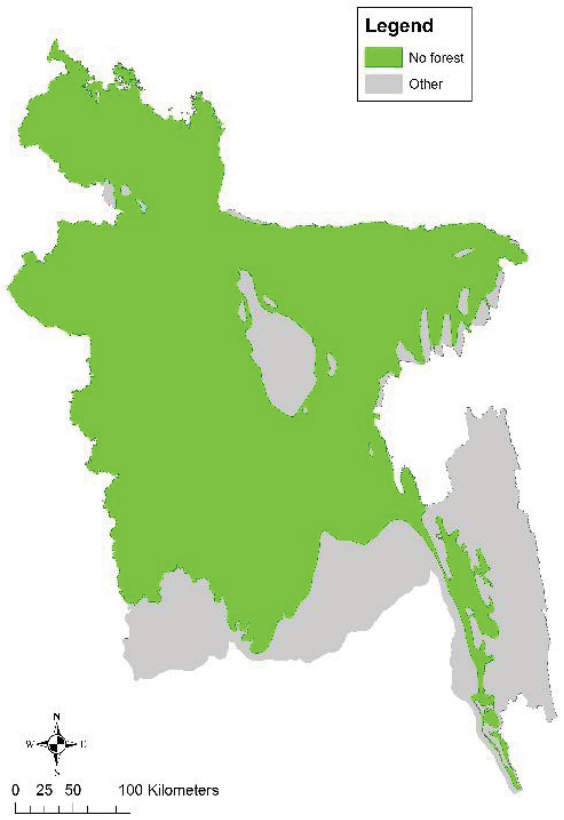
Soil types:
Acid Sulphate Soils– 2885 ha and 0.17% of total land area
Brown Hill Soils– 1158000 ha and 67.56 % of total land area
Kaptai Lake– 49900 ha and 2.91% of total land area
Noncalcareous Grey Floodplain Soils (non-saline)- 33490 ha and 1.95% of total land area
Reserved Forest- 276900 ha and 16.16% of total land area

Precipitation:
Min: 2061 mm, Max: 4370 mm, Average: 2720 mm

Accessibility (%):
Extreme HTR: 51.60, Very HTR: 15.46

Road length: 7069806.495 m
Total Area: 1714000 ha
Road density: 4.12 m/ha

5.6 Village zone



Presence of terrestrial land (%): 92.12
Presence of water (%): 7.88

Soil types:
Acid Basin Clays- 310500 ha and 2.85 % of total land area
Brown Hill Soils- 113100 ha and 1.04% of total land area
Calcareous Aluvium (non-saline) - 343200 ha and 3.15% of total land area
Calcareous Brown Floodplain Soils- 300500 ha and 2.76% of total land area
Calcareous Dark Grey Floodplain Soils- 1960000 ha and 18% of total land area
Deep Grey Terrace Soils- 350800 ha and 3.22% of total land area
Grey Piedmont Soils- 193000 ha and 1.77% of total land area
Noncalcareous Aluvium- 425700 ha and 3.91% of total land area
Noncalcareous Brown Floodplain Soils- 391900 ha and 3.6% of total land area
Noncalcareous Dark Grey Floodplain Soils- 1802000 ha and 16.55% of total land area
Noncalcareous Grey Floodplain Soils (non-saline) - 3457000 ha and 31.74% of total land area
Peat- 111600 ha and 1.02% of total land area
Shallow Grey Terrace Soils- 325100 ha and 2.99% of total land area
No data- 482769.9857 ha and 4.43% of total land area

Accessibility (%):
Extreme HTR: 13.07, Very HTR: 12.10, Moderate HTR: 0.52

Road length: 100971434.5 m
Total Area: 10890000 ha
Road density: 10890000 m/ha

6. Proposed Zoning for forest Monitoring –Option 2

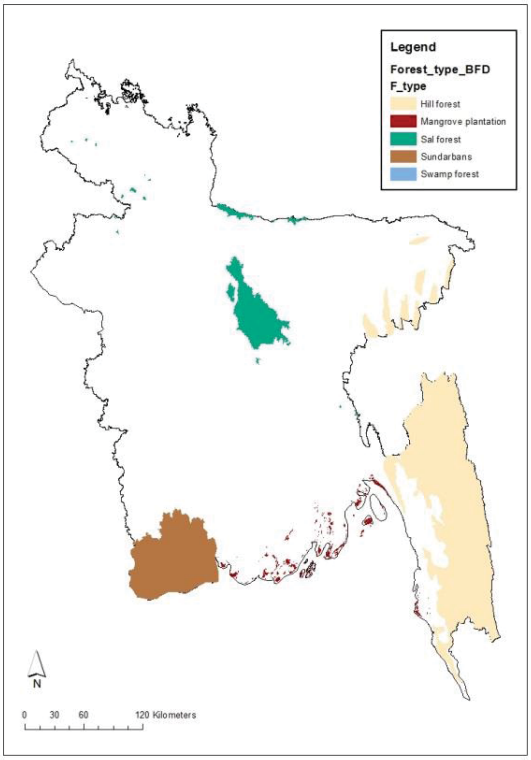


FIGURE 3: PROPOSED ZONES – OPTION 2

6.1 Methodology used to develop zones – Option 2

Reserved and protected forest boundaries for the forest divisions and the updated land cover databases for the forest divisions of 2013 (Forest Department, 2013) were used to prepare the forest management area map. Using this methodology, Hill forest areas occur in Chittagong, Cox's Bazar, Chittagong Hill Tracts, Maulvibazar, Sylhet, Sunamgang, Habigong district.

Sal Forest areas occur in Dhaka, Gazipur, Mymensingh, Jamalpur, Sherpur, Tangail and small patches of Dinajpur, Rangpur and Joypurhat district;

Natural Mangrove (Sundarban) occur in Khulna and Bagerhat district;

Mangrove plantations are defined by areas the newly accreted char lands on the coast of Patuakhali, Barguna, Bhola, Noakhali, Coxsbazar and Chittagong district.

A list of datasets used to prepare the forest management area map can be found in Table 16.

TABLE 16: DATA OF RIMS UNIT FOR THE FOREST AREAS

Zones	Data type
Hill	GIS shape files for the boundaries and forest types 2013
Sal	GIS shape file of the forest divisions and forest types 2013
Sundarban Reserved Forest	GIS shape file of the compartment

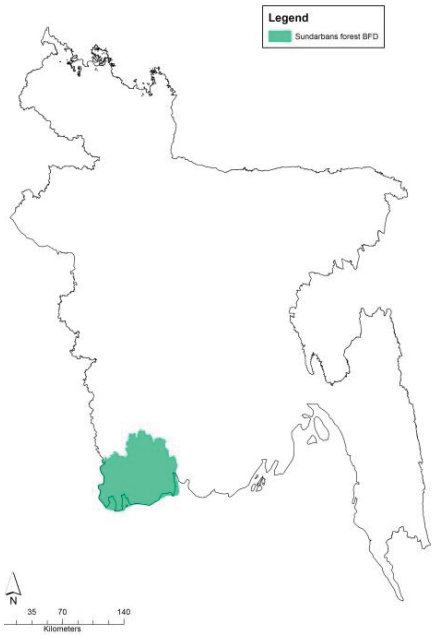
Coastal Plantation	GIS shape file of forest type 2013

All data was merged to prepare the forest management area map. The area therefore includes urban areas, water body, other land uses within it. Table 17 provides the distribution of forest types using the forest area methodology.

TABLE 17: PERCENTAGE OF FOREST (RIMS 2013) IN ZONE – OPTION 2

Zones	Area (ha)	%	Total Area (ha)
Hill	751947.08	45.81	1641503.12
Mangrove plantation	61448.96	99.92	61497.28
Sal	37840.55	13.26	285337.52
Sundarbans Reserved Forest	396384.14	68.26	580707.54
Village	23967.76	0.20	11872366.94

6.2 Sundarbans Reserved Forest



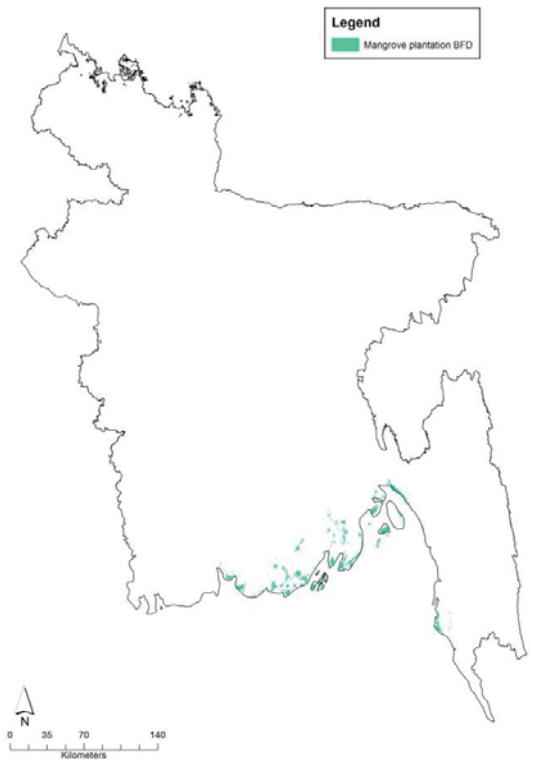
Presence of terrestrial land (%):75.72
Presence of water (%): 24.28

Soil types:
Acid Sulphate Soils– 655.91ha and 0.11% of total land area
Noncalcareous Grey Floodplain Soils (non-saline)– 1236.19ha and 0.21 % of total land area
Sundarban – 428235.35ha and 73.74% of total land area
No data/- 150580.08ha and 25.93% of total land area

Precipitation:
Min: 1783mm, Max: 2343mm, Average: 2007.90mm
Accessibility (%):
Extreme HTR: 35.66, Very HTR: 0.06

Road length: 103670.80m
Total Area: 580707.54ha
Road density: 0.18m/ha

6.3 Mangrove plantations



Presence of terrestrial land (%):29.55
Presence of water (%): 70.45

Soil types:
Acid Sulphate Soils– 493.74 and 0.80% of total land area
Brown Hill Soils– 163.29ha and 0.27 % of total land area
Calcareous Aluvium (non-saline) –10699.71ha and 17.40% of total land area
Calcareous Grey Floodplain Soils- 560.14ha and 0.91% of total land area
Noncalcareous Aluvium- 2088.44ha and 3.40% of total land area
Noncalcareous Grey Floodplain Soils (non-saline)- 4202.69ha and 6.83% of total land area

Precipitation:
Min: 2532mm, Max: 3258mm, Average: 2881.16mm

Accessibility (%):
Extreme HTR: 40.93, Very HTR: 1.78

Road length: 47240.03m
Total Area: 61497.28ha
Road density: 0.77m/ha

6.4 Sal

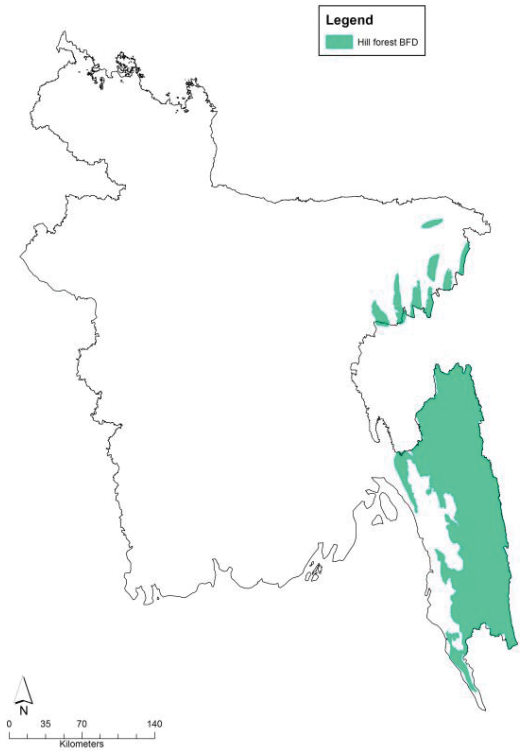
Presence of terrestrial land (%): 99.33
Presence of water (%): 0.67

Soil types:
Acid Sulphate Soils– 4867.41ha and 1.71% of total land area
Brown Hill Soils– 12534.05ha and 4.39 % of total land area
Brown Mottled Terrace Soils- 8709.16ha and 3.05% of total land area
Deep Grey Terrace Soils- 2530.99 and 0.89% of total land area
Deep Red-Brown Terrace Soils- 145683.45ha and 51.06% of total land area
Grey Piedmont Soils- 3711.11ha and 1.30% of total land area
Grey Valley Soils- 775.46 and 0.27% of total land area
Noncalcareous Aluvium- 214.03ha 0.08% of total land area
Noncalcareous Brown Floodplain Soils- 1087.98ha and 0.38%of total land area
Noncalcareous Dark Grey Floodplain Soils- 8281.05 and 2.90% of total land area
Shallow Grey Terrace Soils- 11900.92ha and 4.17% of total land area
Shallow Red-Brown Terrace Soils- 69273.16ha and 24.28% of total land area
Waterbodies- 486.34ha and 0.17% of of total land area

Precipitation:
Min: 1829mm, Max: 2751mm, Average: 2066.33mm
Accessibility (%):
Extreme HTR: 18.48, Very HTR: 8.99

Road length: 1390268.74m
Total Area: 285337.51ha
Road density: 4.87m/ha

6.5 Hill



Presence of terrestrial land (%): 96.57
Presence of water (%): 3.43

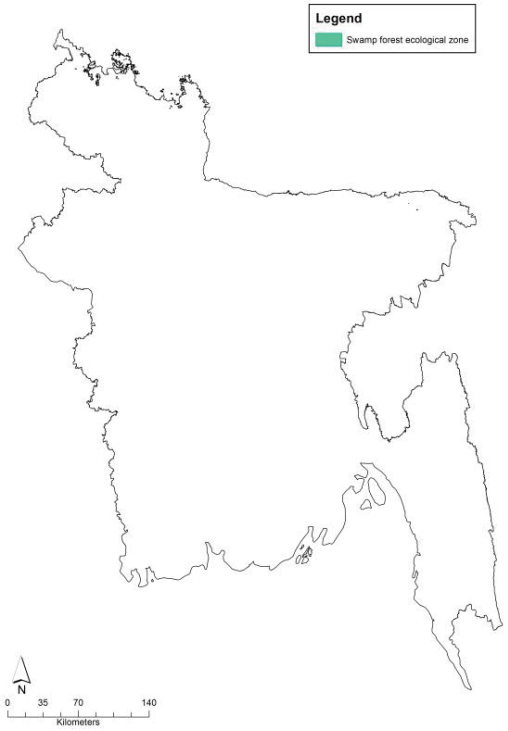
Soil types:
Acid Sulphate Soils– 3409.77ha and 0.21 % of total land area
Brown Hill Soils- 1088441.34ha and 66.31% of total land area
Grey Piedmont Soils- 11850.25ha and 0.72% of total land area
Kaptai Lake- 49897.55 and 3.04% of total land area
Noncalcareous Aluvium- 1638.45ha and 0.10% of total land area
Noncalcareous Brown Floodplain Soils- 4989.67ha and 0.30% of total land area
Noncalcareous Dark Grey Floodplain Soils- 1013.55ha and 0.06% of total land area
Noncalcareous Grey Floodplain Soils (non-saline)- 25208.58ha and 1.54% of total land area
Reserved Forest- 276855.65ha and 16.86% of total land area
Urban-443.75ha nd 0.03% of total land area
Waterbodies-392.54ha and 0.02% of total land area
No data- 177361.98ha and 10.80% of total land area

Precipitation:
Min: 2104mm, Max: 4370mm, Average: 2724.18mm

Accessibility (%):
Extreme HTR: 52.31, Very HTR: 15.24

Road length: 6555347.61m
Total Area: 1641503.11ha
Road density: 3.99m/ha

6.6 Village



Presence of terrestrial land (%): 79.31
Presence of water (%): 20.69

Soil types:
Acid Basin Clays, 323320.5ha 4.8% of total land area
Acid Sulphate Soils- 79569.6ha and 0.7% of of total land area
Brown Hill Soils- 207790.2 ha and 1.8% of of total land area
Brown Mottled Terrace Soils- 32682.6 haand 0.3% of of total land area
Calcareous Aluvium (non-saline)- 566777.2ha and 4.8% of of total land area
Calcareous Grey Floodplain Soils- 141433.7ha and 1.2% of of total land area
Deep Grey Terrace Soils- 353250.4ha and 3% of total land area
Deep Red-Brown Terrace Soils- 130507.1ha and 1.1% of total land area
Grey Piedmont Soils- 195961.9ha and 1.7% of total land area
Grey Valley Soils-1257.3ha and 0.01% of total land area
Noncalcareous Aluvium-456392.7ha and 3.8% of total land area
Noncalcareous Brown Floodplain Soils- 395369.6ha and 33.% of total land area
Noncalcareous Dark Grey Floodplain Soils- 1831995.1ha and 15.4% of total land area
Noncalcareous Grey Floodplain Soils (non-saline)- 3607502.5ha and 30% of total land area
Reserved Forest- 5319.0ha and 0.04%% of total land area
Shallow Grey Terrace Soils- 348480.1ha and 2.9% of total land area
Shallow Red-Brown Terrace Soils- 37929.3ha and 0.3% of total land area
Sundarban- 2701.3ha and 0.02% of total land area
Urban- 80730.0ha and 0.7% of total land area
Waterbodies- 14752.8ha and 0.1% of total land area
Black Terrai Soils- 78479.2ha and 0.7% of total land area
Calcareous Brown Floodplain Soils- 300806.9ha 2.5% of total land area
Calcareous Dark Grey Floodplain Soils- 1964011.3ha 16.5% of total land area
Peat- 112606.5ha and 0.9% of total land area
No data-602740.08ha and 5.1% of total land area

Accessibility (%):
Extreme HTR: 14.6, Very HTR: 11.5, Moderate HTR: 0.54

Road length: 107216318.19m
Total Area: 11872366.93ha
Road density: 9.03m/ha

7. Conclusion

This document was developed to define sub-populations that may be used to stratify the Bangladesh Forest Inventory. Numerous global and national data sets were considered in the process of zone boundary delineation. However, most of the global maps identified were deemed unsuitable as they failed to reflect the spatial distribution of vegetation types and edaphic factors influencing their distribution at an appropriate scale.

Two different zone maps were prepared under this document. They are zone map (option 1) and forest management area map (option 2). Two global maps and three national maps were used for defining the zones for option 1. The analysis of the maps reveals that certain vegetation types, such as the Sundarbans, are well delineated by available maps. Others, such as the Sal forests or the coastal plantation/mangrove plantation, were not as easily defined due to their fragmentation. In consequence, two methodologies were explored: Option 1 was based on natural phenomena (soil, salinity, altitude and climate etc.) and Option 2 was based on legal delineation.

Comparison of Option 1 and Option 2 shows nearly 70% of the mangrove plantation of Option 2 falls in areas not defined as in Option 1. This is due to Option 2 delineating areas defined by the Forest Department as the plantations in newly accreted land, while Option 2 considers a larger area based on soil type and salinity. In this way, Option 1 may be preferable as the larger area may better account for the dynamic environment defined by its erosion and accretion.

Limitations of the process relate to data access which impacted the preparation of the maps. In particular, the national boundaries used for the preparation of the new map are not the latest. In addition, the delineation of the boundaries for the costal plantation/mangrove plantation is difficult because the boundaries change over time because of sedimentation.

Another limitation relates to shape file shifting/mismatch within the coastal and hilly regions and among the boundaries for the zones e.g. Sal, hill and coastal zone. Appendix 5 provides the methodology for the preparation of database to fix some of the mismatch problem. Figure 4 shows the mismatches among the zones and Figure 5 shows the mismatches for the coastal zone.

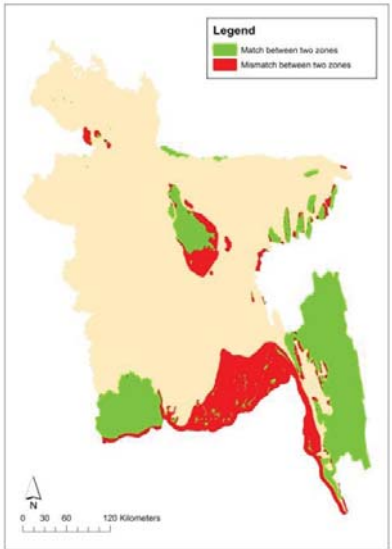


FIGURE 4 MISMATCHES OF TWO ZONES

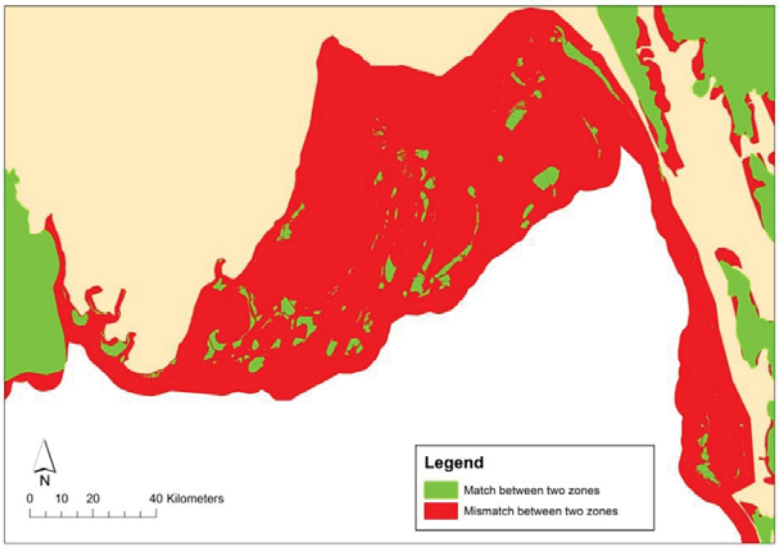


FIGURE 5: GREEN: MATCH BETWEEN ZONE, RED: NO MATCH

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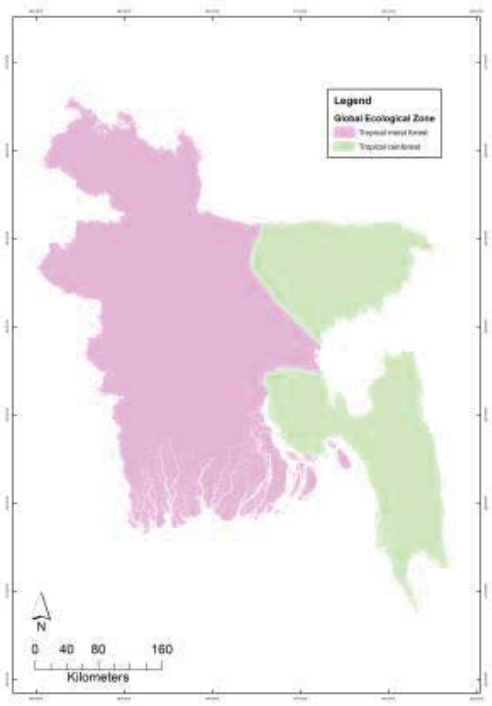
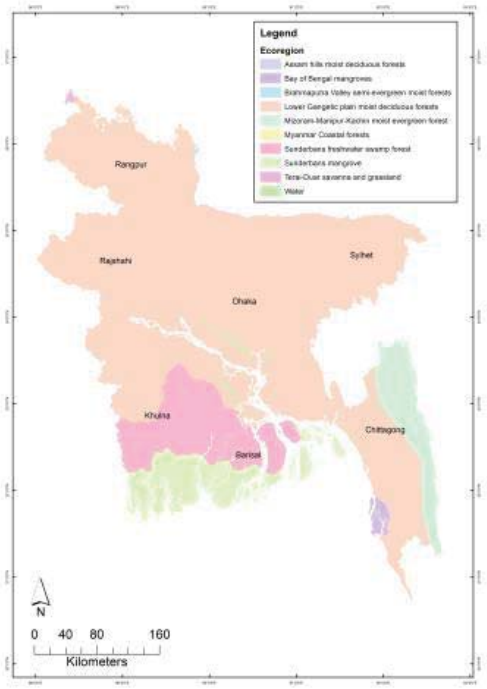
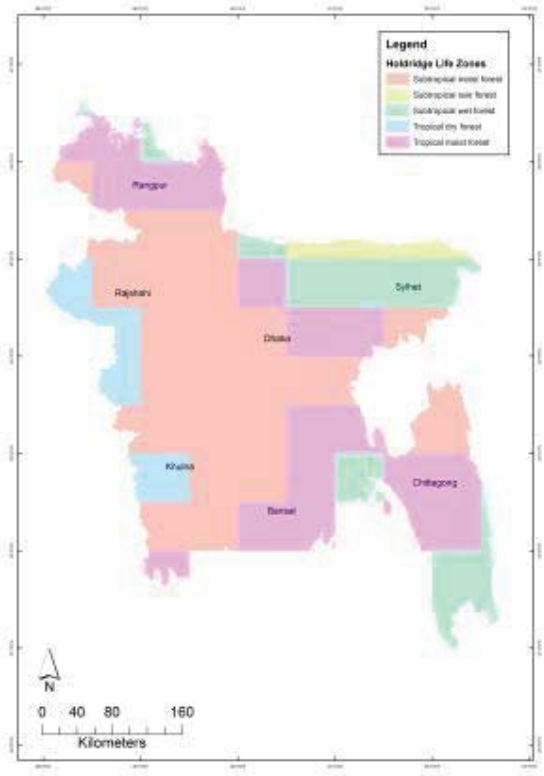
APPENDIX 1: AVAILABLE GLOBAL MAPS



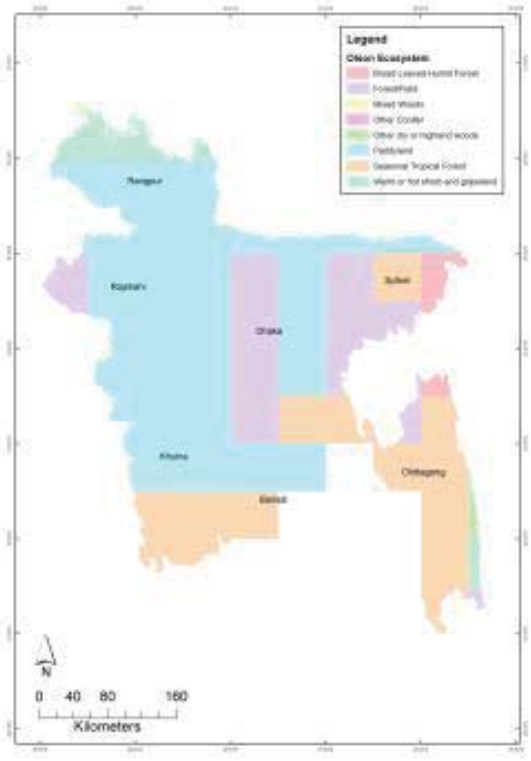
Map 1: Global ecological zones for FAO forest reporting: 2010 Update- (FAO 2012)



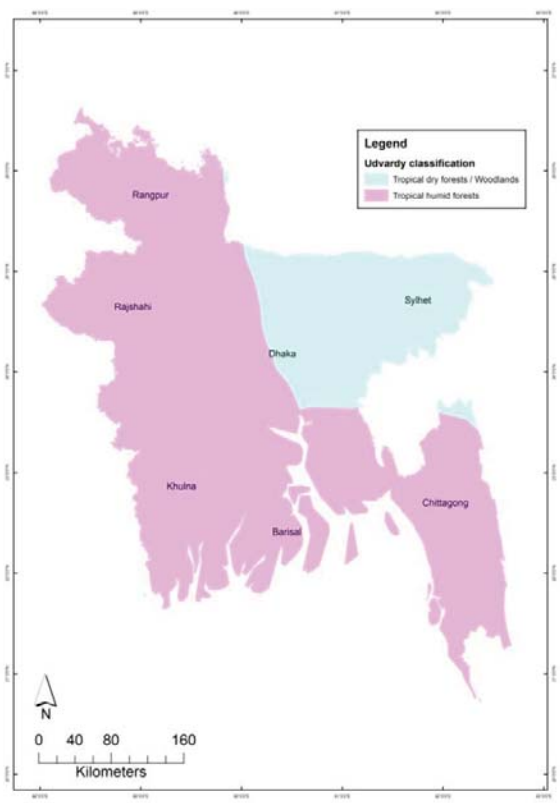
Map 2: Terrestrial ecoregions of the World (WWF 2000)



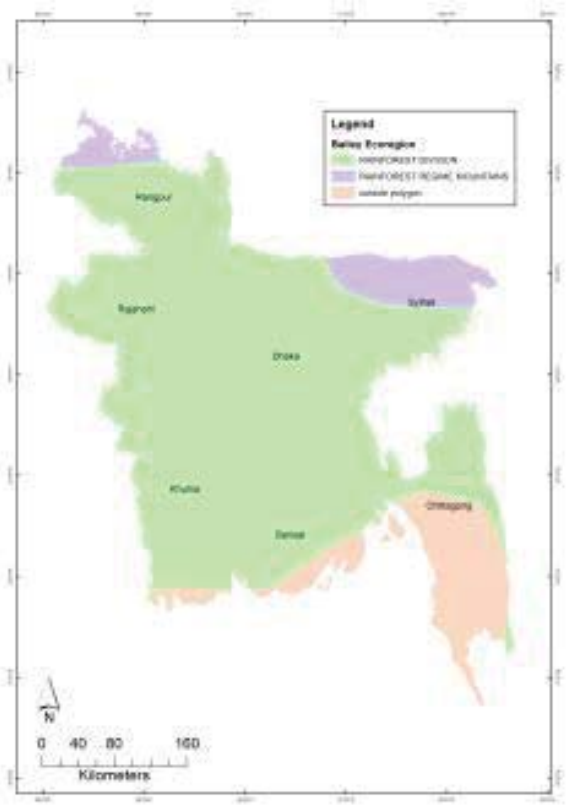
Map 3: The Holdridge Life Zones – (Leemans 1990)



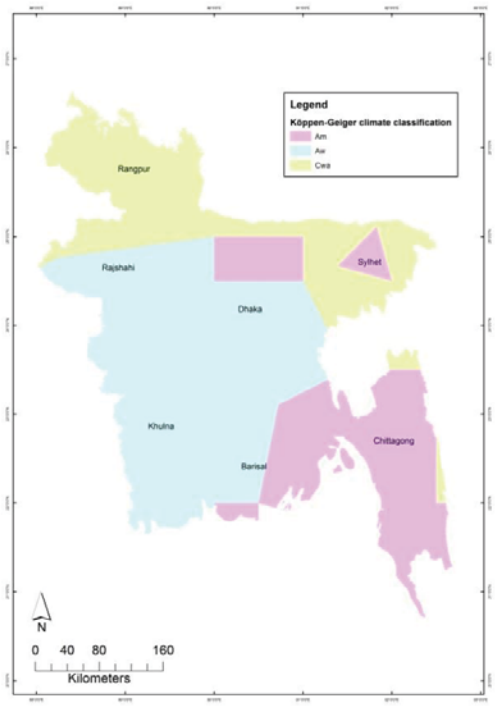
Map 4: Major ecosystem complexes – (Olson 1982)



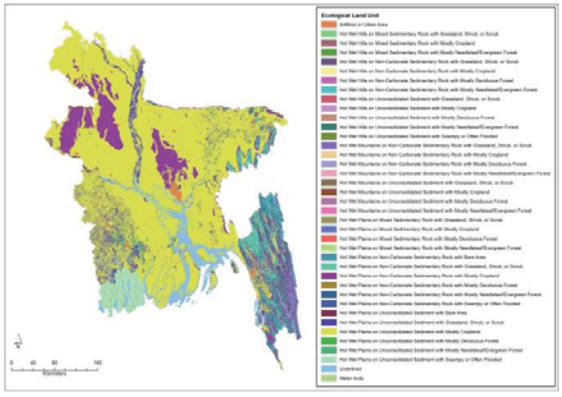
Map 5: Classification of the bio-geographical provinces of the world (Udvardy 1975)



Map 6: Ecoregions map – (Bailey 1989)

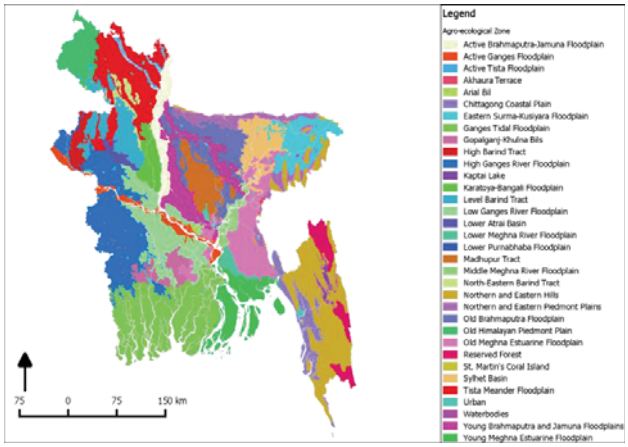


Map 7: Climate classification map (Kottek 2006)

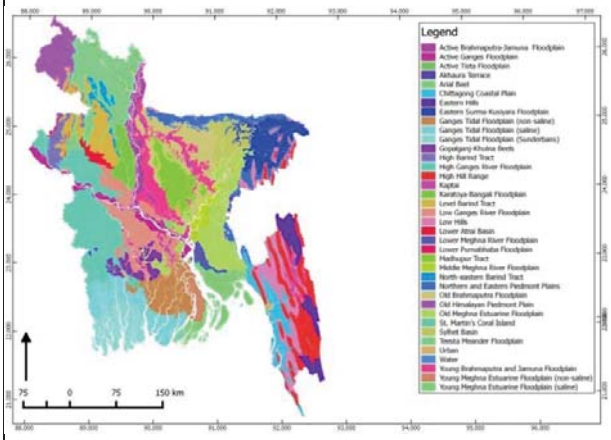


Map 8: Land surface elements of global ecological pattern (Sayre 2014)

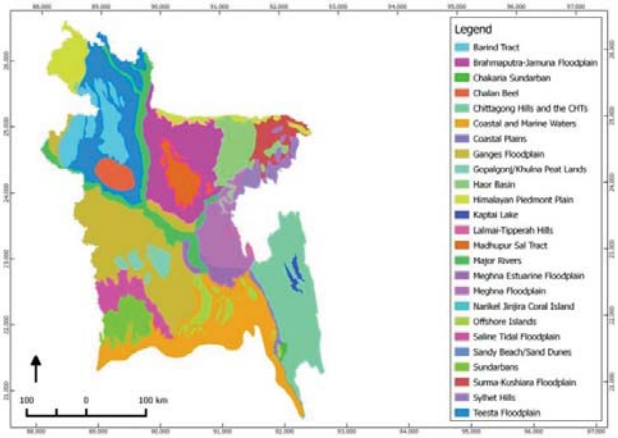
APPENDIX 2: AVAILABLE NATIONAL MAPS



Map 9: Agro-ecological region of Bangladesh (FAO 1988)

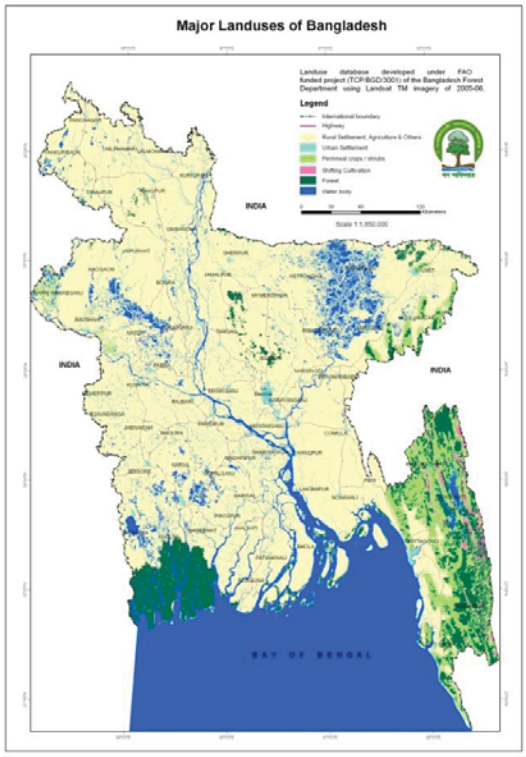


Map 10: Physiographic Unit of Bangladesh (FAO 1988)

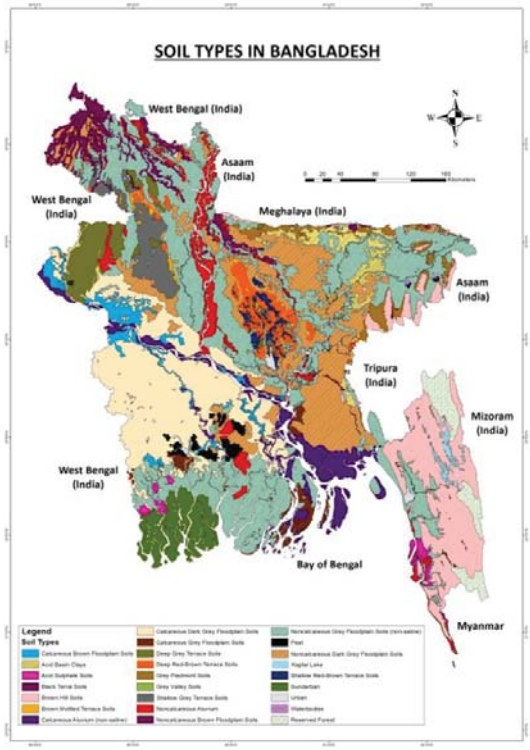


Map 11: Bio-Ecological zone of Bangladesh (Reza 2002)

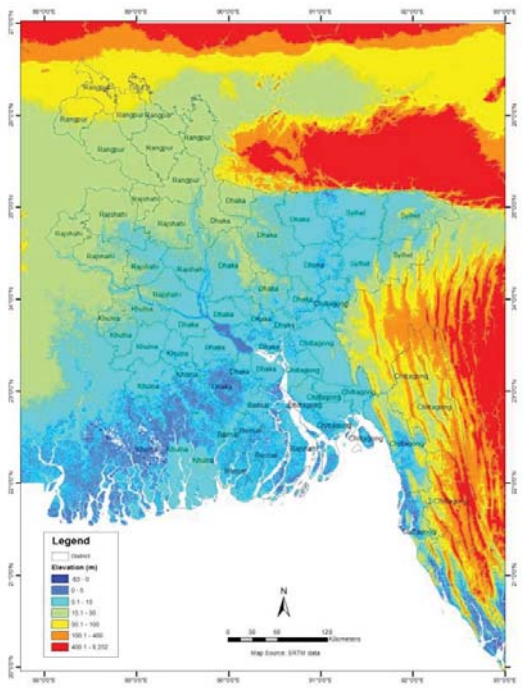
APPENDIX 3: AVAILABLE NATIONAL MAP TO SUPPORT THE SELECTION PROCESS OF THE ECOLOGICAL ZONING



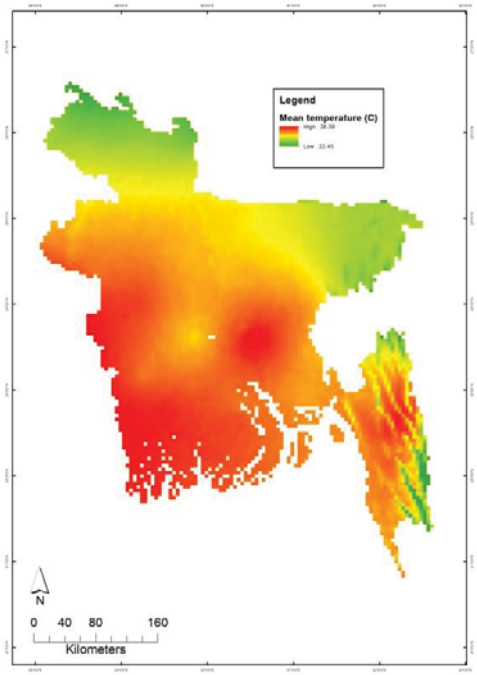
Map 12 Forests and other land uses of Bangladesh (Islam 2007)



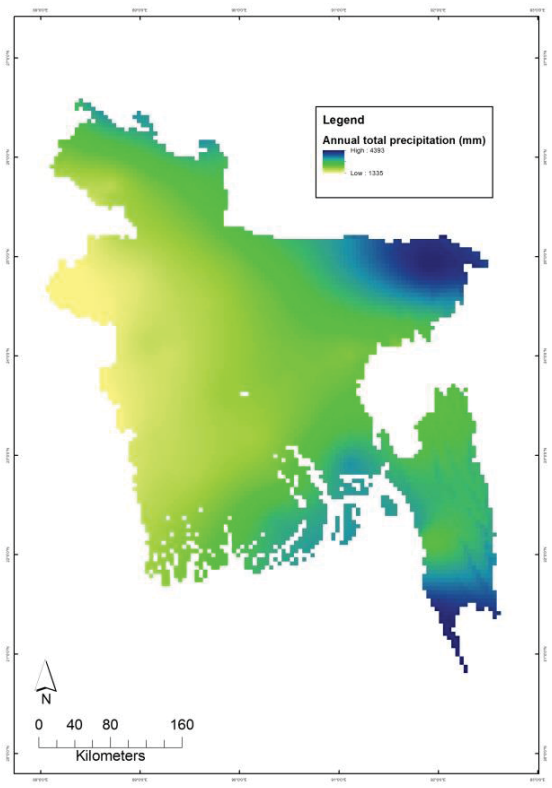
Map 14. Soil type in Bangladesh (FAO 1988)



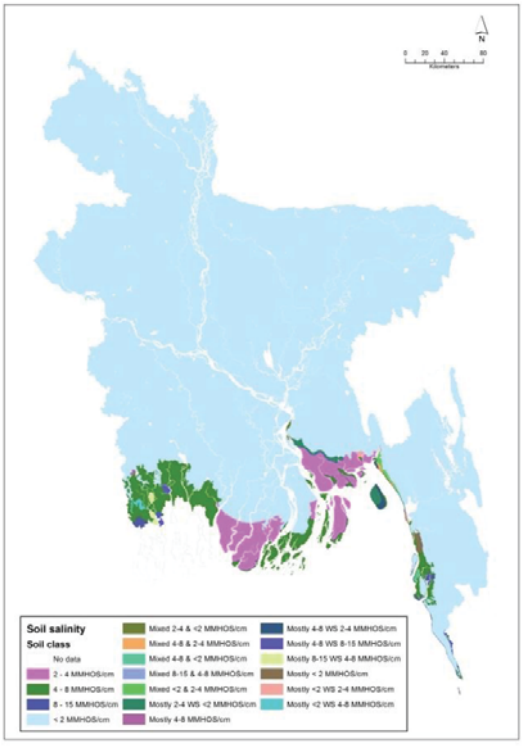
MAp 15: Digital elevation model (http://srtm.csi.cgiar.org/).



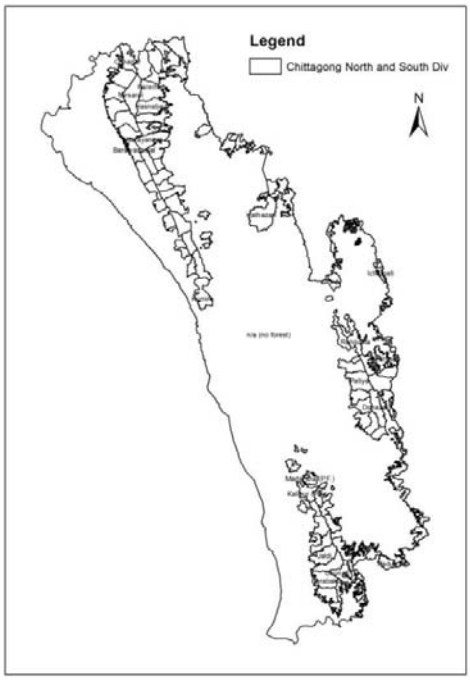
Map 16. Annual temperature (Hijmans 2005)



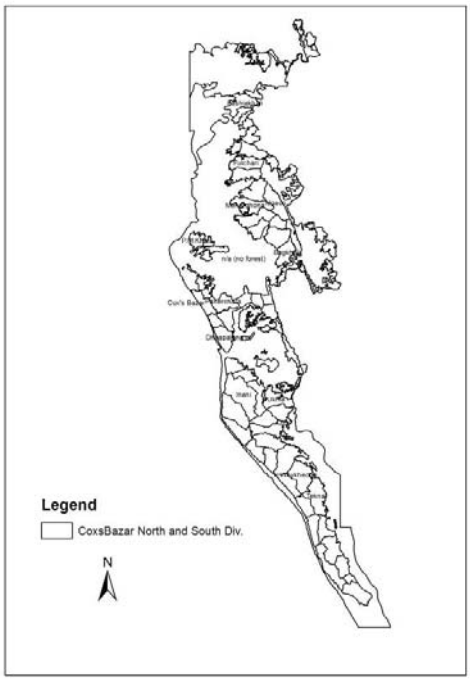
Map 17: Annual precipitation (Hijmans 2005)



Map 18: Salinity map of Bangladesh http://maps.barcapps.gov.bd/index.php?t=shape_file



Map 19. Map of Chittagong North and South Forest Division (RIMS 1998)



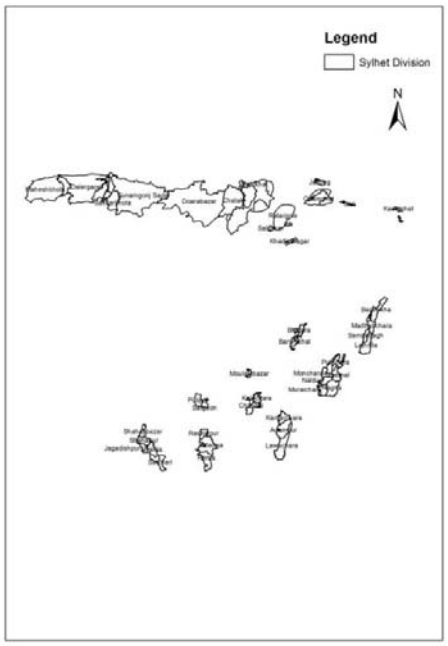
Map 20. Map of Cox'sBazar Forest North and South Forest Division (RIMS 1998)

Map 21. Boundary of the Kassalong Reserved Forest (RIMS 2013b)

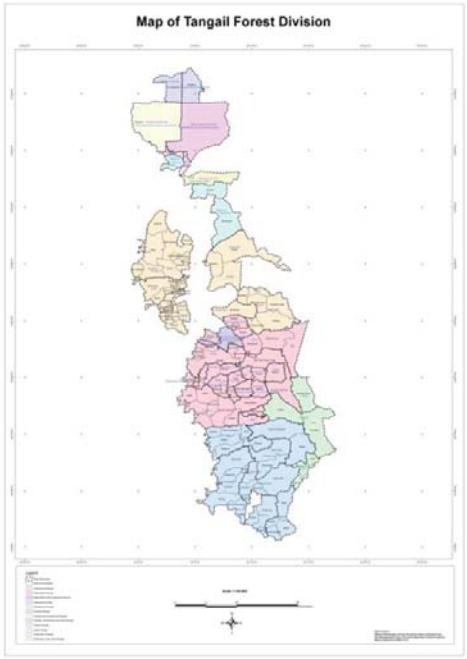
Map 22. Boundary map of Rainkheong Reserve Forest (RIMS 2013c)

Map 23. Boundary of the of Sangu matamuhuri Reserve Forest (RIMS 2013c)

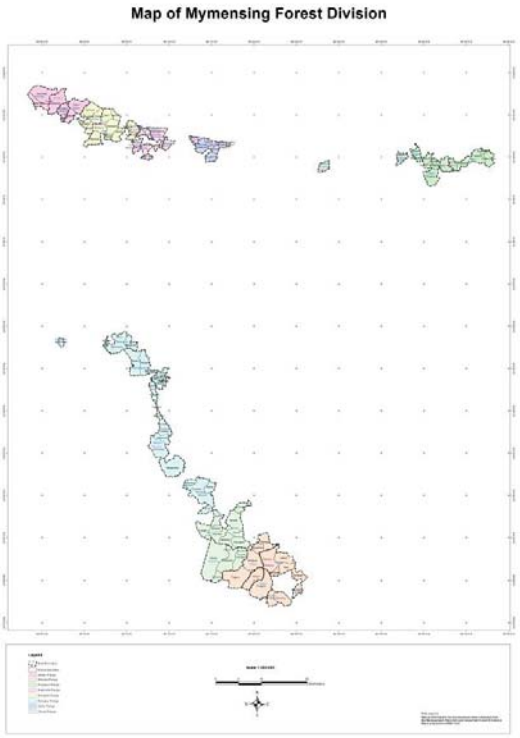
Map 24. Mouza Boundary of Rangamati, Bandarban and Khagrachari, (RIMS 2013a)



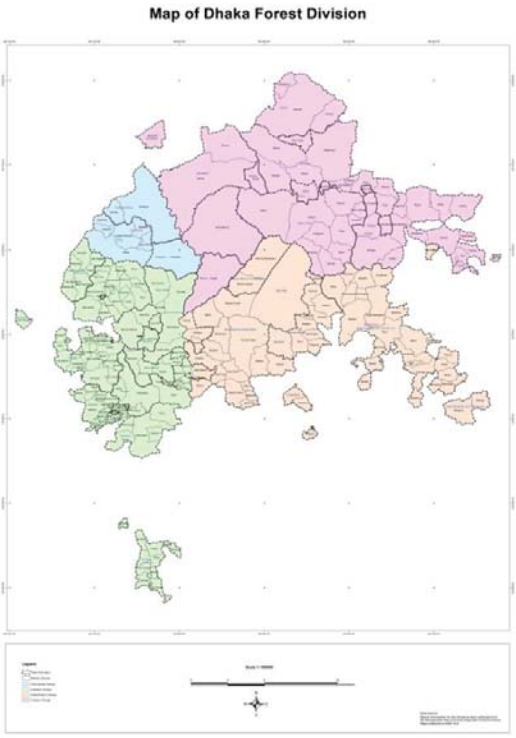
Map 25. Best boundary for the Sylhet Region (RIMS 1998)



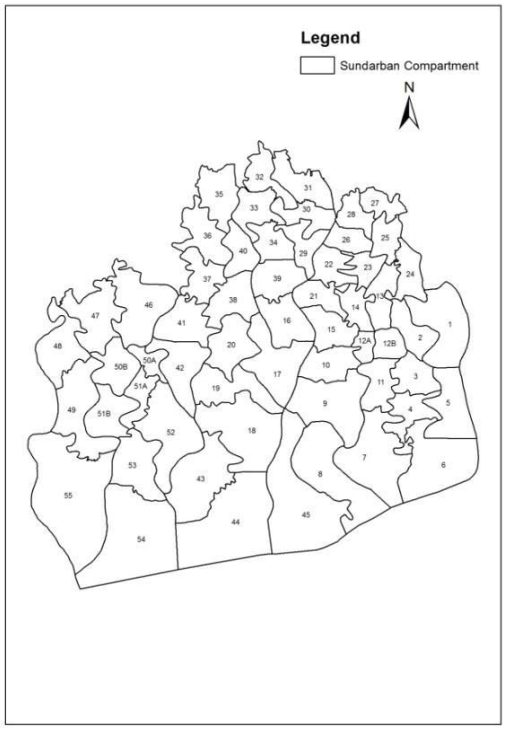
Map 26. Map of Taingail Forest division (RIMS 2014)



MAP 27. MAP OF MYMENSINGH AND DHAKA FOREST DIVISION (RIMS 2014)

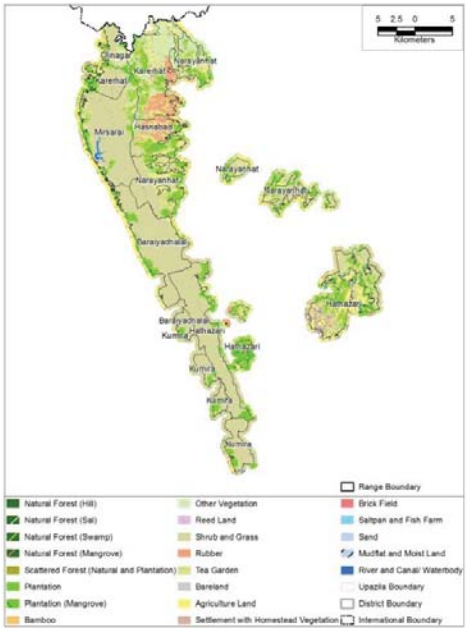


Map 28. Map of Dhaka Forest division (RIMS 2014)

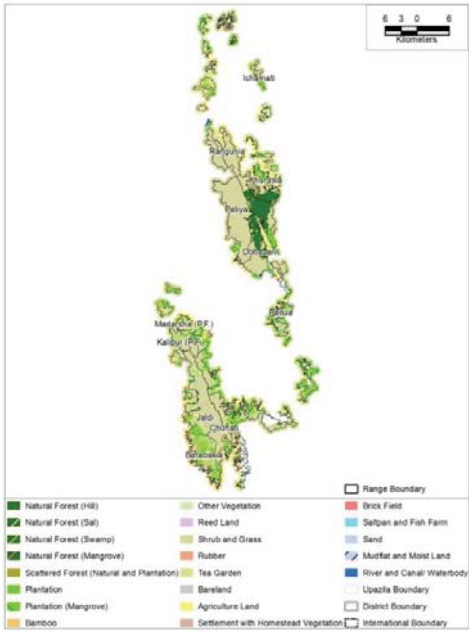
	
Map 30. Compartment of the Sundarban Reserved Forest (RIMS 1998)	Map 31. Map of the coastal plantation (RIMS 2013a)- can be found in Appendix 4.

APPENDIX 4: FOREST DIVISION MAPS FOR FOREST TYPES OF BANGLADESH

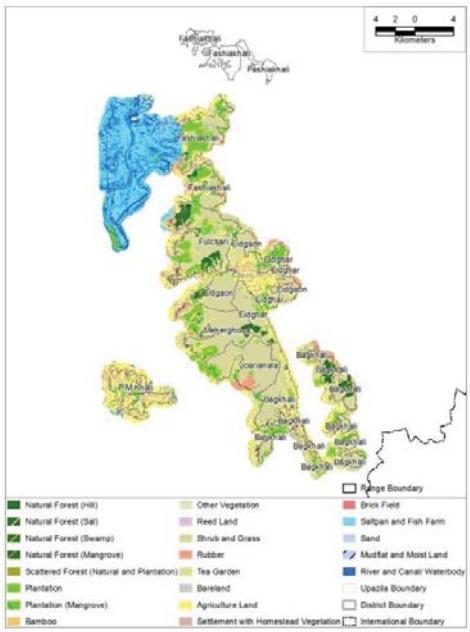
Appendix 4: **Map 13:** Forest Division maps for forest types of Bangladesh (RIMS 2013a)



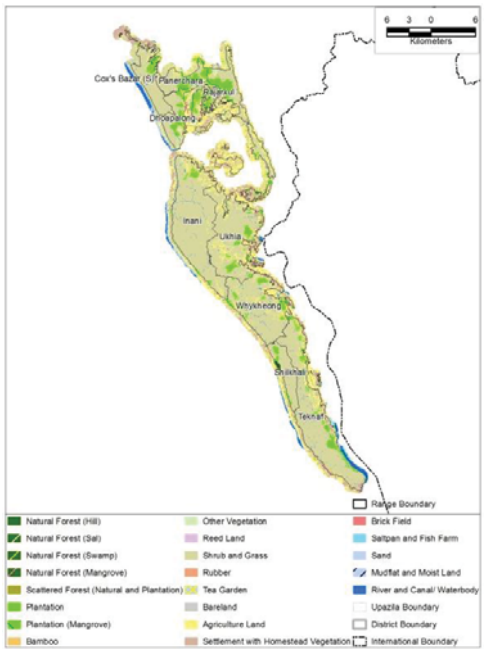
13.a Forest coverage map of Chittagong North Forest Division



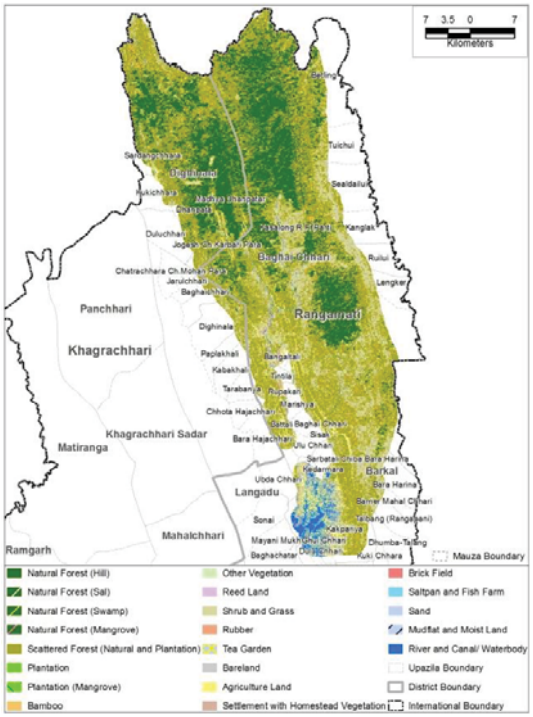
13.b Forest coverage map of Chittagong South Forest Division



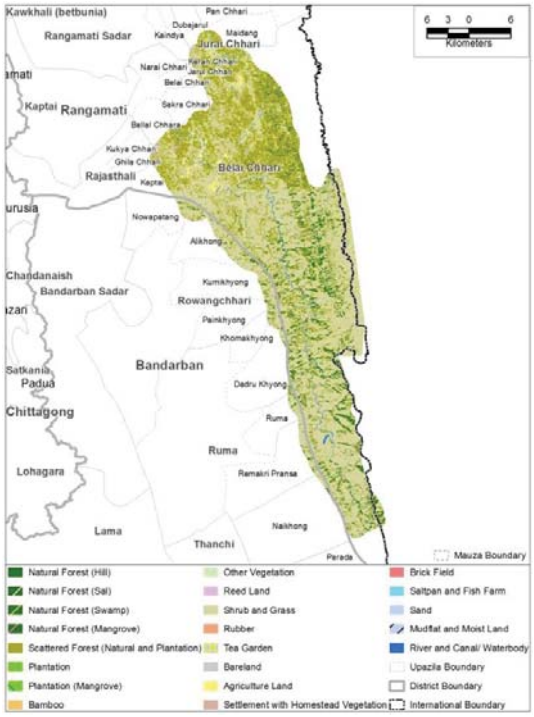
13.c Forest coverage map of Cox's Bazar North Forest Division



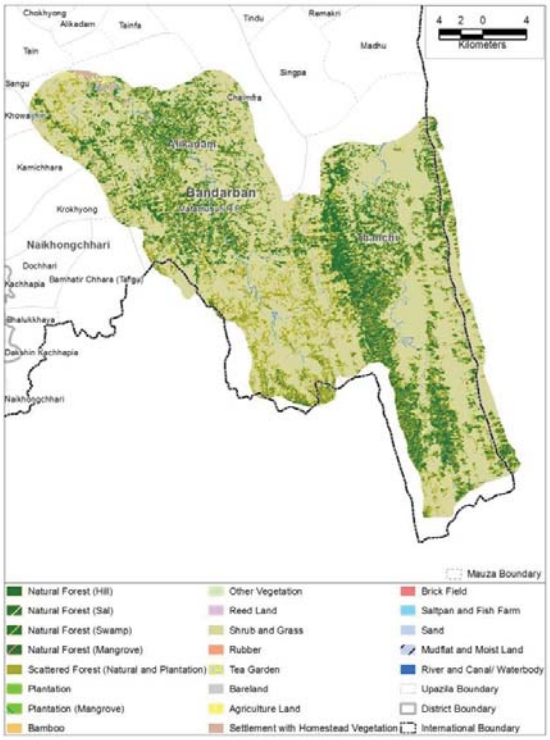
13.d Forest coverage map of Cox's Bazar South Forest Division



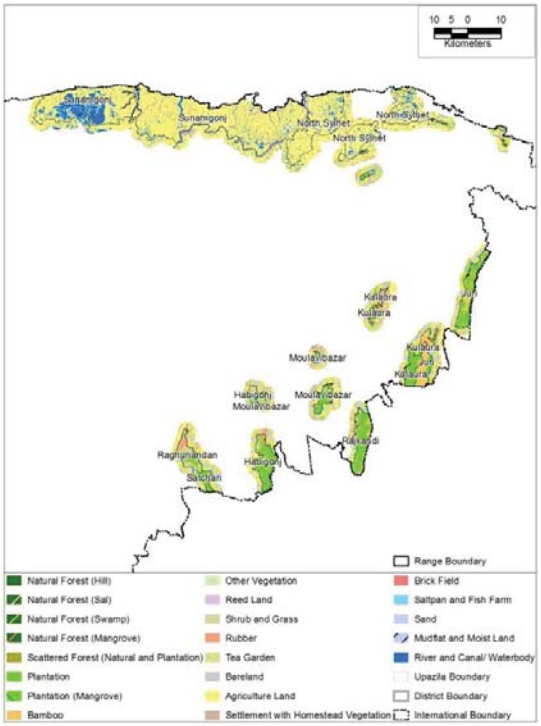
13.e Forest coverage map of Kassalong Reserved Forest of Chittagong Hill Tracts



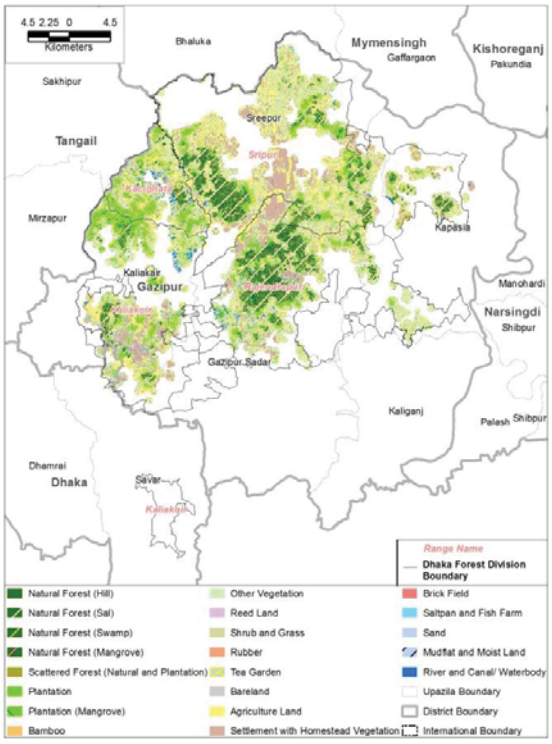
13.f Forest coverage map of Rankhiang Reserved Forest of Chittagong Hill Tracts



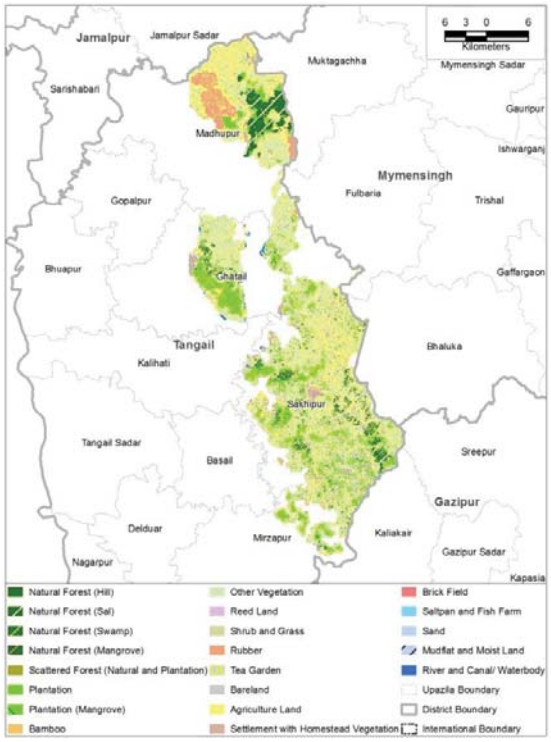
13.g Forest coverage map of Sangu Matamuhuri Reserved Forest of Chittagong Hill Tracts



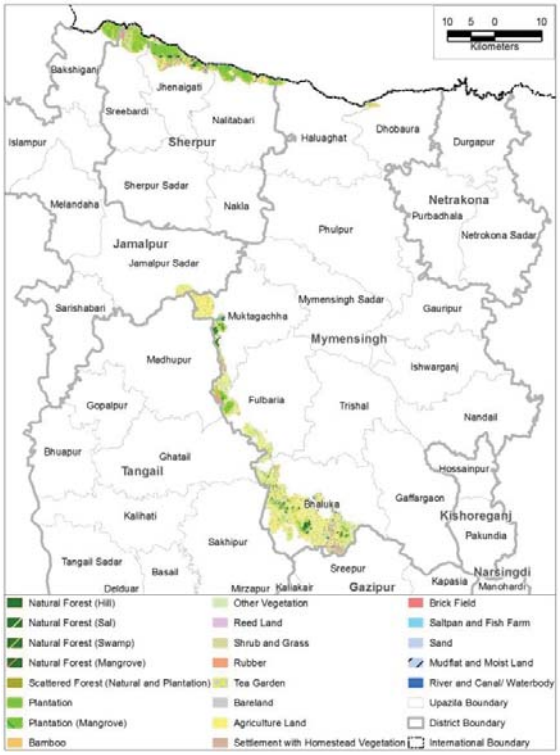
13.h Forest coverage map of Sylhet Forest Division



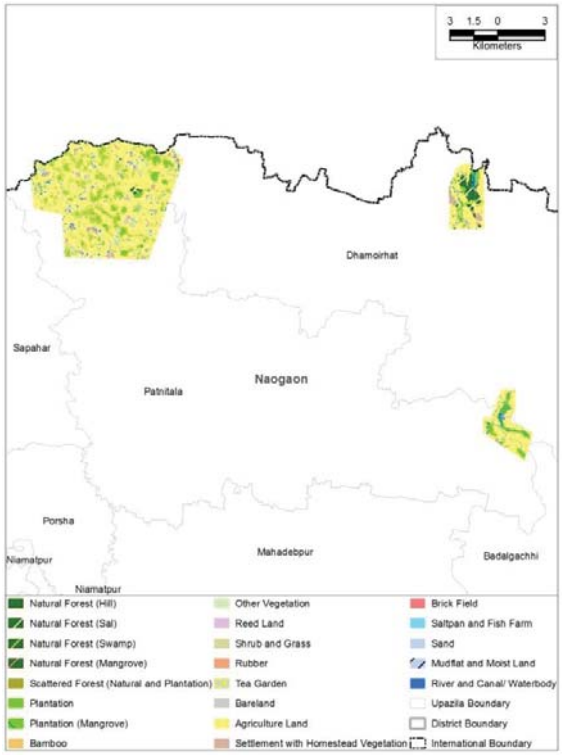
13.i Forest coverage map of Dhaka Forest Division



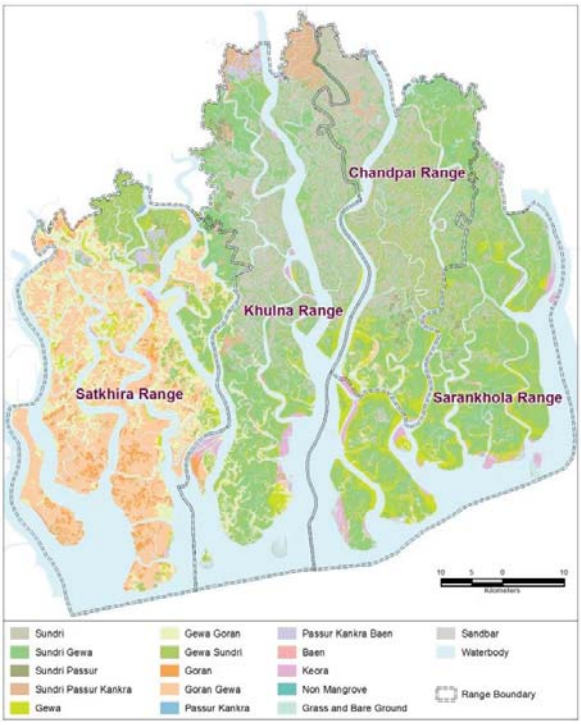
13.j Forest coverage map of Tangail Forest Division



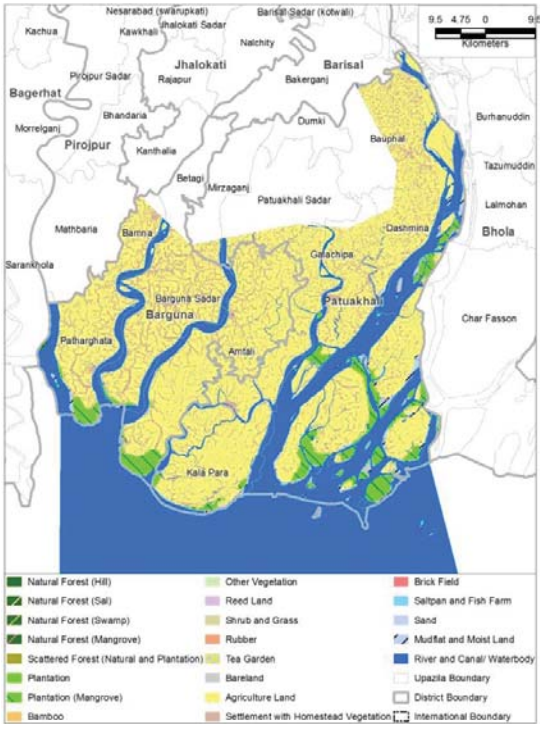
13.k Forest coverage map of Mymensingh Forest Division



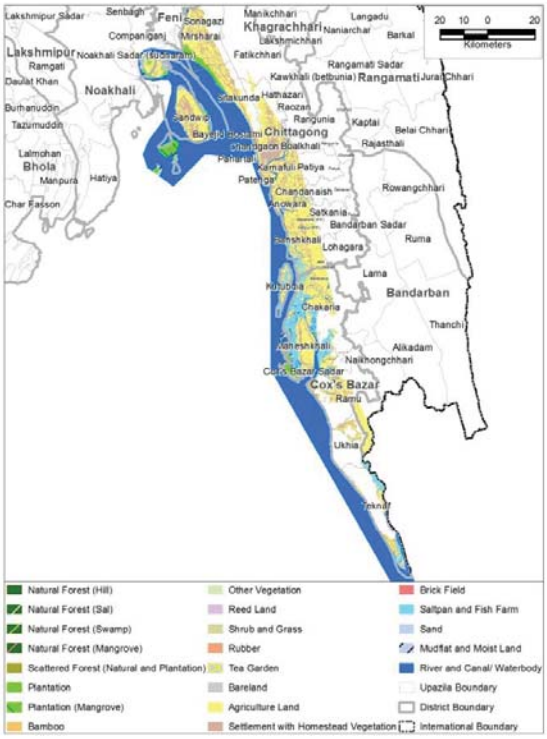
Map 13.l Forest coverage map of Rajshahi Social Forest Division



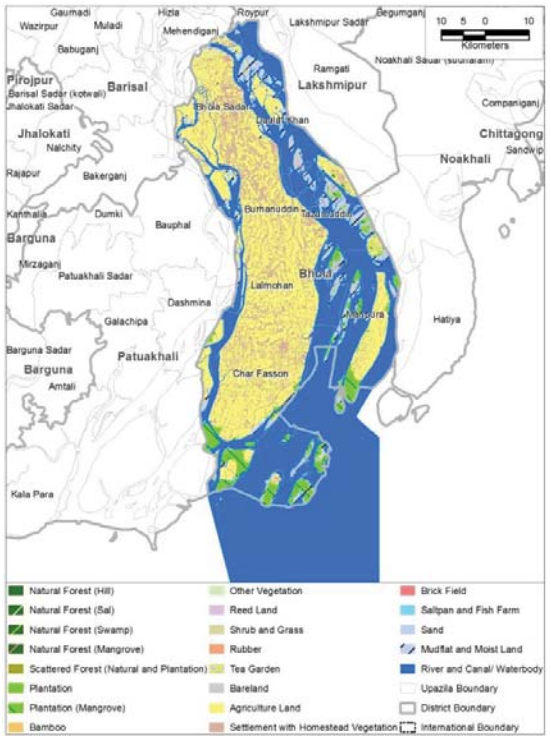
13.m Forest Division map (Sundarban East and West Forest Division)



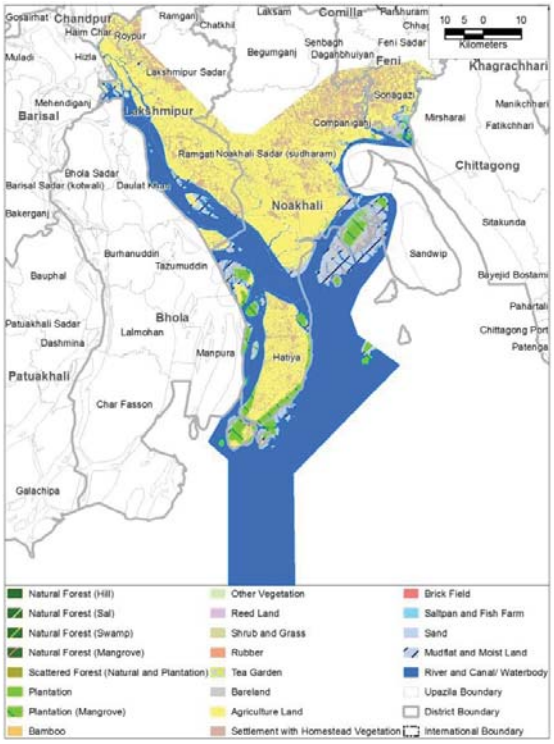
Map 31.a Forest coverage map of Patuakhali Coastal Afforestation Division



Map 31.b Forest coverage map of Chittagong Coastal Afforestation Division



Map 31.c Forest coverage map of Bhola Coastal Afforestation Division



Map 31.d Forest coverage map of Noakhali Coastal Afforestation Division

Sundarban:

The data that have been used while preparing the zone are:

- The SRTM DEM data (elevation map)
- The national boundary of Bangladesh (Upazilla boundary)
- The major rivers (in broader understanding of the delimitation)

The national boundary is overlaid with the elevation map and the major rivers of Bangladesh in order to recognize the area. According to the DEM data some shifting could be seen because of the continuous process of erosion and sedimentation. The area was digitized manually to correct and present the recent area of Sundarban in two ways which generated two shape files:

One shape file contains a polygon for the whole Sundarban including the land and also the water. The other one contains only the land which does not include any water considering only the core part of Sundarban. Finally a 5 km buffer towards the sea is added to the area of the Sundarban that include both land and water.

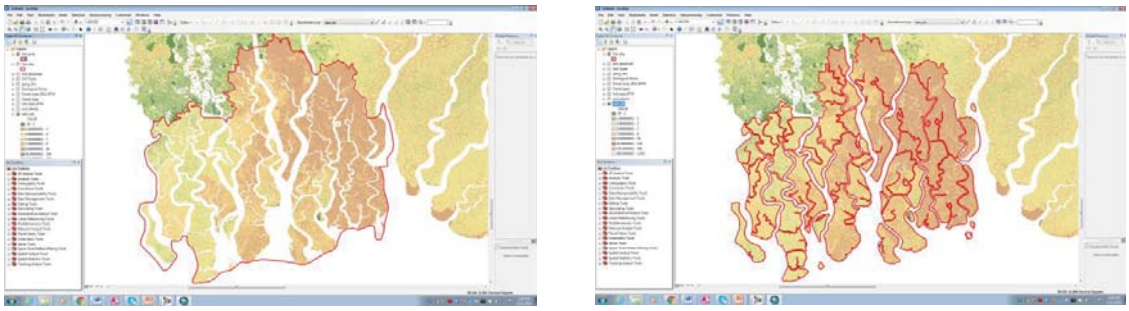


FIGURE 6 DELINEATION OF SUNDARBAN

Hill forest:

Brown hill soil is the dominant soil type for the hill forest of Bangladesh. At first, this soil type is separated from the others. However, the boundary of Hill soil does not match with the national boundary and seemed a bit shifted. Consequently, the hill soil is merged with national boundary. Only the area within national boundary has been considered. Simplification has been done based on base map.

FIGURE 7 SIMPLIFICATION OF HILL FOREST

Sal forest:

The similar process is followed for delineation of Sal forest. The dominant soil type for Sal is found to be Terrace soil. This general soil type is separated and simplified based on national boundary, base map, etc.

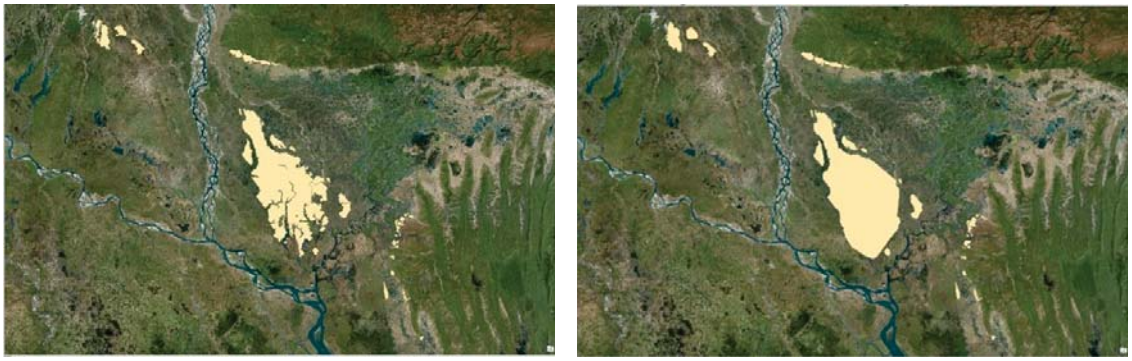


FIGURE 8 SIMPLIFICATION OF SAL FOREST

Coastal plantation:

Since plantations in coastal area are done in newly accreted lands, first it is tried to identify the new land accreted in the area in last 30 years. For this purpose change analysis is performed between the dry seasons (October to march) of 1986-88 and 2014-16. Landsat 5 and 8 images (cloud coverage less than 5%) are used for the respective time periods.

Water-land masks are created based on the Modified normalized difference water index (MNWI) developed from green (Band 2) and SWIR (Band 5) of Landsat 5 and green (Band 3) and SWIR 1 (Band 6) of Landsat 8. A threshold of 0.1 is used to delineate water from land. Values higher than 0.1 are considered as water, the remaining are land. In this way, two water-land masks are created for two different time periods (i.e. 1986-88 and 2014-16). Combining these two datasets provides four types of combinations: land-land, water-land, water-water and land-water as shown in Table 18 below. Water-land combination is the newly accreted lands in last 30 years. Of these lands only lands over 10 ha of area are considered to be suitable for coastal plantation. Further examination (e.g. overlay with base map) reveals that some of these lands fall in mainland where plantation is not practical. Overlay of these newly accreted lands with soil salinity and mangrove plantation map of forest department further clarifies the problem. It is found that mangrove plantations are mostly located in specific soil salinity classes. Hence, accreted lands falling on other soil salinity classes are not considered as potential land for coastal plantation. Based on these findings and suggestions from experts, a 5 km buffer around the newly accreted lands (of over 10ha area) is created and further simplified to delineate coastal plantation zone.

TABLE 18 COMBINATION OF LAND-WATER MASKS AND CLASS ASSIGNED.

1986-88	2014-16	Class assigned
land	land	No change in land
water	land	Accreted land
water	water	No change in water
land	water	Lost land

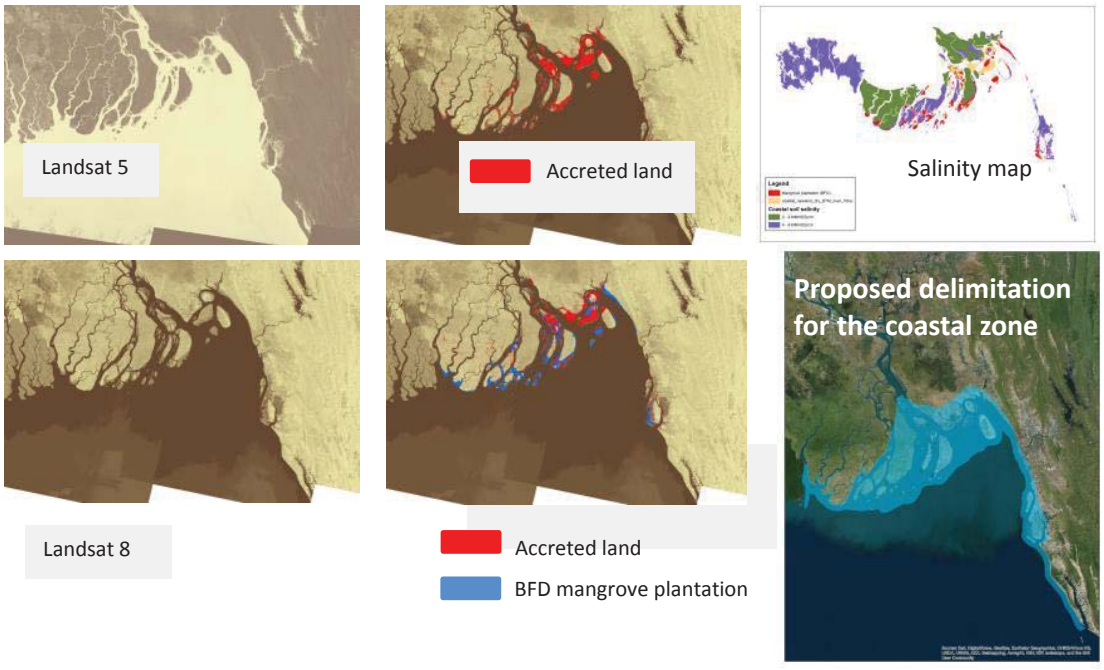


FIGURE 9 DELINEATION OF COASTAL PLANTATION ZONE