The Bangladesh Forest Inventory Design

Methodological approach

The Forest Department of Bangladesh leads actions to improve forest management and conservation, adopting forward thinking, innovative approaches in its management of approximately 1.5 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 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 process also supports climate change mitigation and implementation of REDD+.

The Bangladesh Forest inventory, led by the Forest Department, is a constant and comprehensive process that assesses, evaluates, interprets and reports on the status of trees and forest resources nationally. The activities implemented under the Bangladesh Forest Inventory process are implemented in 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, and climate change mitigation.

Contacts:

Md. Mozaharul Islam
National Project Coordinator and UN-REDD Focal Point
Bangladesh Forest Department
Email: mazhar.raj@mail.com

Uttam Kumar Saha
Project Director
Project Implementation Unit
Climate Resilient Participatory Afforestation and Reforestation Project (CRPARP)
Email : info@crparp-bfd.org

John A Dorr
Chief of Party
Climate Resilient Ecosystems and Livelihoods (CREL) Project
E-mail: jdorr@winrock.org

Matieu Henry
Chief Technical Advisor
Food and Agriculture Organization of the United Nations (FAO)
Email: matieu.henry@fao.org

Rukshana Sultana
Country Coordinator
SilvaCarbon, Bangladesh
Email: rukshana@silvacarbon-bd.org

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Disclaimer

This report is designed to reflect the activities and progress related to the projects GCP/BGD/058/USAID "Strengthening National Forest Inventory and Satellite Land Monitoring System in support of REDD+ in Bangladesh". This report is not authoritative information sources – it does not reflect the official position of the supporting international agencies including USAID, FAO, World Bank or SilvaCarbon and should not be used for official purposes. Should readers find any errors or inconsistency in the documents or would like to provide comments for improving their quality they are encouraged to contact one of above contacts. The report also includes information gathered during previous study prepared by Lars Ravensback (FRMA International specialist) "New Design of Forest Inventory to Meet Multiple Clients and Multiple Uses" and Olaf Krueger who has given notable input in creation of this document. Costello, Liam (FAOBD) <Liam.Costello@fao.org>

CONTRIBUTORS (ALPHABETICAL):

S.M. Rubaiot Abdullah[1], Mariam Akhter[2,3], M. Al-Amin[4], Liam Costello[3], Sourav Das[5], Matieu Henry[3], Md. Belayet Hossain[2], Mahmood Hossain[1], Sirajul Hoque[6], Zaheer Iqbal[2] , Rashed Jalal[3], Olaf Kuegler[7], Ruhul Mohaiman[8], Md. Nazmul Hasan[9], Md. Rakibul Hassan Mukul[2], Laskar Muqsudur Rahman[3], Mahmadur Rahman[4], Md. Motlubur Rahman[2], A. Z. M. Manzoor Rashid[5], Lars Ravensback[4], Khaled Misbahuzzaman[10], A. N. M. Yasin Newaz[2], Mohamed Saket[4], Charles Scott[7], Raihana Siddiqui[2], Baktiar Nur Siddiqui[2], Md. Main Uddin[10], Sarder Nasir Uddin[11], Toms Zalitis[3]

1. Khulna University
2. Bangladesh Forest Department
3. Food and Agriculture Organization
4. CRPAR Project of Forest Department
5. Shahjalal University of Science and Technology
6. Dhaka University
7. United States Forest Service (USFS)/ SilvaCarbon
8. CREL project of Forest Department
9. Soil Resources Development Institute
10. Institute of Forestry and Environmental Sciences
11. Bangladesh National Herbarium

Executive Summary

The aim of the Bangladesh Forest Inventory is to support the Government´s action towards sustainable forest management through the development of regular, reliable datasets related to trees and forests. This includes reports and maps that will improve knowledge on the state, changes and trends of forests, trees outside forest and land use. This information will allow inference to be drawn between tree and forest resources and their users across multiple clients at multi-levels. It will establish a lasting programme of tree and forest resources monitoring and assessment including a system for management of geographical information, forest inventory and the socio-economic aspects within the Bangladesh Forest Department (BFD). BFI aims to be one of the main instruments to guide the implementation of the forest master plan and the revised forest policy.

This report presents the design of the Bangladesh Forest Inventory (BFI) and aims to justify the rigorous approach undertaken by the Forest Department to establish an efficient, accurate and replicable NFI design. The BFI is built on more than five decades of experience in forest assessments and inventories in Bangladesh, which included, in addition to the 2005 National Forest Assessment, several projects carried out in the major forest areas of the country since 1950s. During the last year, in close collaboration with various national and international institutions, several national consultations have been implemented which led to the development of several methodologies, and the BFI design.

The BFI was designed in order to capture national level data within an acceptable range of error (FD aspires to achieve a confidence interval for biomass of at most ±6% at a 95% confidence level) with relatively low sampling intensity (2245 plots). The BFI was developed as per the following process: (1) national consultation to identify the needs and the objective, (2) identification of the preferred sampling design, (3) identification of the objectives and targeted precision, (4) stratification of the national territory in to zones, (5) design of subplot kinds and main attributes to be measured, (6) assessment of the accessibility and forest land area in major zones selected for the stratification, (7) assessment of the cost for the measurement of plots and subplots in the different zones, and (8) optimization of the plot number and plot shape considering the objectives and available resources.

In result, 2245 plots (1858 are visited plots) need to be measured in order to reach a 6% confidence interval of national tree biomass estimates. One plot should be measured in one day and consist of 3 and 5 subplots cluster of 18m radius in Sundarbans and the other zones respectively. The measurement of the field plot will be performed by 13 field inventory teams and 5 QA/QC teams will ensure the implementation of the hot and cold checks. Eight conservators of forest will supervise the implementation of the BFI in each district they have the mandate to operate.

This new design aims at providing more robust and accurate data for purposes beyond timber and resource management and extends to improving the preparation of the GHG inventory and reporting for REDD+. The process takes advantage of new software, methodological approaches and latest technological progresses.

Contents

Acronyms

AFOLU	Agriculture forestry and other land uses
ADB	Asian Development Bank
AF	Acquired Forest
BBS	Bangladesh Bureau of Statistics
BFD	Bangladesh Forest Department
CCTF	Climate Change Trust Fund
CHT	Chittagong Hill Tracts
DBH	Diameter at Breast Height
DO	Decentralized Offices
FAO	Food and Agriculture Organization of the United Nations
FIGNSP	Forest Information Generation & Networking System Project
FMP	Forestry Master Plan
FRA	Forest Resources Assessment
GHG	Greenhouse gases
HtRAs	Hard-to-Reach Areas
IPAC	Integrated Protected Area Ci-management Project
JL	Jurisdiction List
LR	Long Rotation
LRDC	Land Resources Development Centre
LULUCF	Land use, land-use change and forestry
MRV	Measuring, Reporting and Verification
NFA	National Forest and Tree Resources Assessment (2005-2007)
NFI	National Forest Inventory
ODA	Overseas Development Administration
PF	Protected Forest
REDD+	Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
RF	Reserved Forest
RIMS	Resources Information Management System
RS	Revenue Survey
SAT	State Acquisition and Tenancy Act, 1950
SR	Short Rotation
SRDI	Soil Resource Development Institute
SRF	Sundarban Reserved Forests
UMD	University of Maryland
UNFCCC	United Nations Framework Convention on Climate Change
USF	Un-classed State Forest
VCF	Village Common Forests
VF	Vested Forest

Definitions

Accuracy: Inventory definition: Accuracy is a relative measure of the exactness of an estimate. Estimates should be accurate in the sense that they are systematically neither over nor under true values, so far as can be judged, and that uncertainties are reduced so far as is practicable so that estimates are close to the true values. Appropriate methodologies conforming to guidance on good practices should be used to promote accuracy in inventories.

Zone: Zoning divides the area into smaller units based on distribution of soil, land surface and climate (Akhter, Jalal et al. 2016). The level of detail to which a zone is defined depends on the scale of the study, and sometimes on the power of the data processing facilities. The proposed zones for the Bangladesh forest inventory are (1) Hill, (2) Sal, (3) Sundarbans, (4) Costal and (5) Village.

Completeness: Inventory definition: Completeness means that an inventory covers all sources and sinks for the full geographic coverage, as well as all gases included in the IPCC Guidelines in addition to other existing relevant source/sink categories which are specific to individual Parties (and therefore may not be included in the IPCC Guidelines).

Confidence interval: Statistical definition: A confidence interval is the range in which it is believed that the true value of a quantity lies. The level of belief is expressed by the probability, whose value is related to the size of the interval. It is one of the ways in which uncertainty can be expressed (see estimation, statistical definition). In practice a confidence interval is defined by a probability value, say 95%, and confidence limits on either side of the mean value x.

Coefficient of variation: Statistical definition: The coefficient of variation, CV is the ratio of the population standard deviation, σ_x, and mean, μ_x, where CV = σ_x / μ_x. Here it also refers to the sample coefficient of variation, which is the ratio of the sample standard deviation and sample mean.

Error: Statistical definition: In statistical usage, the term 'error' is a general term referring to the difference between an observed (measured) value of a quantity and its 'true' (but usually unknown) value and does not carry the (pejorative) sense of a mistake or blunder.

Land cover: The type of vegetation covering the earth's surface.

Land Cover Classification System: LCCS is the only universally applicable classification system in operational use at present. It enables a comparison of land cover classes regardless of data source, economic sector or country. The LCCS method enhances the standardization process and minimizes the problem of dealing with a very large amount of pre-defined classes.

Land use: The primary type of activity being carried out on a unit of land.

Plot: measurements are collected at independent sample locations called plots. Each of these individual sample areas is one observation in a series of observations called a sample. Plots can be further divided into subplots of different kinds (trees, down woody material, soil, etc.). The plot design specifies the number of subplots of each kind, their size, and the spatial layout (distances between them). Measurements are then aggregated to the plot level to be averaged with other plots in the sample to form population estimates with associated measures of accuracy. This estimate of conditions, species composition, volume and other measured attributes of a forest system can then be used for various purposes.

Population: The population is the totality of items under consideration. In this case, the population for the Bangladesh Forest Inventory is all the area within the national territory. This forms the sampling frame from which to select the sample of plots.

Sample: A sample is a finite set of observations (e.g., plots) drawn from the population.

Soil Organic Matter: Includes organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series. Live fine roots (of less than the suggested diameter limit for belowground biomass) are included with soil organic matter where they cannot be distinguished from it empirically.

Strata: Stratification is the process of dividing members of the population into homogeneous subgroups. The strata should be mutually exclusive: every element in the population must be assigned to only one stratum. The strata should also be collectively exhaustive: no population element can be excluded.

Tracts: Each sampling unit in the 2005 FAO inventory was designated as a "Tract".

Tree: A perennial woody plants having a main trunk and usually a distinct crown. The definitions of the different types of trees are provided in the manual for biophysical aboveground measurement (e.g. live trees, Rotten trees, Seedlings, sapling).

Uncertainty: Statistical definition: An uncertainty is a parameter associated with the result of measurements that characterises the dispersion of the values that could be reasonably attributed to the measured quantity (e.g., the sample variance, coefficient of variation, or confidence interval).

1. Overview

Bangladesh is characterized by one of the highest population densities in the world (The World Bank 2015). Its population is 149.0 million of which 77% live in the rural areas (Bangladesh Bureau of Statistics 2016)and overall per capita availability of land and forest are among the lowest in the world at 0.12 ha and 0.02 ha respectively (FAO 2010). These factors have significant implications for the management and use of the county's natural resources.

In a country like Bangladesh where competition for resources is intense and the carrying capacity of the natural resource base has reached its limits with the rising urbanization and industrialization, the issue of proper management of environment towards achieving sustainable development has immense potential to create not only sustainable growth but also release the social tension leading to public wellbeing. Degraded lands, wetlands, forest areas and other common pool resources have put extra pressure on the situation of poverty, retarding the poverty reduction measure(GoB 2016).

Because of the increasing demand in forestry products and the high dependence of various economic sectors on tree and forestry products, an assessment of tree and forestry resources at national scale is key to guide plans for improving their management. This process was first attempted during 2005 – 2007 as part of the National Forest and Tree Resources Assessment (NFA). According to the NFA, approximately 9.8% of land area is considered 'forest' according to the FAO definition of forests from FRA 2005 (Bangladesh Forest Department 2007)[1]. The assessment also concluded that trees outside of forest make up a significant proportion of the nation's tree resources. In order to account for and better manage the relationship between people, industry and different types of forest products, FD has embarked on the process of a second national forest inventory, this time with greater access to resources and technology. The goal is to establish multi-purpose forest inventory as the centerpiece of FD's national forest monitoring system that is designed in parallel with approaches to socio-economic, natural resources and landcover/land use monitoring.

1.1. Historical context of the Forest Department

Bangladesh became an independent sovereign country in 1971. Historically, the country was under British rule from 1757 till 1947. Formal forest management programs were first initiated in Bangladesh during the British rule. In 1865 the British crown established laws for the management of forests which was the first forestry related 'Act' on the sub-continent. As part of this Act, many forest tracts were declared as "Reserved Forests" placing them under control and management of the Forest Department.

The Forest Department is a century old government organization started functioning from 1862. During British Rule and until partition under British India in 1947, the forests of Bangladesh were under the control of Bengal Forest

[1] *"Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use. Forest is determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 metres (m) in situ. Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 10 percent and a tree height of 5 m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate. Includes: areas with bamboo and palms provided that height and canopy cover criteria are met; forest roads, firebreaks and other small open areas; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest; windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20 m; plantations primarily used for forestry or protective purposes, such as rubber-wood plantations and cork oak stands. Excludes: tree stands in agricultural production systems, for example in fruit plantations and agroforestry systems. The term also excludes trees in urban parks and gardens."*

Department. After partition of British India, East Pakistan Forest Service was created. Responsibility for forestry was passed on to the Bangladesh Forest Department after the independence of Bangladesh in 1971 (FD 2016).

1.2. Geographical context

Bangladesh lies in the north-eastern part of South Asia between 20°34′ and 26°38′ north latitude and 88°01′ and 92°41′ east longitude. According to the latest available national boundaries provided by Survey of Bangladesh, total area of the country is 144,415.14 km^2 with a population of about 149 million with an exponential growth rate of 1.37%(Bangladesh Bureau of Statistics 2016).

The climate of Bangladesh is characterised by tropical monsoon climate(Islam 2009). Bangladesh has three distinct seasons: the pre-monsoon hot season (summer) from March through May, rainy monsoon season which lasts from June through October, and a cool dry winter season from November through February. Average temperature in January varies from 17°C in the northwest and north-eastern parts of the country to 20°C-21°C in the coastal areas. Mean annual temperature everywhere is about 25°C, whereas, extreme temperature ranges between 40°C- 43°C.

Most parts of the country receive at least 2000 mm of rainfall per year. Because of its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest, the regions in north-eastern Bangladesh receives the greatest average precipitation, sometimes over 4000 mm per year. About 80 percent of Bangladesh's rain falls during the monsoon season.

FIGURE 1: WHEATHER DETAILS OF BANGLADESH(THE WORLD BANK 2016)

1.3. Land administrative zones in Bangladesh

Administrative zones of Bangladesh are divided into eight major regions called divisions (Figure 2). The divisions are divided into 64 districts, or *zila*, which presently consists of 490*upazilas*. An *upazila* is made up of several unions. *Mauza* is the lowest revenue collection unit of Bangladesh. Within a *mauza* there could be one or more village however villages are not officially delineated. In some cases, villages may be listed as 'Wards' that exists within a union. Bangladesh's eight official administrative zones as defined in Table 1.

TABLE 1: LAND ADMINISTRATIVE ZONING IN BANGLADESH

Sl. No.	Zone	Number
1	Division	8
2	District	64
3	City Corporation	11
4	Municipal Corporation	324
5	Upazila	490
6	Union Parishad	4500
7	Mauzas	56,348
8	Village	81,891

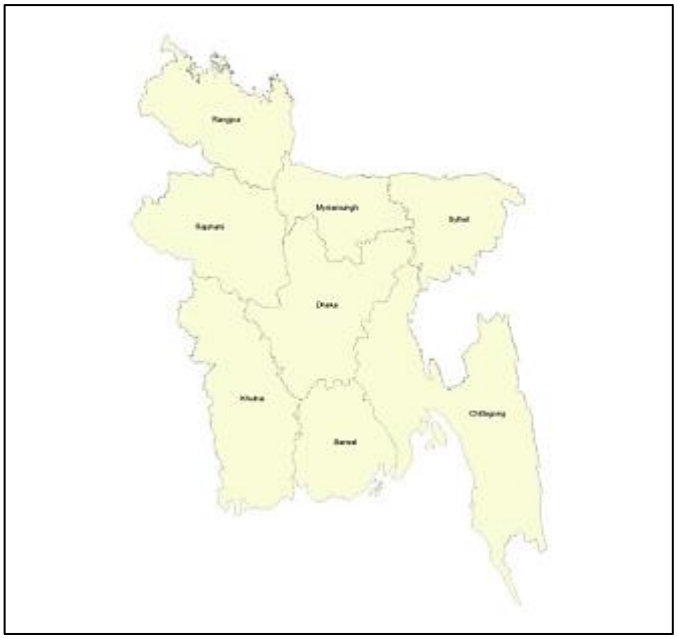


FIGURE 2: ADMINISTRATIVE DIVISIONS IN BANGLADESH

The Forest Department maintains separate administration to manage the legal forest land which was declared as Reserved, Protected, Acquired and Vested forests by the Government. The existing forest administrations are shown in Table 2. Forest lands at the *Mauza* level is under direct supervision of forest beat. One or more Beats are under the management of Forest Range and Ranges are under the management of Forest Divisions. Nine regional forest circles control all the forest divisions allocated under those circles throughout the country their Social Forestry Nurseries and Training Centers (SFNTC) are mostly at district level. The SFNTS is headed by Forest Ranger. Under a SFNTC there are several Social Forestry Plantation center (SFPC) at upazilas level. Each SFPC is headed by a forester (Appendix 2).

TABLE 2: FOREST ADMINISTRATIVE UNITS OF BANGLADESH

Sl. No.	Name of administration	Number
1.	Forest Circle	9
2	Forest Division	41
3	Management Plan Division	3
4.	Forest Range/SFNTC	255
5.	Forest Beat/SFPC	672

1.4. Land tenure

According to the 2005-2007 NFA, around 80% of the area of Bangladesh is owned by individuals while 14% is owned by the state(Bangladesh Forest Department 2007). Government-owned land may be owned by government bodies, public agencies, or government-owned corporations. The Ministry of Land is the custodian of public (*khas*) land while land tenure among ethnic populations, such as those in the Chittagong Hill Tracts (CHT) is different. Rights over land in the CHT may be divided into two broad categories, namely, common rights and private rights. Common rights are based upon customs and usage and include the right to jhum (slash-and-burn agriculture), use of forest resources for domestic purposes, cattle grazing on common pastures and for homesteads on non-urban land. Private rights are the rights of individuals over a clearly demarcated piece of land.

1.5. Forest tenure

There is approximately 2.58 million hectares of forests in Bangladesh (Table 3).FD manages 1.58 million hectares of land referred to as 'Forest Land' (FD 2016)irrespective of the presence or absence of trees. Out of these 0.73 million hectares of forests in the Chittagong Hill Tracts (CHT), named as Unclassed State Forests (USF). The USF were until recently under the control of the Deputy Commissioner (Chowdhury 2014)and now USF falls under the management of Hill District Council (HDC). Public forests are managed under various legal arrangements such as Reserved Forests, Protected Forests, Acquired Forests and Vested Forests. The forest tenure in social forestry is different where lands belongs solely to the different land-owning agencies such as Forest Department (FD), Roads and Highways (R&H), Railways (BR) and Water Development Board (BWDB). The participants have only usufructuary rights to receive the share of the interim and final harvests. Different types of FD managed forests are defined below:

Reserved Forest (RF): RFs are managed under the Forest Act, 1927 (Act XVI of 1927). Although these areas are titled "forest", in many cases they may not present canopy cover in line with national definitions of forest. RFs are eccentrically distributed in north-eastern to south-eastern region of the country.

Protected Forest (PF): PFs are managed under the Forest Act, 1927. PF are mostly located in Chittagong and Cox's Bazar districts and in patches in Noakhali, Nilphamari and Naogaon districts(Bangladesh Bureau of Statistics 2016).

Vested Forests (VF): The Private Forests Ordinance, 1959 (E.P. Ordinance No. XXXIV of 1959) allows the Government to take over management of improperly managed private forest lands. Such private forests under government management are called "vested forests" under the said Ordinance. This area is relatively small and virtually non-expanding.

Acquired Forests (AF): The private forest lands acquired by the government under the State Acquisition and Tenancy Act (SAT), 1950 (E.B. Act No. XXVIII of 1951) are called "acquired forests". The government has reserved many of these acquired lands under the Forest Act, 1927.

Protected Areas (PAs): PAs are established in Reserved or Protected Forest. PAs include sanctuaries, national parks, community conservation areas, safari parks, eco-parks, botanical gardens and special biodiversity conservation area under the provisions of wildlife laws. PAs represent some 1.8% area of the country and 11% of the designated forest land of the country (see Figure 3 for a map of PAs in Bangladesh).

Notified Area: The forest-land or waste-land or any land suitable for afforestation which is the property of Government, and for the purpose of reservation which has been notified under section 4 or section 6 or awaiting declaration as Funder the provisions of the Forest Act, 1927.

Social Forest: Plantation raised in marginal lands (embankment, railways etc.) belonging to different public agencies under government-led social forestry programmes where the participants have only usufructuary rights.

Un-classed State Forest Land (USF): The USF are located in the Chittagong Hill Tracts (CHT). The USF were until recently under the control of the Deputy Commissioner and now have been placed under the control of CHT District Councils where they are used as jhum (slash and burn agriculture) by indigenous communities (Chowdhury 2014).

Private Forests: Planned private forest in Bangladesh is scanty. But plenty of trees are growing in the rural and urban areas throughout the country(BFD 2007).This privately owned forest is commonly known as homestead forest or village forest extending over an aggregate area of 0.27 million hectare (Hammermaster 1981).Besides, in many places of CHT the village common forest (VCF) is one of the traditional practices of managing forest by the communities (UNDP 2011).There are also trees growing outside the forests in fallow and marginal land of urban and peri-urban region that may belong to different individuals and families, institutions and public agencies.

TABLE 3: LEGAL STATUS OF THE FORESTS AND THEIR DISTRIBITION IN BANGLADESH (FD 2016)

Zones	Legal status	Location (land administration-Districts)	Area (million hectares)
Hill	Mostly Reserved Forest, smaller areas of Protected forest and Acquired/Vested forest	The three districts of the CHT (Rangamati, Khagrachari, Bandarban) and six other districts in the east and north-east (Chittagong, Cox's Bazar, Sylhet, Moulavibazar, Habigong and Sunamganj)	0.67
Sal	Mostly Reserved Forest, small areas of Protected Forest and Acquired/Vested forest	North and north-west districts (Mymensingh, Tangail, Gajipur, Dhaka, Tangail, Rangpur, Pacnchagar, Dinazpur, Thakurgaon, Naogaon, Nilphamari and Comilla)	0.12
Sundarbans	Reserved Forest	South-west districts (Khulna, Satkhira, Bagerhat and Patuakhali)	0.60
Coastal	Mostly Reserved Forest, more recent plantations yet to be declared	South central and south-east districts (Noakhlai, Laxmipur, Feni, Bhola, Lakshmipur, Patuakhali, Barguna, Pirozpur, Chittagong and Cox's Bazar)	0.19
Un-classed State Forest	Under Hill Tracts Board administration	CHT districts: Bandarban, Rangamati and Khagrachari	0.73
Village forests	Private	Scattered throughout the country	0.27
TOTAL AREA			**2.58**

(SOURCE: MODIFIED FROM (FD 2016)

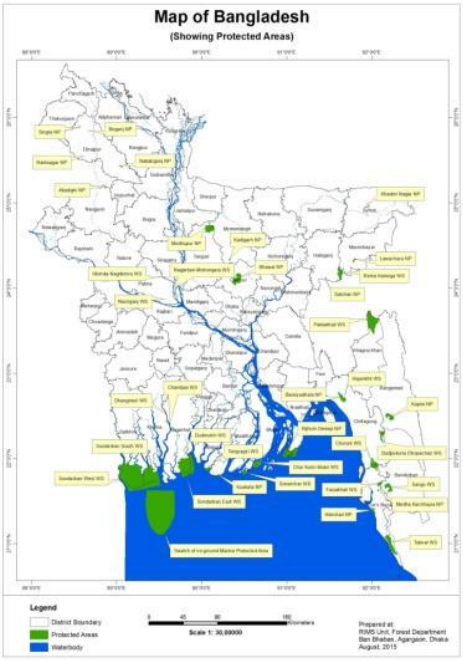


FIGURE 3: LOCATION OF PROTECTED AREAS IN BANLGADESH

1.6. National ongoing efforts for tree and forest management and conservation

1.6.1. Forest management and conservation

Forest management objectives have evolved in since the previous NFA in 2005. Current Forest Department objectives not only consider the country's timber resource, but also consider valuing the forest resource contribution to local climate regulation, air quality, water, healthy habitat for wildlife, biodiversity conservation, nature-based tourism and their carbon potential within the context of climate change. The broad objectives of forest management are therefore defined as(FD 2016):

- Enhancing environment preservation and conservation;
- Increasing public participation and benefit from the forest;
- Institutional strengthening;
- Improving management practices;
- Addressing climate change issues.

In light of these objectives, the government has set a target to raise total forest area to 20% of national area, and to increase extent of protected area network from 5% of total forest area to 10%(GoB, 2016). Contributing to this aim is the still operative 1989 moratorium on tree felling to conserve the health of forest.

The 20-year Forestry Master Plan expired in 2012 and effort to create the Forestry Master Plan for next 20 years are underway. The new plan will address FD aspirations including crucial issues such as food security, employment and access to basic services for the poorest and most vulnerable; conservation of ecosystems and biodiversity, climate change, management of natural disasters, enhancement of social forestry and coastal afforestation, adequate capacity and institutions, increased afforestation and reforestation in degraded forest areas, and improved participatory forest management.

1.6.2. Management and conservation of trees outside forests

In Bangladesh, the term Trees Outside Forests (TOF) represents the aggregation of scattered trees grown on cropland, grazing lands, marginal lands, canal banks and roadsides, along railways and in homestead garden surrounded by human settlements. In Bangladesh, TOF supplies a major source of timber and non-timber forest products and used to diversify household economies.

Almost all of the village area (2.86 million ha) is covered by trees of varying density; a very small area has no tree cover at all. Almost 50% of the area of Bangladesh has some kind of tree cover(Bangladesh Forest Department 2007).

The National Forest Policy (BFD 1994) acknowledges the limited national forest resource availability to promote effective measures for afforestation in rural areas, newly accreted char land in the coastal areas and in the Barind Tract. FD provides technical assistance to communities in support of nursery production and planting programmes to meet these aims. Afforestation programs delivered under the policy promote strip plantation along roads, railways or embankments often involving local communities on participatory basis. In addition, FD lead participatory forestry programmes managed under the provision of Social Forestry Rules, 2004 framed under the Forest Act, 1927.

1.7. Mandate for forest management

The Forest Department has the mandate for the conservation and protection of national forests, parks and forest resources including conservation of wildlife and management of watersheds. As a custodian of national forests, the enforcement of laws and regulation pertaining to forest management and wildlife conservation is one of the major mandates of FD. The maintenance of records for the forest land is also a vital responsibility of the FD.

FD also works for creation of forest-based employment generation for poverty alleviation and also promotes people's oriented forestry and ecosystem development for economic development of the country. Moreover, FD is responsible for afforestation and conservation of accreted land (char land) in coastal areas, achievement of plantation target through social forestry initiatives in degraded and marginal land. The FD also has initiatives to rehabilitate areas used for jhum cultivation[2].

FD assists in implementation of International Convention and Treaties ratified and endorsed by the Government for climate change mitigation, combat desertification and sustainable development of forests, biodiversity and environment. Monitoring and reporting responsibilities of the FD include undertaking forest inventory, monitoring and assessment and the preparation and implementation of management plans for forests and protected areas.

1.8. Status of previous inventories

A comprehensive desk review of previous inventories has been undertaken (MoEF/BFD 2012, CREL 2016). The review focused on general approaches, objectives and sampling designs of inventories conducted in Bangladesh. Different samplings designs used for different forest types in Bangladesh are presented below-

1.8.1. Sub-National Inventories

Details on various sub-national inventory designs developed under different projects, in different forest types, in different time periods are provided in Table 3.

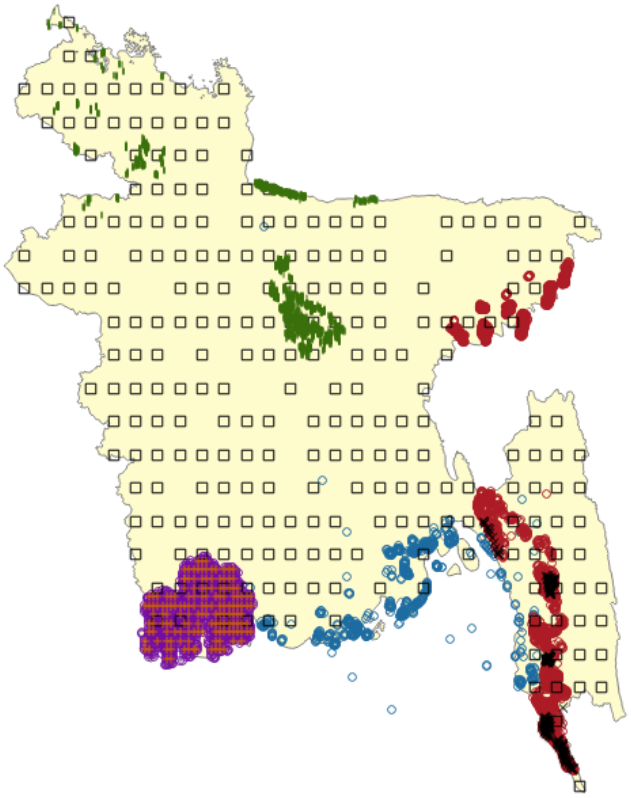
[2]also known as the slash and burn agriculture, is the process of growing crops by first clearing the land of trees and vegetation and burning them thereafter.

TABLE 3: PAST SUB-NATIONAL INVENTORIES IN DIFFERENT FOREST TYPES

Zones	Period	Location	Sampling/plot design	Sample Plots
Coastal	1981-84	Bhola, Noakhali, Patuakhali and Chittagong Forest Division	Stratified random sampling with 0.1 to 0.2ha Circular plots at 5.64 - 7.38	113
	1996-7	Bhola, Noakhali, Patuakhali and Chittagong Forest Division	20"x20" Systematic Sample Grid with 0.38ha Circular plots at 11m	1090
Hill	1981-82	Kaptai (Pulp wood Division)	Random Line sampling with 0.08ha Rectangular plots at 40X20m	815
	1983	Kassalong and Rankhiang reserved Forest	Predominantly aerial survey due to restricted access. Small sample carried out in Teak plantation only	26
	1984-85	Chittagong and Cox's bazar	Primary Unit: Block of 480mX480m with two secondary Unit and Secondary Unit: Line of 480mXcomprised of 16 plots of 0.03 ha (radius of 9.77m)	Not specified
	1986-87	Sylhet	Lines of regular interval (100m or 200m) with 0.48ha Circular plots	1740
	1996-97	Chittagong, CoxsBazar, Sylhet	Systematic sampling (20" X 10" for HF, LF, ST' 40" X 40" in natural bamboo forests & 20" X 10" in the forest plantations)	3208
	2009- 10	Sitakunda Reserve Forest, Teknaf wildlife sanctuary, Dudpukuria-Dhopachari Wildlife Sanctuary, Fasiakhali Wildlife Sanctuary, Inani National Park, Medhakachhapia National Park	Systematic 1'x1' grid with 0.157ha Circular plots	317
	2014	Kaptai National Park, Khadimnagar NP, Lawachara National Park, Modhupur National Park, Rema-Kalenga Wildlife Sanctuary, Satchari National Park	Systematic sampling design at a spacing of 30'' X 30'' with 0.01ha Circular plots arranged in 5 clustered sub plots	244
Mixed	2005-07	National	3' x 2.5' national grid with 2ha Rectangular plots at 250x20	251
Sal	1999-2001	Dhaka, Tangail, Mymensingh, Dinajpur, Rangpur, Rajshahi Divisions	Systematic sampling design with 400m between lines & 200 m between plots along lines. Plot dimensions: 0.02 100 m2 in area in Dhaka, Tangail and Mymensingh Divisions and 200 m2 in area in Dinajpur, Rangpur and Rajshahi Divisions.	4000
Sundarbans	1958 - 59	Khulna and Bagerhat district	Rectangular 40x20 plots (0.4ha)	1240
	1983 - 84	Khulna and Bagerhat district	Circular plots of 0.03 ha for all species and transect of 0.02 ha for Gewa and fuelwood	2099
	1996-97	Khulna and Bagerhat district	Five subplots at 1, 2, 5, and 11m for seedling, saplings, poles and trees; and three plot clusters for (2 and 5m subplots) for Golpatta	1202
	2009-2010	All	Systematic 1'x1' grid with 0.157ha Circular plots arranged in 5 clustered sub plots	150

FIGURE 4: GEOGRAPHIC LOCATION OF EXISTING FIELD INVENTORY PLOTS

1.8.2. National Inventory



CREL FKWS	Fasiakhali Wildlife Sanctuary
CREL SRF	Sitakunda Reserved Forest
CREL INP	Inani National Park
CREL TWS	Teknaf Wildlife Sancturay
CREL DDSW	Dudpukuria Dhopachari Wildlife Sanctuary
FD-97-coastal	Forest inventory 1997 coastal forests
FD-97-hill	Forest inventory 1997 hill forests
FD-97-sundarban	Forest inventory 1997 sundarbans forests
FD-NFA	National forest assessment
FD-SAL	Sal forest inventory
FD-97-sundarban	Forest inventory 1997 sundarbans forests
FD-NFA	National forest assessment
FD-SAL	Sal forest inventory
Sund RF	Sundarban Reserved Forest

The National forest and tree resources assessment was conducted in 2005-07 by Forest Department, FAO and local experts(Bangladesh Forest Department 2007). The methodology followed a global approach for systematic sampling used by FAO whereby each sampling unit was designated as a "Tract" (1km X 1km) and identified 299 tracts over the country which was laid out at10 minutes longitude and 15 minutes latitude intervals (Figure 5). Each Tract comprises of 4 Plots with a dimension 20m x 250m (0.5 ha) and three sub-plots (having a diameter of 3.99 m; i.e. 50 m^2) at 5m, 125m and 245m from the plot starting point along the Plot central axis.

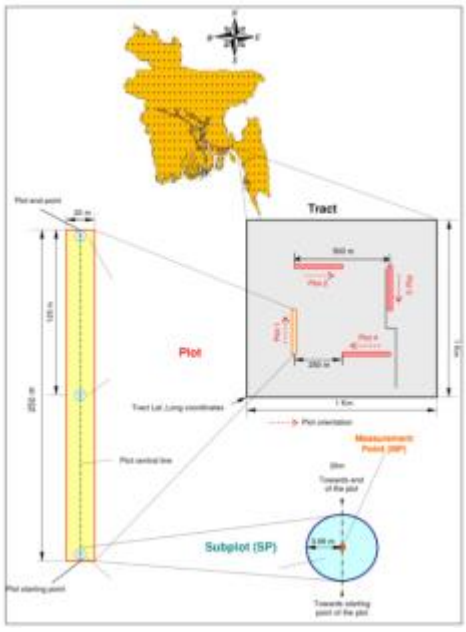


FIGURE 5: NATIONAL FOREST AND TREE RESOURCE ASSESSMENT SAMPLING DESIGN AND LAYOUT OF TRACT, PLOT AND SUBPLOT (BANGLADESH FOREST DEPARTMENT 2007).

The review shows that most of the inventories carried out in the country since the 1950s, were based either on circular plots or rectangular plots. Both sample plot shapes were used to meet specific objectives from the inventory. The circular plots were used in forest plantation for timber assessment as well as in natural forests for targeted variables carbon inventory or other, generally, narrow range of parameters.

The rectangular shape of plots was applied in nationwide inventory or in some natural forests across the country. This latter plot shape has the potential to optimize the data collection system, to generate reliable estimates of the covered population and to explore the variations due to natural trends in the forest.

1.9. Status of Forests

According to the NFA 2005-2007, the total forest land area is estimated 1.44 million ha, or 9.8% of total land area. In addition to this, the NFA estimated that approximately 50% of land area is under tree cover, indicating the significance of trees outside of forests.

An up to date assessment of forest is not fully known as there is no national level inventory since last 10 year and the sub-national inventories outlined above do not provide adequate information to infer national estimates. However, an analysis from FD RIMS (Akhter, Siddiqui et al. 2014)provides an estimate to forest cover changes over the decades (Figure 6).

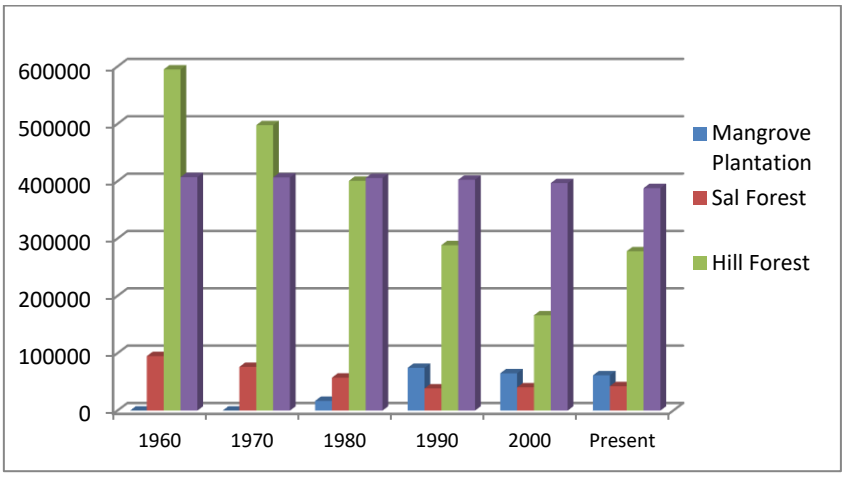


FIGURE 6: GRAPHICAL REPRESENTATION OF THE TRENDS FOR DIFFERENT FOREST TYPES (HA). THE ANALYSIS USED THE PAST SUB NATIONAL INVENTORY DATA AND THE RECENT ASSESSMENTS CONDUCTED FOR THE DIFFERENT FOREST TYPES(AKHTER, SIDDIQUI ET AL. 2014)

Since 1865, the declaration of forest reserves, during British Government rule, access to forest resources by local communities has been restricted and consequently a large proportion of reserved forests has been converted to other land uses, largely attributed to increasing population settlement and encroachment (Hassan 2011).

However significant efforts are being made in reforestation and afforestation programs to increase forest cover. Strip plantations, which average at 10m in width now covering approximately 72,498 ha. Village homestead forests account for approximately 270,000 ha of tree cover(FAO 2010) and the 7th Five Year Plan promote a target of 20% canopy cover for 2016-2020(GoB, 2016)(Table 4).

TABLE 4: PROGRAMMES ALLOTTED FOR THE FORESTRY SUB-SECTOR IN THE 7TH FIVE YEAR PLAN (2016-20)

Sl. No.	Programs	Target
1.	Hill forest plantation	50,000.0 ha
2.	Plain land forest plantation	5,000.0 ha
3.	Coastal afforestation	30,000.0 ha
4.	Reed land afforestation	5,000.0 ha
5.	Agar plantation	2,000.0 ha
6.	Development of NTPFs (Bamboo, cane & murta)	2,000.0 ha
7.	Rehabilitation of natural forests &older plantations (Enrichment & ANR)	55,000.0 ha
8.	Strip plantation	20,000 km
9.	Homestead/institution/other planting/sale & distribution	55.0 million seedlings
10.	Protected Area coverage	15% of total forest area
11.	Tree coverage (≥ 50% tree density)	20% of national land area

2. Design

2.1. Sampling Design Outlook

An optimal design is developed through a comprehensive planning process. The ultimate goal of the inventory planning is to generate a methodology for timely and accurate information through an "optimal" sampling design, which allows for, within a given budget, an estimate of desired variables with a sampling error (uncertainty) as small as possible. Apart from the cost, which is the main constraint, inventory planning considers the tolerable range of error for the parameters of the forest to be surveyed, the available personnel, and the geographic or thematic units of reference.

Sample design optimization is a process aimed at increasing cost efficiency within the sample design whilst maintaining an acceptable level of sampling error. This can be achieved in part by dividing the sample population into subpopulations and tailoring sampling intensities specific to those subpopulations. When considering permanent sample plots (where repeat inventories are planned) it is essential to ensure these subpopulation boundaries do not change over time. One method to ensure subpopulations do not change is to define them by zone: an area defined by its ecological, climatic, edaphic and geographic elements. By defining a zone as a subpopulation (or strata) the boundaries will not change from one measurement occasion to the next.

2.2. NFI design process

A step-wise method was followed for the design of the new national forest inventory. This included the development of a specific set of objectives and a process of variable selection that considered those objectives. The approach aimed to deliver a multi-purpose forest resources monitoring system beyond the context of carbon or timber alone. Central to all stages of design development is the process to ensure sustainability to the process: building adequate capacity within national institutional to ensure long term and continuous data collection, processing and analysis can be achieved. Initiatives taken in this regard include:

- Information needs assessment;
- Assessment of the national capacities for the field data collection and analysis;
- Analysis of the national forest policy and how such policy mandates FD and allows it to financially generate information on forests and trees on continuous basis;
- Strengthening national capacities through capacity building activities and collaborative activities.

Figure 7 below describes the process which aims at upgrading the forest inventory capacities, approaches, technologies and tools in FD, building upon what exists.

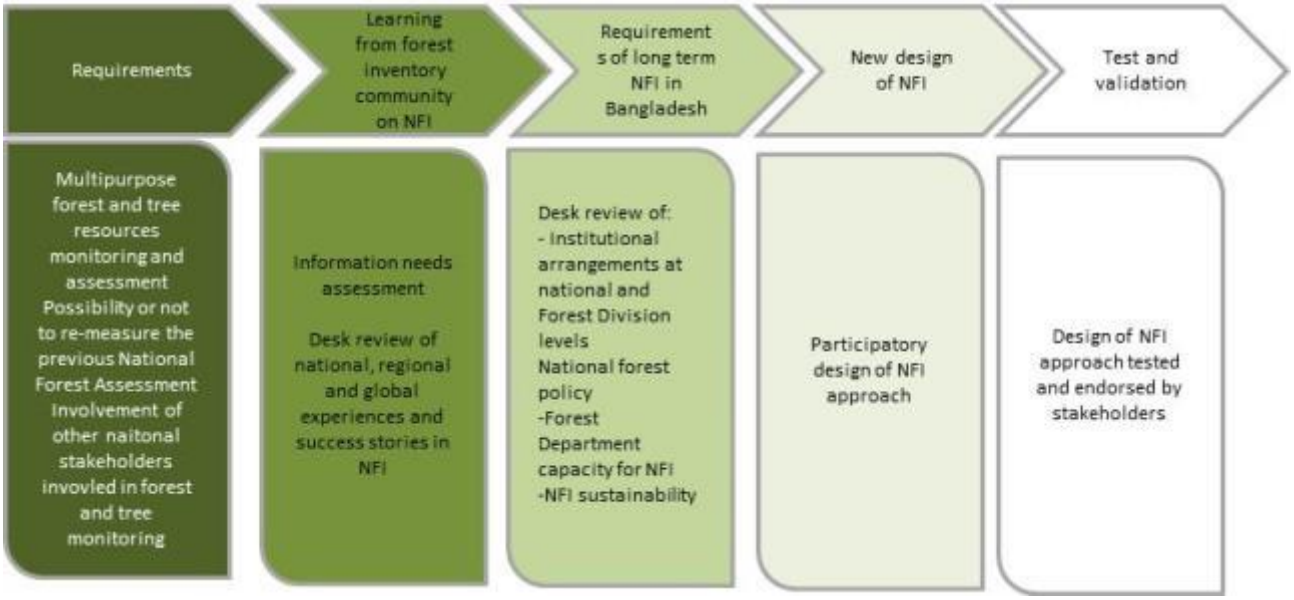


FIGURE 7: Process for upgrading forest inventory capacities, approaches, technologies and tools in BFD (modified from Saket, Ravensbeck et al. (2015)

Defining objectives and planning for the forest inventory, whether for technical, logistical and financial processes, were decided under the authority of the CCF and the NFMS group (National Forest Monitoring System) with technical support of CRPARP projects, SilvaCarbon, UN -REDD and FAO[3].

Several projects are involved in the assessment of forest resources. To ensure unified adoption of a single inventory design a broad set of contributions have been sought from the various projects' stakeholders through various consultations. The events outlined below have involved over 250 participants, mostly from the forest department but also the BFRI, SPARRSO, SRDI, BNH, universities and many others. Some of these events include:

- March 3&5th 2015: National Forest Inventory Information Needs Workshop, Dhaka;
- July 2015: Mission of statistician from USFS;
- July 27th 2015: Field visit of plots 187 and 188;
- August 27th 2015: visit of plot 180/3 – 4;
- November 6th 2015: visit of plot 179;
- March 7th 2016: visit of plot 180 1/3/4;
- March : Several NFMS working group meeting (definition of the costs, definition of plot shape, definition of the grid);
- April 11, 12 : Working session for NFI finalization in BFD;
- April 13th : National consultation about the National Forest Inventory Design;
- April 24th: endorsement of the National Forest Inventory Design.

The forest inventory is built on the basis of the knowledge accumulated by the implementation of previous forest inventories. In particular, the establishment of data sharing between projects and agencies which have allowed for the analysis of thousands of data records that are used to inform the new inventory (Sola, Costelo et al. 2016).

[3] The NFMS group was created in 2015 to facilitate dialogue and decision making within the forest department on the implementation of the evaluation and forest monitoring system

Considerable effort was made to assess the possibility of remeasuring the plots established as part of the 2005-7 forest inventory. The report by Costello et al. (2016) details these various efforts and explains why it was best not to re-measure plots measured in 2005-7. The main factors relate to (1) accuracy of the plot and plot marker locations and the implications for being able to physically find the previous plots, and (2) the dynamic nature of the landscape of Bangladesh meaning secondary plot identifiers (existing trees) cannot be relied upon.

Through consultation facilitated by the NFMS working group among various stakeholders, it was agreed to develop one unified NFI grid and sample plot design. Stakeholders involved in decision related to the design include several national and international experts from, FAO, SilvaCarbon and the CRPARP project. Data and software used throughout the design process are outlined in Table 5.

TABLE 5: DATA AND SOFTWARE USED THROGHOUT THE DESIGN PROCESS

Data	Description
	High resolution SPOT 6.5m multicolor for 2015
	SRTM DEM 30m 2007
	Map of permanent water (BFD/FAO, 2016)
	Zoning map developed for the Forest Assessment (Akhter, Jalal et al. 2016)
	Map of the location of decentralized offices (BFD/FAO, 2016)
Software	
	QGIS (http://www.qgis.org/en/site/) for GIS based analysis
	Open Foris Suite www.openforis.org for data collection, storage and analysis
	ArcGIS (https://www.arcgis.com/features/) for GIS based analysis
	DTIM for identification of the objectives, questions, indicators, and metrics (Scott, Bush et al. 2009)
	FRIED (Scott 1993) for plot & sample design optimization
	R software (https://www.r-project.org/) for statistical calculations

2.3. BFI objectives

The regular review of forest inventory objectives ensures that information drawn for the process is in line with the needs of national managers and policy makers. In this regard, the specifications, designs and methods to address new emerging demands and technologies should also adapt and/or change. On the other hand, the processes need to be sustainable and provide consistent information over time and ensure the possibility to have robust estimates of tree and forest trends and their relationship with policies, measures and actions.

A national consultation was carried out in March 2015 to assist in the process of defining the objectives using the Design Tool for Inventory and Monitoring (DTIM) (SilvaCarbon 2015). DTIM (Scott 2009) was used for the identification of the broad monitoring objectives, the related monitoring questions, and the main metrics to address those questions. Through this process a set of functional objectives were proposed by various stakeholder groups and ranked in order of priority. Once the functional objectives were defined, the DTIM tool assisted in framing questions that need to be asked to meet the defined objectives. The tool then helped identify the main metrics to address those questions. The biophysical attributes are then associated with the relevant metrics. An example of this process is defined in Table 6.

TABLE 6: RESULT OF THE DTIM PROCESS USED TO ESTABLISH BROAD OBJECTIVES OF THE NFI.

Functional Objective	Related Broad Objective from DTIM	Rank
Social forestry - value to livelihoods, including non-carbon benefits	Value of Forests (ecosystem services)	1
Timber production	Forest Productivity	2
Plant Diversity	Biological Diversity	3
Expanding forest cover (degradation, reforestation, afforestation)	Ecosystem Restoration	4
Forest governance	Forest Governance	5
Measurement, Reporting and Verification for REDD+	Carbon Sequestration and Greenhouse Gas	6

The major objectives of the BFI are:

- Integrate field inventory, remote sensing and socio-economic survey information to provide results for a multitude of purposes including the valuation of ecosystem services;
- Provide information on the status and trends of trees and forest resources to assist management planning, policy decisions and national and international reporting requirements, in priority for the functional objectives;
- The sustainability, adoptability, adaptability and feasibility of the process.

3. Zoning and Stratification

Data collection, analysis, interpretation, and reporting on forest and tree 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 to know the general status of the resources. However, they can be too coarse for operational planning purposes. The NFA 2005-7 (Bangladesh Forest Department 2007) reflects the status of trees and forests at national scale but it failed to capture information about certain forest types such as Sal forests, and mangrove plantations. Defining sub-populations within the national boundaries is one way to more accurately provide information about the status of natural resources, especially where there is a particular interest.

Zoning or stratification is a process for the creation of sub-populations, dividing the population into non-overlapping subpopulations called strata that together comprise the entire population and then drawing an independent sample from each stratum (Czaplewski 2004). In the context of the national forest inventory, this process aims at optimizing the survey design. Numerous reasons may be given as justification for stratified sampling (Cochran 1977, Schreuder, Gregoire et al. 1993).

A comprehensive document outlining the methodology used to define the zones was prepared by Akhter, Jalal et al. (2016). The document reviews available global and national zoning map. Two global maps and four national maps were compared with one available forest map (RIMS 2013). It appears that the existing zoning maps are considered as not appropriate to capture the distribution of forest types (Akhter, Jalal et al. 2016). In consequence, two new zoning maps were developed for two main objectives that are: ecological zoning, and management zoning. While the ecological zoning map aims at delineating the edaphic factors influencing the distribution of five zones, namely: hill, Sal, costal, Sundarbans and village zones, the forest area map aims at delineating the land area under the management of the Forest Department.

The ecological zoning map considered the following datasets in priority (1) soil types (1988), (2) digital elevation model 2013, (3) climate types and (4) salinity map. The forest area map has been developed using the following datasets (1) forest reserve boundary, (2) protected area boundary, (3) forest division map of 2013 for the forest types and (4) mauza map for territorial forest administration divisions.

On one hand, the ecological zoning map may be more appropriate for assessing the status of the resources on an ecological point of view and its boundaries may not be modified in the future depending on modifications of land tenure or management plans. On the other hand, the forest boundaries may be more appropriate for management point of view considering that it would allow more samples in the forest types of interests, but its boundaries may be modified depending on changes of the land tenure and forest management plans.

In order to ensure that the pre-stratification is based on boundaries that do not change over time and consider edaphic factors that explain the distribution of the vegetation and land uses, the ecological zone map has been identified as the preferable option (Figure 8). The ecological zoning map is hereafter referred as the "zoning map".

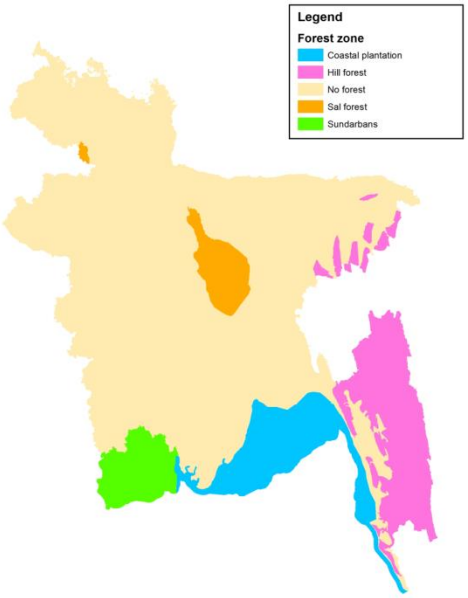


FIGURE 8: PROPOSED ZONING FOR THE PRE-STRATIFICATION OF THE BANGLADESH FOREST INVENTORY

Forest Zones	Area (1000 ha)
Sundarbans	
Land area (unit)	379.31
Forest land area (RIMS 2013)	394.36*
Presence of water (ha)	229.89
Coastal	
Land area	472.00
Forest land area (RIMS 2013)	62.72
Presence of water (ha)	737.00
Sal	
Land area	517.58
Forest land area (RIMS 2013)	36.90
Presence of water (ha)	17.22
Hill	
Land area	1658.07
Forest land area (RIMS 2013)	754.41
Presence of water (ha)	55.93
Village	
Land area	10032.27
Forest land area (RIMS 2013)	10.85
Presence of water (ha)	857.73

* Forest land area in Sundarbans is higher than land area due to the presence of forest under water

TABLE 7: SUMMARY INFORMATION FOR THE PROPOSED ZONES

4. Precision

The FD aspires to achieve a confidence interval for tree biomass of at most ±6% at a 95% confidence level. In seeking this goal, a range of options were explored to ensure efficiency and cost effectiveness. The analysis focused on three parameters: biomass, volume and number of trees of live trees over 10 cm DBH. As Bangladesh has the majority of biomass in trees outside the forest, achieving these levels at the country level does not mean that the levels will be achieved for the forested land alone.

A targeted precision can be achieved by changing three different components: field plot design, overall number of plots and the relative distribution of plots between the different strata. In general, the larger the subplot area and the more subplots are selected, the smaller the variance. The variance reduction achieved by increasing the number and size of the subplots are not completely inversely related so that doubling the number or size of the subplot will reduce

the variance by less than half. In contrast to this, doubling the sample size within one stratum will decrease the variance by exactly half within this stratum, assuming random sampling.

In order to evaluate different field plot designs, we modelled the coefficient of variation (CV). Using the data from the previous NFI (Bangladesh Forest Department 2007) and Sundarbans Reserve Forest inventory (Donato, Ahmes et al. 2011), the CV was modelled as a function of number of subplots, subplot size and average distance between them for the three target parameters (biomass, volume and number of trees) for three different land types (forest, Sundarbans, and non-forest) and for forest-only and over all lands.

The models were developed by first partitioning the NFI data into forest and non-forest models then using the Sundarbans data to re-calibrate the forest model for use in mangroves. Since the position of each tree within each plot had been recorded, we were then able subset the tree data so that we were able to estimate the CV for different combinations of subplot sizes, number of subplots and distance between subplots. Figure 9 gives an example of the subset we used for three subplots with a distance of 60 meters between subplots. Trees greater or equal to 10 cm are selected from only the dark grey area (10 m by 10 m), while trees greater or equal to 30 cm are selected from the lighter grey area (20 m by 20m). All other trees are not selected for this example.

The outcome of all the different possible combinations was then used to model CV as

$$CV = b_0 \, m^{b_1} (d+1)^{b_2} \, z_1^{\,b_3} \, z_2^{\,b_4}$$

where

m = number of subplots

d = average paired distance between subplots (in meters)

z_1 = subplot size (in hectare) for trees greater or equal 30 cm

z_2 = subplot size (in hectare) for trees greater or equal 10 cm

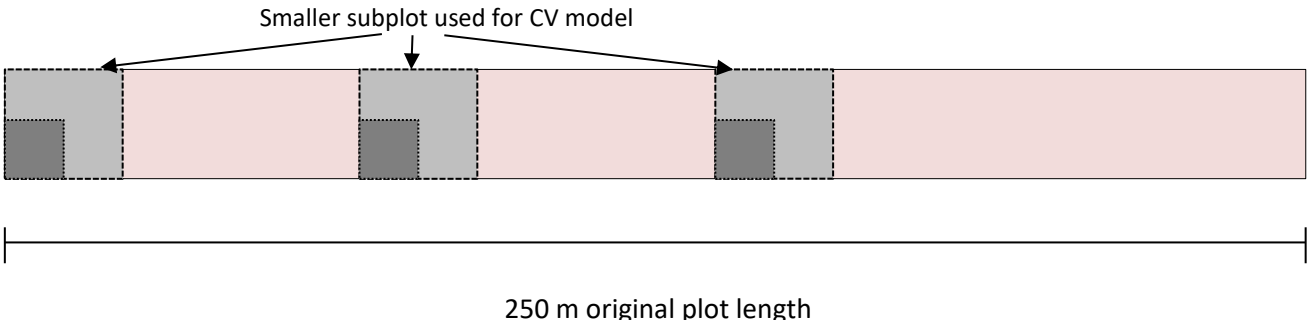


FIGURE 9: EXAMPLE OF A SUBSET FOR CV MODEL BASED ON THE 2005 NFI DATA

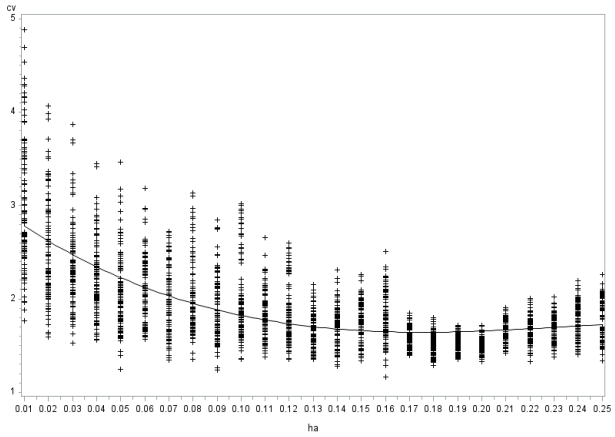


FIGURE 10: EXAMPLE OF CV FOR FOREST BIOMASS, PLOTTED AGAINST SUBPLOT SIZE FOR ONE SUBPLOT

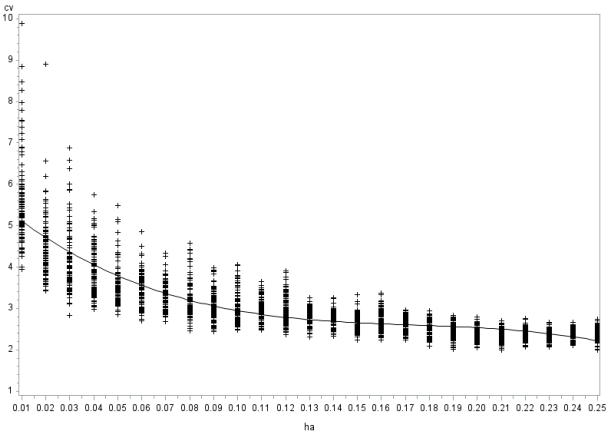


FIGURE 11: EXAMPLE OF CV FOR NON-FOREST BIOMASS, PLOTTED AGAINST SUBPLOT SIZE FOR ONE SUBPLOT

For each target parameter we developed three different models: A non-forest model, a Mangrove model and a forest model.

TABLE 8: MODEL PARAMETER FOR CV:

Land Type	Target Parameter	b_0	b_1	b_2	b_3	b_4
Forest	Trees/ha (10+ cm DAP)	1.02260	-0.08196	-0.01174	-0.01343	-0.06093
Forest	Volume/ha (10+ cm DAP)	1.05440	-0.17398	0.01380	-0.12920	-0.00497
Forest	Biomass/ha (10+ cm DAP)	1.02426	-0.15451	0.01647	-0.11686	-0.00693
Mangrove	Trees/ha (10+ cm DAP)	0.43316	-0.08196	-0.01174	-0.01343	-0.06093
Mangrove	Volume/ha (10+ cm DAP)	0.67363	-0.17398	0.01380	-0.12920	-0.00497
Mangrove	Biomass/ha (10+ cm DAP)	0.65438	-0.15451	0.01647	-0.11686	-0.00693
Nonforest	Trees/ha (10+ cm DAP)	2.10850	-0.05398	-0.04885	-0.02017	-0.07576
Nonforest	Volume/ha (10+ cm DAP)	1.87569	-0.16764	-0.02199	-0.09830	-0.03787
Nonforest	Biomass/ha (10+ cm DAP)	1.69313	-0.19222	-0.02474	-0.13056	-0.03453

In addition to the CV, we also estimated the per hectare mean for each metric.

TABLE 9: PER HECTARE MEAN FOR EACH METRIC

Land Type	Target Parameter	Mean
Forest	Trees/ha (10+ cm DAP)	46.5
Forest	Volume/ha (10+ cm DAP)	68.1
Forest	Biomass/ha (10+ cm DAP)	331.0
Mangrove	Trees/ha (10+ cm DAP)	57.6
Mangrove	Volume/ha (10+ cm DAP)	96.8
Mangrove	Biomass/ha (10+ cm DAP)	748.8
Nonforest	Trees/ha (10+ cm DAP)	11.9
Nonforest	Volume/ha (10+ cm DAP)	7.9
Nonforest	Biomass/ha (10+ cm DAP)	57.8

5. Composition and responsibility of the field inventory teams

The field work data collection is subdivided by administrative and forestry divisions from regions down to districts. The figure below represents the different levels of involvement for the measuring and QA/QC of field inventory plot.

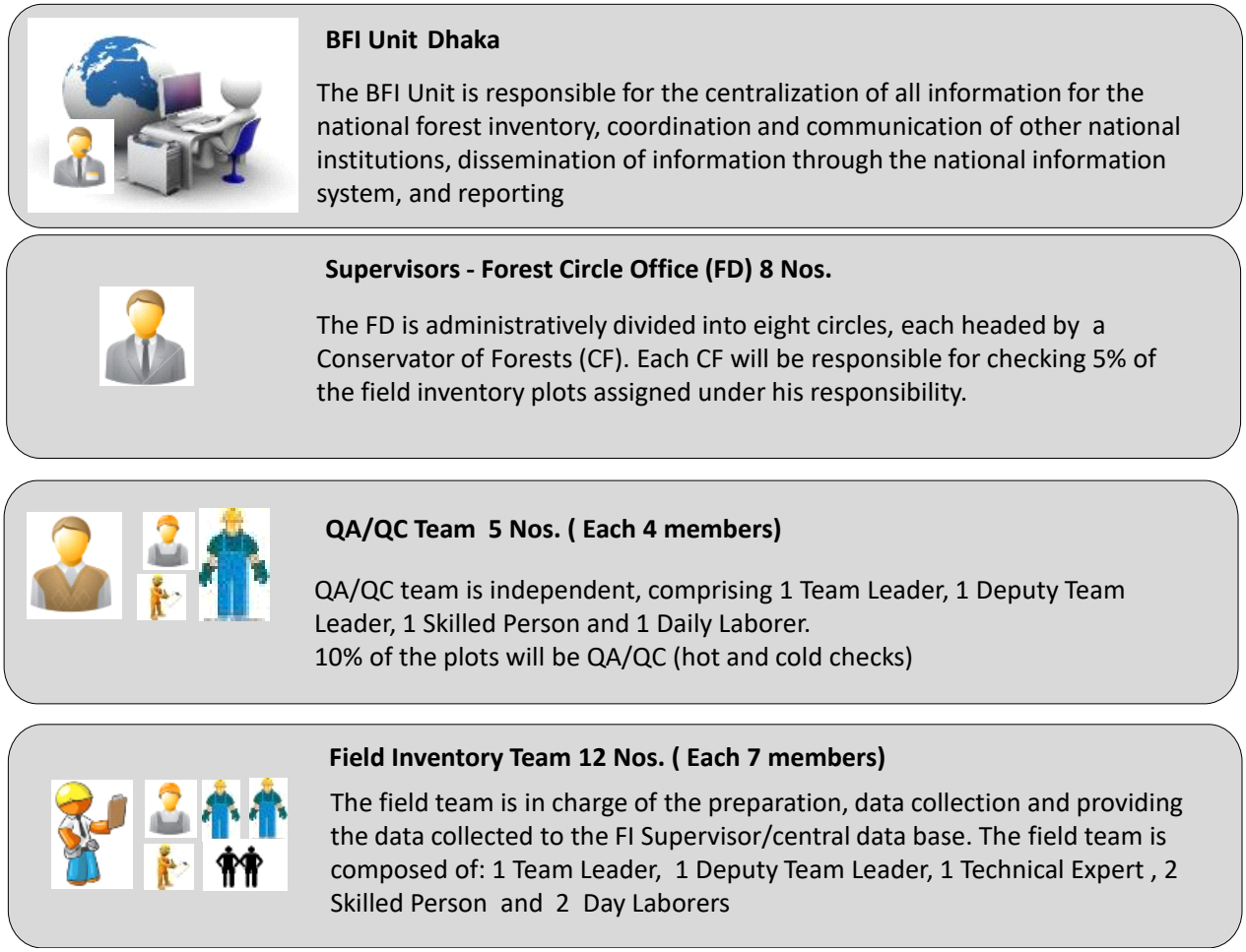


FIGURE 12: REPRESENTAITION OF THE INSTITUTIONAL ARRANGEMENTS FOR THE NATIONAL FOREST INVENTORY

5.1. Field team

Each field team consists of 7 members (Table 10). Each team will receive trainings before initiating the field measurement. Field teams will have the responsibility of field inventory preparation, field inventory data collection and transfer of the data to the central data base.

Local FD staff will provide information about access conditions to the site and about the people who can be locally recruited as guides or workers with required local knowledge on relevant subjects (land use practices, forest use, etc.). They will inform the local people about the project and fieldwork and generate interest in the survey findings by local stakeholders.

Preparation of the field work also includes the preparation of maps, preparation of the necessary digital field forms, procurement and checking of the necessary equipment as well as preparation of a logistic plan.

TABLE 10: COMPOSITION AND RESPONSIBILITY OF FIELD TEAM MEMBERS

Position	Nos.	Status	Responsibility
Team Leader (TL)	1	ACFs will be the TL, to be nominated by the Forest Department	TL supervises the field team and activities. He makes local contacts. He distributes the fieldwork and ensures the team maintain the time frame and liaison with the supervisor and the BFI Unit in Dhaka. He is responsible for the security of the team members and ensures that all team members can implement their activities on time and in appropriate conditions.
Deputy Team Leader (DTL)	1	Foresters will be the DTL, to be nominated by the Forest Department	DTL organizes the logistics for the transportation of the field team members and for collected samples. He ensures that all the data are properly collected, that field forms are properly filled. He ensures that the equipment is properly transported between plots and functional and well maintained.
Technical Expert (TE)	1	University forestry graduates with special knowledge on species and acquainted with/knowledge of using inventory equipment will be engaged as TE in consultation with universities. For Chittagong Hill Tracts and Madhupur Tracts forestry graduates will be selected from IP.	TE is responsible for plant species identification, measuring tree dendrometric parameters, tree and crown cover measurements and maintenance of the tablet device.
Skilled Person (SP)	2	Forest Guards will be engaged as SP, to be nominated by Forest Department	SP are responsible for proper layout of the field, plot delimitation, collection of the LCCS parameters, collection of the soil and litter samples, and collection of the field inventory data using the tablet device.
Daily Labourers (DL)	2	DL will be recruited locally. Local workers are supposed to be acquainted with local plant species by vernacular names. They should preferably have local knowledge on the area in order to facilitate the movement to the tracts and plots and contact with the local people.	DL are responsible to transport the equipment, facilitate access to/and movement in plots, orientation in the field; identification of local tree species names (as far as they can), collection of plant species in plant press, preparation of samples for transportation and carrying of samples in the field.
Total	7		

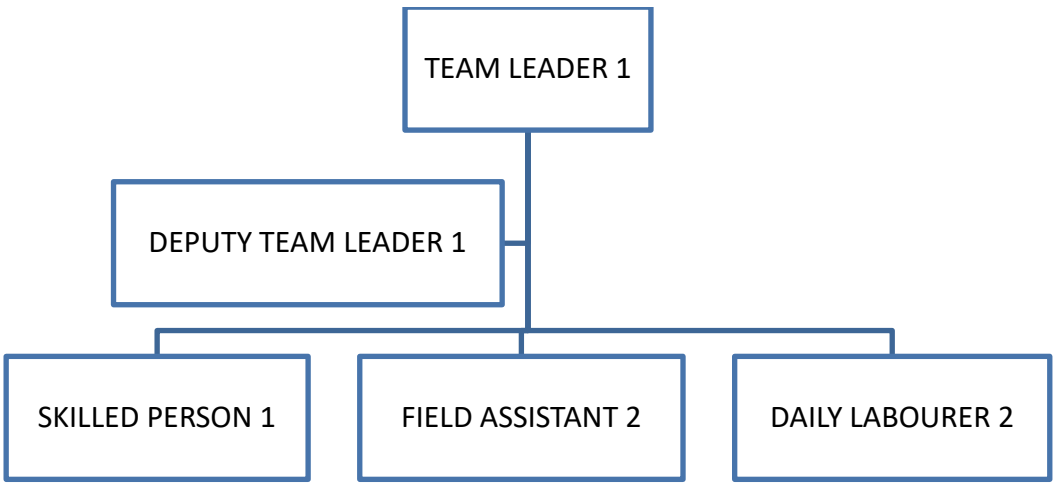


FIGURE 13: COMPOSITION OF THE FIELD TEAM

5.2. Base camps for the field crews

The Bangladesh Forest Inventory aims to complete the inventory within two years period, from October 2016 to April 2018. For logistic purposes and to ensure the proper implementation of the BFI, it was decided to start the inventory by measuring the Hill, Coastal and Sundarbans zones during the first year. In order to ensure the field teams and the QA/QC teams get support to perform their activities, out of the 162 FD decentralized offices and forest division offices, 109 offices have been primarily identified as suitable (Figure 15). Those offices will be at the disposition of the field and QA/QC teams to send the specimen for their identification and to send the soil samples and field inventory data for their analysis.

The criteria of selection of the decentralized offices were (1) proximity to one of the zones, (2) available infrastructure, and (3) office capacity to accommodate the field teams and store equipment and samples.

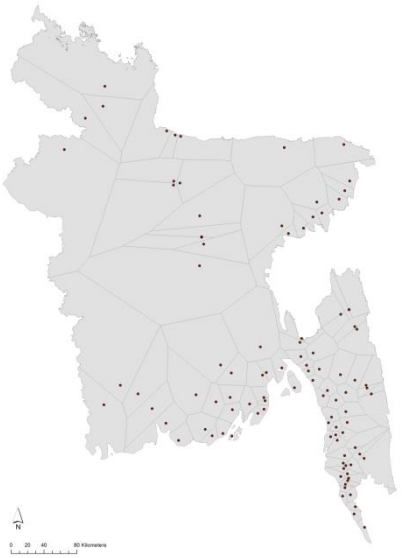


FIGURE 14: GEOGRAPHIC LOCATION OF THE DECENTRALIZED OFFICES USED FOR THE FIELD MEASUREMENTS

TABLE 11: NUMBER OF TEAMS AND PLOTS PER ZONE

	Hill	Sal	Sundarbans	Coastal	Village	Total
Number of plots	443	150	278	291	1083	2245
%	20	7	12	13	48	100
Decentralized forest offices	63	15	4	27		109
Number of field team for the first year	8	0	2	2	0	12
Number of field team for the second year		2			10	12

5.3. Quality assurance/ quality control team

Quality Assurance is the process of providing feedback to field teams whilst the data collection process is happening. Quality Control occurs independently, to check whether the field teams are achieving their targets. The aim of QA/QC is to ensure data collected is accurate. QA/QC also assists in the evaluation of the process. The QA/QC team is responsible for ensuring and monitoring the quality of data collection. The QA/QC Team Leader will report to the NFI Unit.

Quality control is performed by an independent team (Table 12). To ensure an adequate level of independence, selected universities will be involved in the QA/QC team. The universities will assist QA/QC activities closest to their location. The teams will conduct both hot check and cold checks.

Hot checks occur whilst the field team is collecting the data and immediate feedback and instruction will be provided. Hot checks will be carried out on 3% of plots.

Cold checks will be carried out after the field team has completed their task for 7% of the plots. A report on the accuracy level of the field team will be created. The QA/QC teams may only need to re-measure a portion of the plot to establish the level of accuracy.

TABLE 12: COMPOSITION AND RESPONSIBILITY OF QA/QC TEAM

QA/QC Team Composition	Number	Status	Responsibility
QA/QC Team leader	1	DFO/ACF will be nominated by FD	TL supervises the field team and activities. He makes local contacts. He distributes the fieldwork and ensures the team maintain the time frame and liaison with the supervisor and the BFI Unit in Dhaka. He is responsible for the security of the team members and ensures that all team members can implement their activities on time and in appropriate conditions. Scores crew in the QA score sheet and prepares feedback reports to the regional supervisor for the crews. Serves as the lead trainer for the crews in the region.
Deputy Team leader(DTL)	1	Forester with special knowledge on species and bio-diversity to be nominated by FD or University teacher to be engaged in consultation with Universities.	DTL is responsible for proper layout of the field, plot delimitation, collection of the LCCS parameters, collection of the soil and litter samples, and collection of the field inventory data using the tablet device. Responsible for plant species identification, measuring tree dendrometric parameters, tree and crown cover measurements and maintenance of the tablet device.
Skilled Person (SP)	1	Forest guards will be nominated as SP by FD	SP is responsible for layout of the field, plot delimitation and collection of the LCCS parameters.

Daily Labour (DL)	1	Local knowledge on the area in order to facilitate the movement to the tracts and plots and contact with the local people and identification of plant species using local names.	DL is responsible for carrying the equipment, facilitate access to/and movement in plots, orientation in the field; identification of local tree species names (as far as they can), collection of plant species in plant press, preparation of samples for transportation and carrying of samples in the field.
Total	4		

5.4. Supervision of field team activities

The direct supervision of field team activities will be performed by eight Conservator of Forests as assigned by the Chief Conservator of Forests. They will visit the field team on at least 5% of the plots to be inventoried in a year as a means of ensuring that the field teams applying the protocols correctly and to train those on the spot if there are issues. These are sometimes referred to as Hot Checks, since field teams are actively working while checked.

The supervisor will ensure that:

(i) Certification of the field teams in plot location, layout, measurements as well as data collection and handling according the established protocol. It is important that all members of the field teams have an adequate educational background. Particularly it must be required that the team leaders are well-informed of all aspects of the protocol and the data handling.

(ii) Rigorous supervision of the field teams by adequately trained Field Supervisors ensures that the plot location and layout are correctly done and the data collection from measurements, interviews and other techniques are properly performed. It is essential that the supervisors provide adequate feed-back to the field teams under and after each inspection.

6. Cost assessment

Assessment of costs is a very important part of the entire process of development of NFI design and planning the budget. Basically, it consists of two fixed components:

1. Fixed costs;
2. Changing (variable) costs.

Fixed costs include costs for equipment purchased for NFI purposes. Changing (variable) costs include all other costs based on calculations about plot localisation, distances to the plots from the base, all transportation costs, remuneration to the field group members and other sampling design-dependant costs.

Accordingly, to previous studies we assume that there is no relationship between the shape of the plot and the cost. Therefore, all costs are based on correlations between plot design, distances, accessibility and metrics.

Some cost factors were not considered in this analysis since they were deemed to be either in-kind contribution by the Bangladesh government (NFMS team), already part of a separate activity (remote sensing and mapping) or provided by FAO (communication, computer and office equipment).

The cost for transportation is based on the following assumptions:

- One plot is measured in one day;
- Field and QA/QC will measure the hill, coastal and Sundarbans zones during the first year (October 2016 – April 2017);
- Field teams go to the field for a period of average 15 days for all zones at the exception of the costal zones where field and QA/QC teams must go back to the duty station after each mission;
- Transport modes are different in each zone;
- The composition of the QA/QC and field inventory teams as described in section 5.

In order to assess the average distance between the duty stations and any location in the zone, the average distance between the selected field offices and any location within the selected zone was calculated to assess the average transport cost within each zone (Figure 15 and Figure 16).

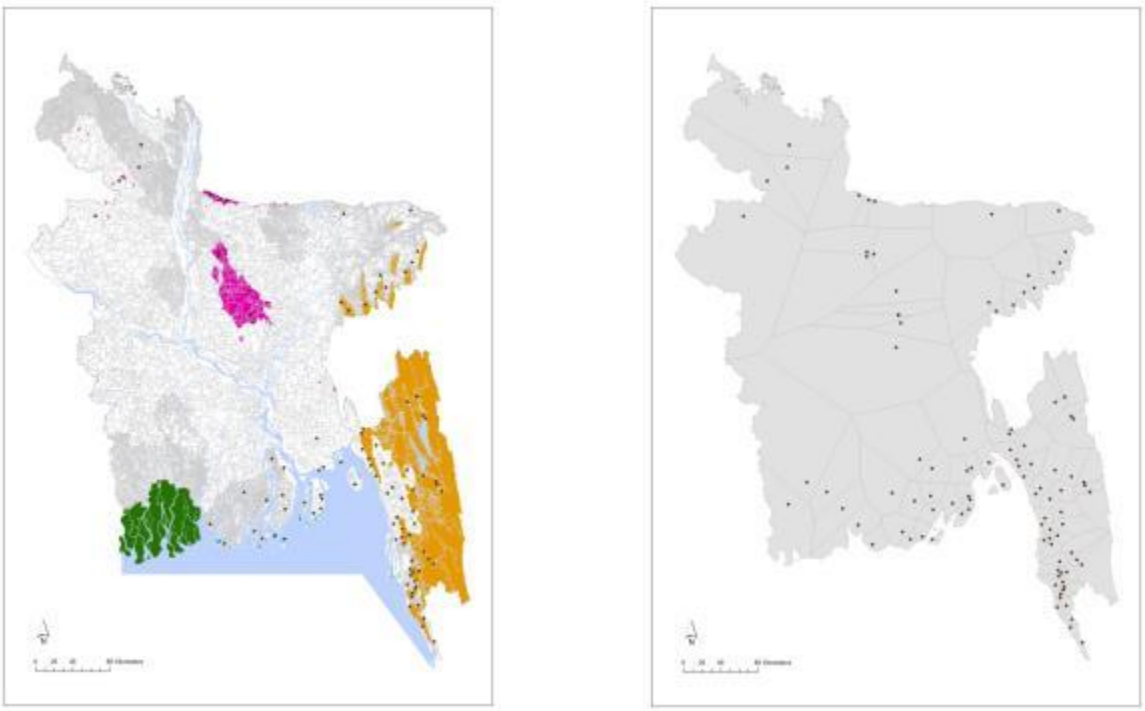
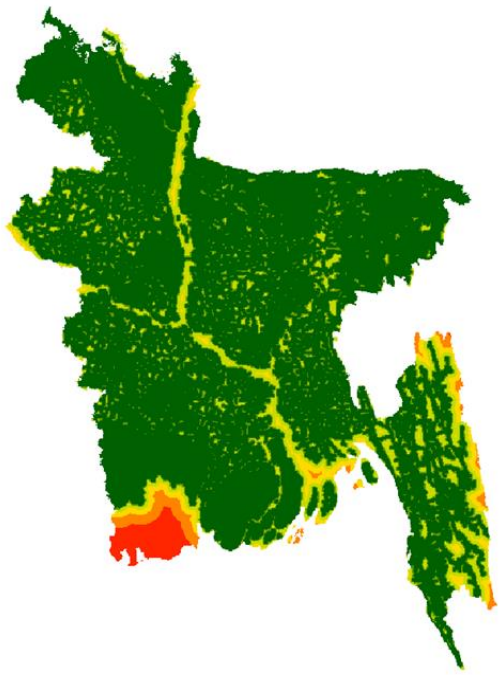
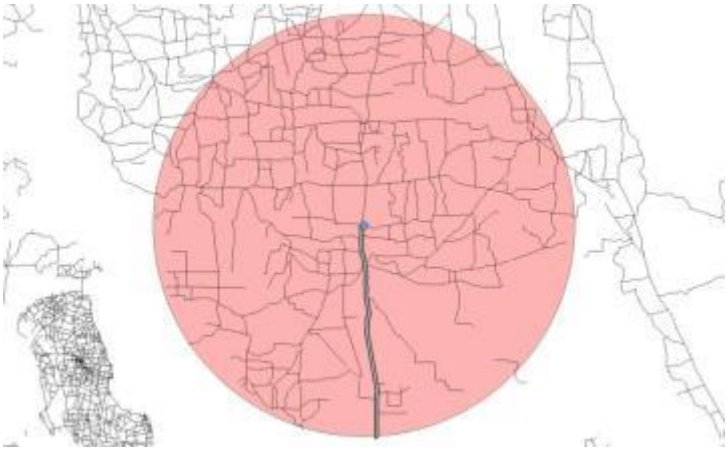


FIGURE 15: SELECTED DECENTRALISED OFFICES (A: LOCATION OF DECENTRALIZED OFFICES, ECOLOGICAL ZONES AND ROAD NETWORK, B: VORNOÏ POLYGONS AROUND DECENTRALIZED OFFICES, C: LOCATION OF DUTY STATIONS, D: VORONOÏ POYGONS AROUND DUTY STATIONS



Calculation of the average distance from Road to plot



Road network around the decentralized office. The pink circle represents the average distance from a decentralized office to reach the location of the plot

FIGURE 16: AVERAGE DISTANCE FROM DECENTRALIZED OFFICE TO ROAD NEAREST THE FIRST PLOT

In order to assess the distance from the decentralized offices (based on the 109 selected DO presented in Appendix 6) to the field inventory plot, we calculated the average distance between DO and any of the locations within the voronoï polygons. This represents the average distance to reach any plot within the area subject to be inventoried by the team from the DO.

The average distance from DO to plot based on the zoning map and based on the FD-RIMS forest map, the average distance to walk from road to plot and the cost for transportation, the cost for the soil analysis and the collection of plant specimen are detailed in appendix Appendix 7.

7. Optimization process

Once the precision models were completed, they were entered the FRIED optimization spreadsheet. FRIED was used to try to identify optimal plot designs and sample sizes for each zone for the sampling design chosen. Two basic approaches can be applied:

- Minimize the total inventory cost subject to fixed precision requirements (confidence interval and confidence level) for key metrics of interest, or
- Minimize the weighted average variance of the key metric(s) subject to a fixed inventory budget.

In the first case, the optimization can be stated as:

> **Minimize cost** (a function of the crew, travel and measurement costs which depend on the plot design variables and the number of plots)
>
> Subject to:

$$n \geq \max\left[\left(\frac{t\, CV_i(m,d,z)}{Error_i\%}\right)^2\right]$$

$$n > 2$$

where:

n = minimum sample size across all metrics

$Error_i\%$ = confidence interval half width for the key metric i, e.g., ±5%

t = Student's t-value based on the desired confidence level, e.g., 90%

CV_i = modeled percent Coefficient of Variation for key metric i based on the plot design variables, m, d and z.

m = number of subplots

d = average pairwise distance between subplots based on the distance between subplot centers, the number of subplots and the spatial arrangement, such as L-shape or radiating from a single center subplot.

z = subplot size (hectares for area and meters for transects)

The plot design variables are m, d, and z. These must be specified for each subplot kind, such as the overstory plot (trees ≥ 30 cm diameter), mid story (trees 10-30 cm diameter), understory (<10 cm diameter), and down woody material transect. As m, d and z increases, the precision generally improved, but the cost also increases. The optimization attempts to find the best balance between the two simultaneously for all the key metrics (Scott 1993). The sample size, n, for each metric i is computed using the formula above based on the variability of the metric (CV_i) and the precision requirements (t and Error%). Since each metric can result in a different sample size, the most limiting (the largest) one is selected for the inventory's sample size. One goal is to adjust the plot design variables so that the sample sizes are about the same, thus avoiding oversampling.

While there are linear, nonlinear and integer programming algorithms and software to do optimizations, the cost models used here do not lend themselves due to the mixture of linear and nonlinear models and of integer and continuous design variables. As a result, FRIED uses a grid approach to evaluate hundreds or thousands of combinations of the design variables and identify the least-cost options. For each combination, FRIED computes the expected precision and resulting sample size for each metric, then the cost. The grid is formed by giving FRIED a list of values for each design variable, such as:

- Number of subplots (m) = 1,2,3,4,5
- Distance between subplots (d) = 30, 40, 50, 60, 70, 80 m
- Subplot size (z) = 0.07, 0.08, 0.09, 0.10, 0.11, 0.12 ha

In this case, the number of combinations evaluated would be 5 x 6 x 6 = 180. When a second subplot kind (e.g., overstory vs. understory) is added, then a similar set of 180 options could be formed for it. When used together, this would form 180 x 180 = 32,400 combinations! Typically, we forced the number of subplots of each kind to be the same. Applying this restriction reduces the number of combinations by a factor of 5 = 6,480.

FRIED then provides a summary of the 10 best solutions for a particular run then provides detail on the best option. Looking at the top 10 options and evaluating the sample size requirements for each of the key metrics can help identify where to refine the search. For example, if the minimum sample size for the overstory plot is larger than for the down woody transect, then the transect length can be shortened to free up time to install a larger overstory plot. Or if it becomes clear from the 10 best solutions that the subplot size is between 0.08 and 0.09 ha, then the subplot size list can be changed to: 0.080, 0.082, 0.084, 0.086, 0.088, 0.09 ha. This process was repeated until no further improvements could be found.

We also evaluated other existing designs and other logical combinations to identify the cost of various alternatives. We also evaluated the cost implications of somewhat simpler solutions in order to find a design which is both easy and efficient to implement, such as using subplot radii that are in tenths of meters rather than centimeters.

This process was repeated for each zone using initial precision requirements. However, the ultimate requirements are at the national level. An efficient way to allocate the plots to the zones is to use Neyman allocation (Cochran 1977). In proportional allocation, the plots are allocated based on weights computed as the proportion of the total area in each zone. In Neyman allocation, the weights reflect the zone's contribution to the variance of the total. So the larger and more variable zones get more plots.

$$n_h = n\frac{N_h S_h}{\sum N_h S_h} = n\frac{N_h \bar{x}_h CV_h}{\sum N_h \bar{x}_h CV_h}$$

where:

n_h = sample size in stratum (zone) h
N_h = area of stratum h
S_h = standard deviation of the metric in stratum h
$\bar{x}_h$ = mean of the metric in stratum h

Thus the initial FRIED runs were used to compute the Coefficients of Variation (CV). The means were known from prior inventory data. FRIED used this information then to compute the weights for each metric. The next step was to compute the overall CV in order to compute the required sample size (see above).

$$CV = \frac{\sum N_h \bar{x}_h CV_h}{N\bar{X}}$$

The resulting sample size is computed for each metric. The largest one is then used to allocate the sample to each stratum (zone). The precision targets (Sampling Error percent) were then allocated to the strata:

$$SE_h\% = t\ \frac{CV_h}{\sqrt{n_h}}$$

FRIED was then rerun with the revised precision requirements to re-compute the inventory costs by zone and overall.

Because the budget is not unlimited, the overall precision requirements were revised to target the plot-related total costs of $2M.

8. Field plot layout

After reviewing the data from various prior inventories and considering the different cost factors, we identified the preferable field plot layout as a cluster of nested circular subplots with three different radius and different diameter thresholds for all zones (

Figure 17).

Data are collected from field at the following levels. Plots and subplots are never “substituted” or “moved” in order to keep the entire plot or subplot within a homogeneous land feature type.

Plot - refers to the entire cluster of five nested subplots in the Sal, Village, Hill and Coastal zones and three nested subplots in Sundarban zone.

Subplot - Data that describe a single subplot of a plot and which consists of Large, Medium and Small plots, referred to in this document as L, M and S plots respectively. L, M and S plots have radius of 19, 8 and 2.5 m respectively. The distance between the subplot centres is 38.0 meters arranged in cardinal directions (bearings 360, 90, 180 and 270 degrees.

L Plot – Circular plot of 19m radius where large trees ≥ 30cm DBH are measured.

M Plot - Circular plot of 8m radius where medium and large Trees ≥ 10.0 cm< 30 cm DBH are measured. Since the M Plot overlaps the L Plot, all trees ≥ 10.0 cm are measured within the 8m radius.

S Plot - Circular plot of 2.5m radius where trees ≥ 2 cm< 10 cm DBH are measured. S Plot is also used to collect data on seedling (DBH<2 cm) for regeneration record. The centre of the S plot is offset 90 degrees and 5.0 meters horizontal (+/- 0.3 meters) from each Subplot centre in order to avoid excessive trampling.

The proposed plot shape and size ensures the measurement of one plot in less than one day. The plot in Sundarbans consists of 3 subplot clusters. The plot in the other zones consists of 5 subplot clusters. The distance between subplots is 38 meters (Figure 18).

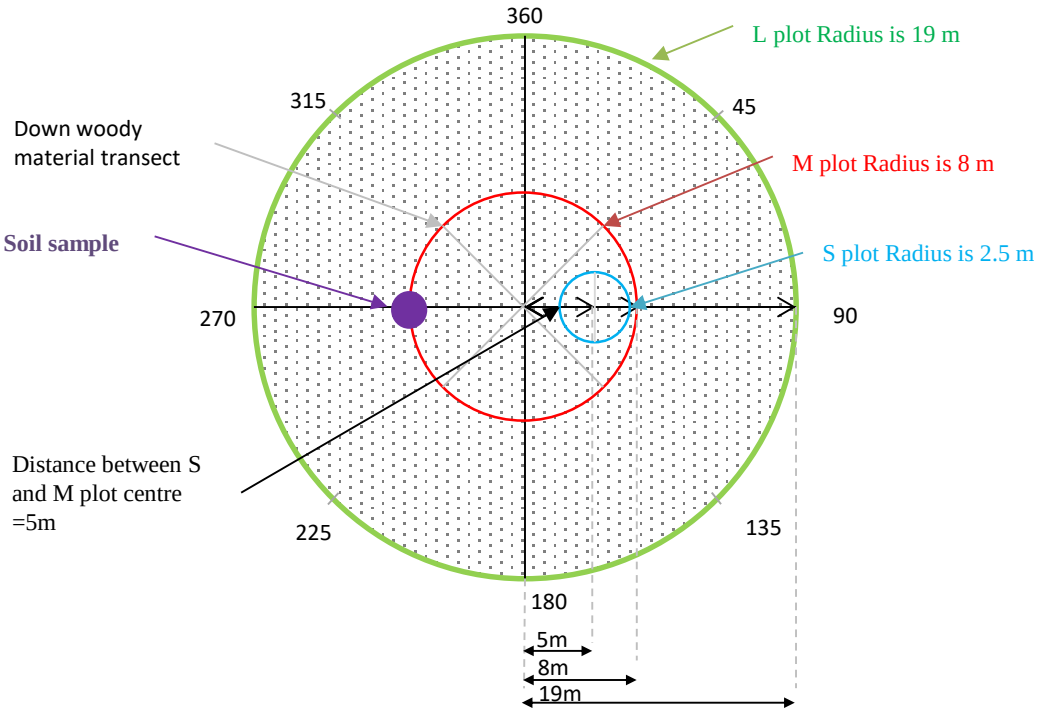


FIGURE 17: SUB-PLOT LAYOUT

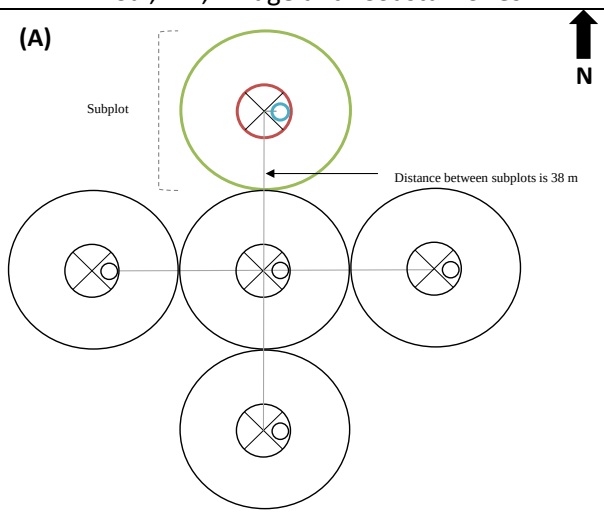
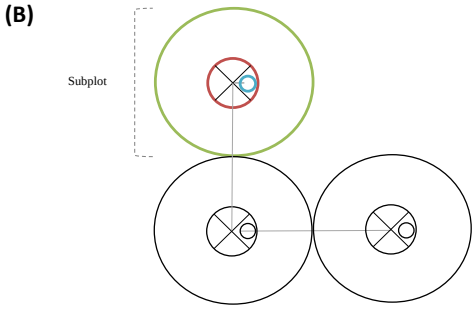
Sal, Hill, Village and Coastal zones	Sundarbans zone
	
Cluster five sub-plots	Cluster of three circular plots

FIGURE 18: PLOT LAYOUT

At sub-plot level, the following measurements are done.

Tree measurements (live and dead)

The largest subplot (L plot) has a radius of 19 meters. Every tree with a DBH ≥ 30 cm will be measured. The second subplot radius is 8 meters and every tree with a DBH ≥ 10 cm is measured. The smallest plot (S plot) radius is 2.5 meter and every tree > 2 cm DBH (sapling) is measured; seedlings (DBH <2 cm) are counted. The S plot is offset by 5 meters to the east of the subplot centre in order to avoid excessive trampling.

TABLE 13: TREE MEASUREMENTS USING NICHE SAMPLING

	Hill, sal, Sundarbans and coastal zones
19 meter	DBH ≥ 30cm
8 meter	DBH ≥ 10cm
2.5 meter	DBH ≥ 2cm

Dead Woody Debris (still under discussion)

Option 1

Dead woody debris is measured on 2 transect per subplot that would extend to the radius of the large circle (38 m transect).

Option 2

Dead woody debris is measured on 4 transect per subplot. Transect start at the subplot centre and extend 8 meters (horizontal distance) at 45°, 135°, 225° and 315°.

Option 3

Dead woody debris is measured on 3 transect per subplot that would start at the supblot centre and extend 8 meters (24 m transect).

Dead wood is measured within four classes:

Classes	Diameter	Method
Small	< 0.6 cm	Count number of pieces
Medium	0.6 – 2.5 cm	Count number of pieces
Large	2.5 – 7.6 cm	Count number of pieces
Extra-large	≥ 7.6 cm	Measure intercept diameter

Small, medium and large pieces are counted only. Only the intersect diameter of extra-large pieces is measured and recorded. Large and extra-large pieces are assessed for the entire 7 meter transect. Small and medium pieces are counted only for the last 2.5 meter.

Soil Sampling

Soil samples are taken at 8 meters at 270° from the subplot centre. Four parameters are measured: 1) soil depth, 2) soil bulk density and 3) organic carbon concentration and 4) texture.

More details related to the field inventory measurements are provided in the field inventory protocol (Hayden, Iqbal et al. 2016).

9. Sampling Design

The design of the BFI is a pre-stratified systematic sample with different intensities for each zone or stratum. Hence, the sample intensity within each zone will not be the same. Post-stratification within each zone will be used to further reduce the sampling error.

The zones were chosen so that they remain stable over time. For example, the Sal zone is relatively fragmented surrounded by non-forest. Additionally, while the broad area of Sal zone is known, the exact forest locations are not always known. We chose a broader delineation of this zone in order to capture all of the Sal zone within one stratum. As a consequence the Sal zone contains a large percentage of non-forest and only about 6.9% of forest based on BFD (2013). Plot distribution per strata is shown in Table 14.

NFI plot selection

Equidistant sampling grid was developed using Lat 1.5' X Long 1' grid. All the vertices of the grid (point locations) constitute the initial sampling frame. Then hexagonal cells of the area to be represented by individual selected plots are created (i.e., area of a hexagon for a specific zone (Akhter, Jalal et al. 2016) is the area of that specific zone divided by the number of plots for that zone). This hexagonal grid is then laid over the base grid to randomly select one of the base grid points within each hexagon. If the point selected falls outside the zone of interest, then no plot in that zone is selected for that hexagon. From the resultant points within a zone the plots to be visited are selected randomly. An illustration of the selection process is shown in below.

Selection of plots for Sundarbans by hexagonal grid

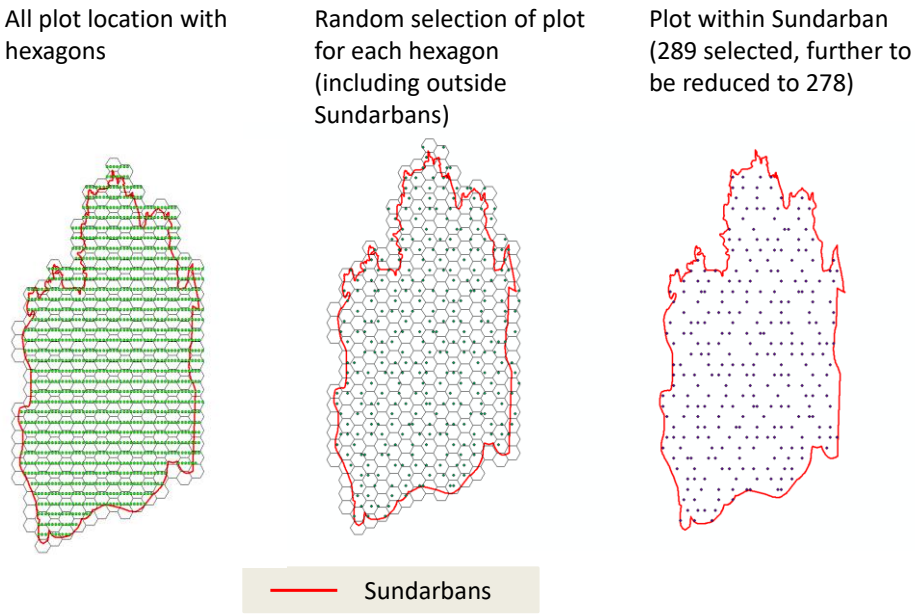


FIGURE 19: SELECTION OF PLOTS BY HEXAGONAL GRID (FOR SUNDARBANS)

TABLE 14: PLOT DISTRIBUTION IN DIFFERENT ZONES

Zone	Number of plots	Expected number of visited plots
Hill	443	428
Sal	150	145
Sundarbans	278	173
Coastal	291	113
Villages	1,083	998
Total	2,245	1,858

9.1. Non-response

Sometimes the field crews are not able to measure some or all of a plot. These plots are called inaccessible and are referred to as non-response in the statistical and social survey literature. There are a variety of reasons, including:

- Dangerous (cliffs, land mines, weather, flooding);
- Illegal activities (crops or rebels);
- Denied access (tribal protected area, owner, resident);
- Disputed areas;

- Protected areas (no tribal contact);
- Too far.

Since the inaccessible plots may differ from the rest of the population, this can introduce bias into the estimates. Thus, it is important to minimize the problem. Alternatives include:

- Try again later (weather better or different owner at next measurement cycle);
- Send socialization crew – specialists at getting access to denied access plots;
- Measure using imagery. In the case where the plot can be fully characterized from imagery, record the values as if measured on the ground. For example, the land use and land cover for water, glaciers, buildings, etc. can be accurately classified from good imagery;
- Replace plot – use a strict protocol to replace an inaccessible plot with a preselected alternate plot nearby in the same stratum. However, this can create bias by moving plots away from those characteristics associated with difficult access. For permanent plots, this approach is not recommended.

Even after concerted efforts to minimize the number of inaccessible plots, not all plots will be fully measured. The next step is to develop estimates to minimize the bias (Gregoire and Scott 1990). Below are five methods with different assumptions and results, especially in terms of bias. Some methods may be more appropriate for some causes than others.

1. Treat as zeros but show the area by inaccessible class. This method has the advantage of being transparent, so it is recommended to always present the proportion of inaccessible plots. However, the values for most metrics will be underestimates.
2. Partition inaccessible zones and report them as such. Similar to 1), this clearly identifies regions that could not be sampled, such as protected areas with no tribal contact. However, this does not account for some of the other causes.
3. Use model-based estimation for large inaccessible areas (e.g., using LiDAR in Protected Areas). As in 2), this method applies to inaccessible regions but provides estimates. However, the models must be based on plots collected outside the region, so if the plots are not representative of the inaccessible area, then the bias can be large. It also requires high resolution imagery, such as LiDAR, for both the inaccessible and surrounding areas (in order develop relationship between the imagery and accessible plots).
4. Use imputation to substitute another plot's data for the missing one based on similarity of remotely sensed characteristics. This is similar to 3) but uses available imagery and maps to group similar sampled plots in order to find matches for inaccessible plots. An advantage is that this approach can be applied to all causes and may have the best potential to minimize the bias. Estimating precision is challenging.
5. Drop the plots from estimation. This treats the inaccessible plots as if they had the strata mean. This has the advantage of being able to make population estimates for all metrics and increases the variance by reducing the sample size by the number of completely inaccessible plots. For partially accessible plots, a special estimator must be used, such as the ratio-to-size estimator or that used by FIA (Bechtold and Scott 2005) to account for the missing portion of the plot.

At a minimum, methods 1 and 5 are recommended. Use 2 if there are inaccessible regions. If the capacity exists to use 4 (imputation), then it could be pursued.

10. Field work

Several information sources will be made available to the field crew to facilitate the field measurement.

- Equipment list (see (Hayden, Iqbal et al. 2016))

- The land cover map for the year 2015 will provide information about the distribution of the field inventory plot in the different land cover/use types;
- The accessibility of each plot will be evaluated using maps of road network;
- Maps and other ancillary information (for field survey);
- Open Foris Collect survey for the field data collection;
- Administrative maps (districts, sub-districts, unions, mauza, upazila);
- Other topographic elements such as: ponds, homesteads, water ways etc.;
- Printed high resolution satellite images around each plot;
- Derived sampling design based on basic sampling grid.

Prior to the field visit, each team must plan the easiest and least time-consuming itinerary to access the plot. Advice of local informants (local forestry and extension staff, for example) are usually valuable and help saving time in searching the best option to access the plot. The starting points of the five sub-plots in each plot are to be indicated together with their respective coordinates. The plot order (1 to 5) for data collection will vary according to conditions of accessibility. It is determined during the preparation phase, before going to the field. Reference objects (roads, rivers, houses) that contribute to better orientation of the team in the field are identified. Pictures are being taken at the centre of each plot following the instruction of the LCCS field manual (BSGI 2016).

The Open Foris Collect module provides a flexible solution for field data management (data collection and data analysis and reporting), allowing full customization of inventory structure, variables and data checks. Collect module ensures data quality through an integrated data entry and data cleansing workflow. The module introduces the concept of the Inventory Data Meta-model (IDML), a formal description (i.e., metadata) of the types of variables, classifications and coding schemes used by the inventory. All inventories documented in this way may be entered and retrieved through a user-friendly interface, without additional programming.

10.1. Preparation of the field crews

The following trainings have been organized prior to field mobilisation:
1) Overview of the design;
2) Use of Open Foris Mobile Data Recorder (data collection, export/import, cleansing, and preparation for analysis);
3) GPS navigation (GPS manual);
4) The field measurements ((BSGI 2016), biophysical measurements and soil measurements manual);
5) Species lists, and code lists are made available (botanical identification document).

Training on the survey methodology should be undertaken in theoretical and practical sessions on test sites where techniques of different land measurements, use of mobile devices, handling of data and techniques of interviews will be explained and practised.

10.2. Preparation of the field forms

The forms are prepared in digital and analogue form in Open Foris environment.

1) The digital forms are loaded in mobile data recorders for automated data collection, database enter, cleansing and validation;
2) The analogue/paper forms serve as backup.

The team leader must ensure that the necessary field forms are available. Some information will be filled in before going out in the field such as sections for identification of the plot and sub-plots, general information related to location, coordinates of the starting point of the plot, names of field staff.

10.3. Fieldwork procedures

The field procedures are detailed in (Hayden, Iqbal et al. 2016). The field procedures manual is structured in thirteen chapters: 1 Introduction, 2, Travel planning and locating the plot, 3. Plot layout and referencing, 4. Plot level data, 5. Land feature data, 6. Subplot data, 7. Tree and sapling data, 8. Bamboo data, 9. Palm and coconut, 10. Seedling data, 11. Down wood material data, 12 the appendices and 13. References.

15. Conclusion

Based on collaborative efforts between the projects involved in inventorying forest resources in Bangladesh, a desk review has been undertaken to identify the needs and the gaps of existing inventories. The objectives of the national forest inventory have been identified in consultation with national stakeholders. In order to ensure the NFI captures some forest types of interest such as the Sal forest, particular attention has been given when designing forest zones. The proposed forest zones aim to support the pre-stratification and to ensure that field inventory plots capture the forest types of interest. Using the existing field inventory data and considering the costs related to field measurements and transportation, several sampling design options have been proposed. The current document will be modified after the national consultation and will be adapted to become the Bangladesh Forest Inventory design.

16. References

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17. Appendix

APPENDIX 1: AGENCIES INVOLVED IN MAPPING THE LAND USES BY APPLICATION OF REMOTE SENSING

Agencies	Major Mandates
Centre for Environmental and Geographic Information Services (CEGIS)	A public trust established in 2002 with the mission as a scientifically independent centre of excellence is to support the management of natural resources for sustainable socio-economic development using integrated environmental analysis, geographic information systems, remote sensing, and information technology
Soil Resource Development Institute (SRDI)	Soil Survey of the whole country on the basis of aerial photo interpretation, field and laboratory investigation of soils; Interpretation of aerial photos, land sat imageries and topographic maps for soil and land use surveys; Preparation of various maps and reports on the above-mentioned surveys for publication; Coordination with the beneficiary agencies at local, regional or national levels regarding planning and execution of land use development program.
Bangladesh Society of Geoinformatics (BSGI)	To build capacity on Geoinformatics among governmental and non-government agencies and to guide and assist the proliferation of Geoinformation technology and the sharing of ideas, information and knowledge among users, professionals and institutions.
Space Research and Remote Sensing Organization (SPARRSO)	SPARRSO's mandates include application of space and remote sensing technology, in the field of Agriculture, Forestry, Fisheries, Geology, Cartography, Water Resources, Land use, Weather, Environment, Geography, Oceanography, Science, Education, science-based Knowledge and other related space research areas. It also performs research activities for developing this technology and its practical application.
Survey of Bangladesh (SoB)	SoB provides geodetic, photogrammetric, cartographic, and GIS services. Existing SOB GIS products can help user to visualize the ground more realistically then before and thus helping him to make appropriate decision in time.
Ministry of Land (MoL)	The important aims and objectives of Ministry of Land are management and settlement of the Government owned lands vested properties and abandoned properties as well as land survey and record keeping and updating. The National Land Use Policy 2001 of the Ministry of Land is one of the main policies of the government that has highlighted the need, the importance and modalities of National Land Zoning for integrated planning and sustainable management of land resources of the country.

Department of Environment (DoE)	DOE's mandate is to ensure sustainable environmental governance in the face of climate change for achieving high quality of life for the benefit of present and future generation.
Bangladesh Water Development Board (BWDB)	Research and coordinating institution of BWDB such as the Institute of Water Modelling (IWM) are responsible for mathematical water modelling; and Centre for Environmental and Geographic Information Services (CEGIS) for integrated environmental analysis using GIS, remote sensing (RS), database and IT.
Bangladesh Bureau of Statistics (BBS)	BBS provides with statistical information to guide decision making and the development process at national and local levels.
Bangladesh Forest Industries Development Corporation (BFIDC)	The mandates include to be a sustainable and profitable corporate institution in this field of Rubber and Wood industries.
Bangladesh Centre for Advance Studies (BCAS)	Land use Survey and Mapping of the Sal Forests in Modhupur Tracts under Tangail district of Bangladesh. Mouza wise land use survey and GIS mapping were carried out in Modhupur tracts under Tangail district of Bangladesh. Study reports related to the Sal forests, field survey by mouza maps and topography sheets, discussion with stakeholders, PC ARC/info, ATLAS GIS were used as methodologies for the research.
Department of Urban Development (UDD)	Considering disaster risk and climate change involved in town planning and regional planning through participatory conservation of agricultural land, wetland, forest land and ecosystem for best utilization of land
Local Government Engineering Department (LGED)	Planning, implementation and monitoring of infrastructure development projects in rural and urban areas
Bangladesh Agricultural Research Council (BARC)	BARC has prepared a crop zoning map of Bangladesh based on soil and agro-climatic conditions. The purpose of the crop zoning is better utilization of land and water resources for maximization of crop production with least cost. [4]The land resources activity was initiated in 1979 under FA)/UNDP Land Use Advisory Project to make Soil Survey information as a basis for more rational planning of agricultural development. During the period 1980-1987 a national AEZ based computerized land resources data base system was successfully developed with financial support from UNDP and technical assistance from the FAO. The physical resources data base on land, soils, climate, hydrology, and land suitability is used for national and sub-national agricultural research and development planning. The BARC is the custodian of this data base and is maintained at its Computer & GIS unit.
Water Resources Planning Organization (WARPO)	WARPO is an apex organization under the Ministry of Water Resources, dealing with nationwide water resources planning. Its major mandate is to formulate water resources master plans in an environmentally

[4]http://archive.barcapps.gov.bd/uploads/Documents_1_1__1441184156.pdf

	sustainable manner and to develop national water resources It has developed flood map, transboundary river maps etc. for national and sub-national planning.
Bangladesh University of Engineering and Technology (BUET), Dhaka	Teach and undertake projects on urban and regional planning, flood hazard mapping, vulnerability to earthquake and fire hazard mapping and land use change using Remote Sensing and GIS Application

APPENDIX 2: ONGOING MAJOR FORESTRY PROGRAMMES OF THE FOREST DEPARTMENT

Name of the Projects, Location & Period	Major objectives of the Projects
Bangabandhu Sheikh Mujib Safari Park, Gazipur (3rd Phase), Gazipur, March 2010 to December, 2017	1. To conserve animal and plant biodiversity of Sal forest. 2. To provide ex-situ conservation support to complement in-situ conservation of endangered and threatened wildlife of Bangladesh. 3. To promote ecotourism facilities close to Dhaka Mega City for recreation and poverty alleviation. 4. To provide recreation, education and scientific research facilities.
Establishment of Sheikh Russell Aviary and Ecopark at Rangunia, Chittagong (3rd Revised), Rangamati, July 2010 to December, 2016	This project mainly aims at conserving and preserving the rare and precious flora and fauna and particularly birds' population by creating food sources and habitat for birds and tourism development within forests.
Strengthening Regional Cooperation for Wildlife Protection Project. (SRCWP)(1st Revised), July, 2011 to December, 2016	The development objective of the project is to assist the participating governments to build or enhance capacities and institutions and share knowledge and expertise to jointly tackle illegal wildlife trade and improve management of endangered wildlife and their habitat by addressing selected regional conservation threats.
Biodiversity Conservation and Ecotourism Development in Bangladesh (2nd Revised) (Nationwide), July 2011 to June 2016	1. Conservation of plants and animals' biodiversity in the country. 2. To promote ecotourism and recreational facilities in the national parks, wildlife sanctuaries, eco-parks, botanical gardens, safari parks, special conservation areas, reserved forest and potential ecotourism sites. 3. To stop illegal poaching, hunting and trade of wild animals. 4. To resolve wildlife-human conflict.
Development and Extension of Bangabandhu Sheikh Mujib Safari Park, Cox's Bazar (1st Revised), Dulahazara, Cox'sbazar, July 2012 to June, 2017	With the major goal of serving the national need of biodiversity conservation education, research, recreation and in-situ and ex-situ conservation of the threatened, extinct and endangered animals.
Climate Resilient Participatory Afforestation and Reforestation Project (CRPARP) (1st Revised), Chittagong Division - Chittagong, Cox's Bazar, Noakhali, Laxmipur, Feni and Borisal Division - Borisal, Potuakhali, Borguna and Bhola, July, 2012 to December, 2016	To reduce forest degradation through participatory planning/ monitoring and to contribute in building the long-term resilience of selected communities in coastal and hilly areas to climate change.
Sustainable Development and Biodiversity Conservation in Coastal (Protection) Forests	The resident population in the pilot regions of the Sundarbans is participating and conserving biodiversity and the management of

(SDBC - Sundarbans) Shatkhira, Khulna and Bagherhat, July 2012 to September, 2015	the ecologically sensitive embankment areas (vulnerable areas of the embankment/dyke), serving as a model for others
Char Development and Settlement Project-IV (FD Component) Subarna Char, Hatia and Companigong of Noakhali District. Shandweep of Chittagong District. January 2011 to December, 2016	To reduce poverty and hunger for poor people living in the newly accreted coastal chars. This would be achieved via the development of improved and more secure rural livelihoods in agriculture, provision of legal title to land, and through provision of climate resilient infrastructure.

APPENDIX 3: THE NINE REGIONAL FOREST CIRCLES CONTROL ALL THE FOREST DIVISIONS

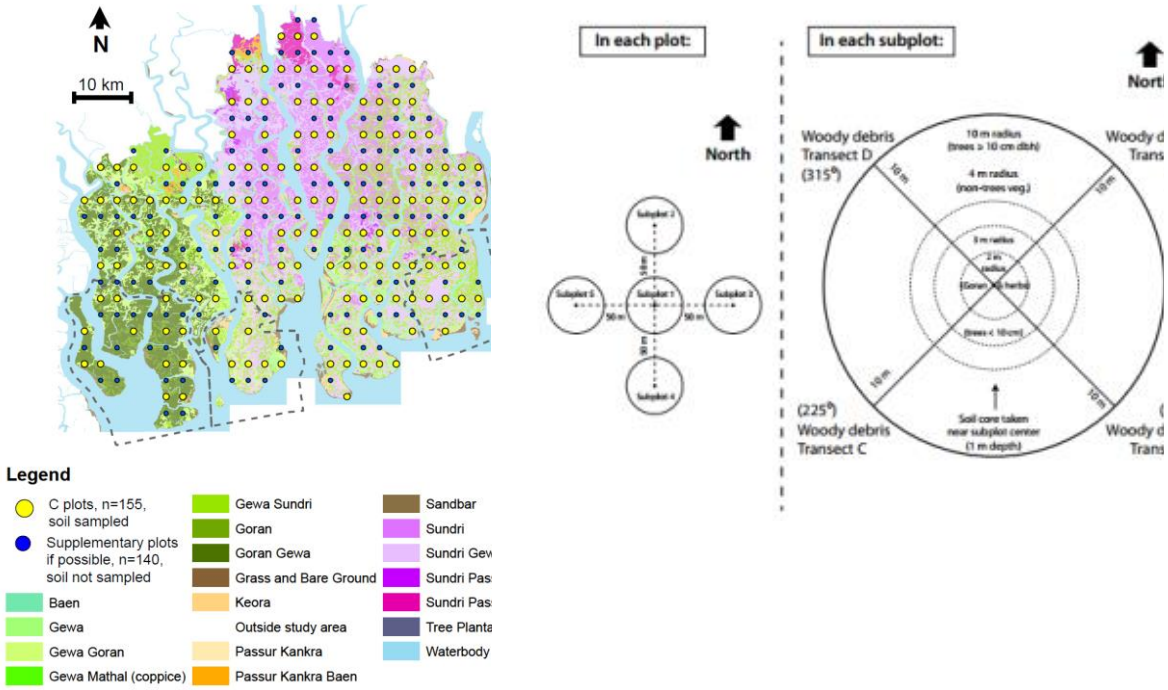

FIGURE 20: FOREST CARBON INVENTORY FOR THE SUNDARBAN RESERVE FOREST (EXAMPLE OF SAMPLE DESIGN (LEFT) AND CLUSTERED PLOT LAYOUT (RIGHT)

Left: Proposed sampling scheme for Sundarbans carbon and forest inventory. A systematic grid is employed, with 295 plots spaced at regular intervals of latitude/longitude. Gaps in the grid are due to watercourses. These plots are a systematic subsample of an existing inventory grid of ~1200 plots that were measured in the 1990s, thus enabling past inventory data to be utilized for baseline comparisons.

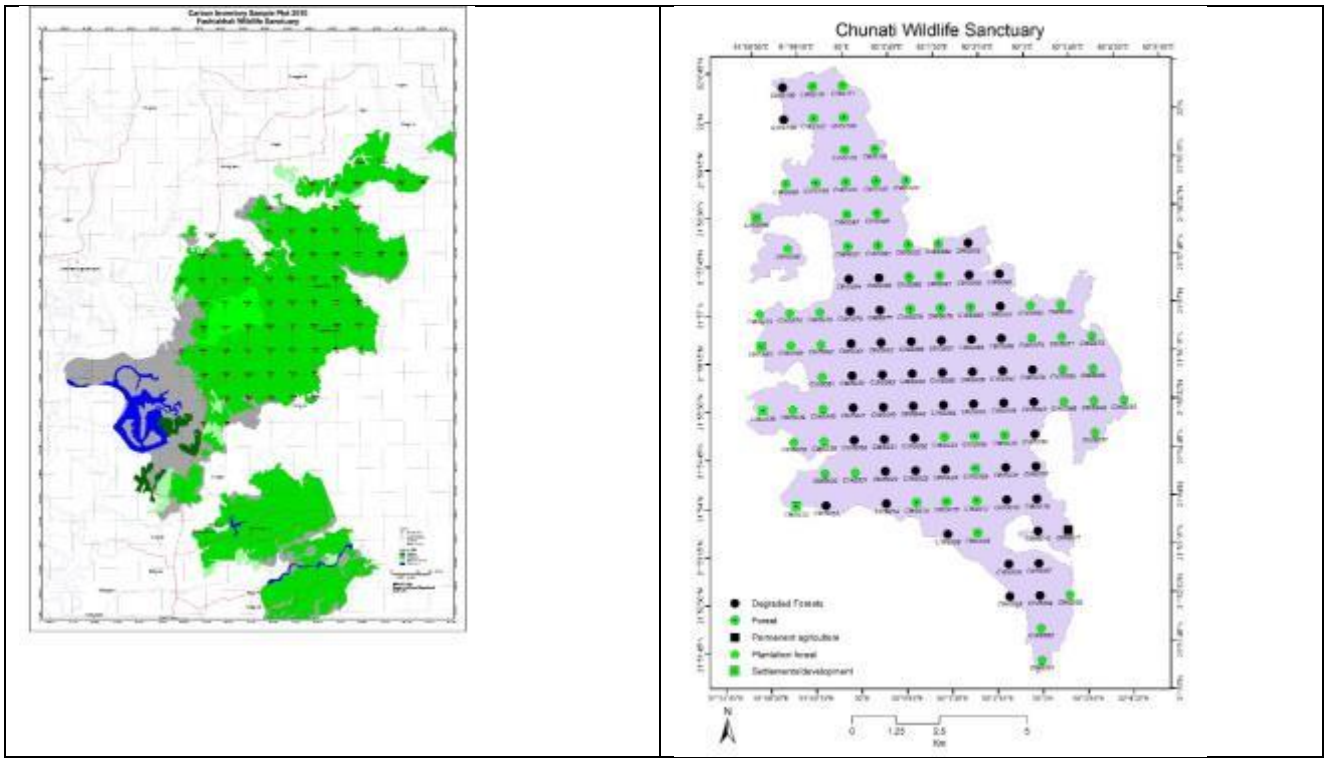

FIGURE 21: EXAMPLE, ESTIMATION OF PLOTS FALLING IN DIFFERENT LAND USES IN CHUNATI WILDLIFE SANCTUARY BY CREL (2006)

APPENDIX 5: OVERVIEW OF FIELD INVENTORYIES IN BANLGADESH

Entity code	Entity full	File name	Scale	Forest type	Year	GPS coordinates?	CRS
CREL INP	Inani National Park	6-2-1 C Inventory INP august05.10.xls	Forest	Hill	2010	yes	wgs84 (guessed)
CREL SRF	Sitakunda Reserved Forest	6-2-2 Inventory Sitakunda RF 2010- 18 Aug 2010_Sita_Final April 10 2011.xls	Forest	Hill	2010	yes	wgs84 (guessed)
CREL DDSW	Dudpukuria Dhopachari Wildlife Sanctuary	6-2-4 Carbon Inventory DDWS 27.02.2011-verAug23 2011.xls	Forest	Hill	2010	yes	wgs84 (guessed)
CREL FKWS	Fasiakhali Wildlife Sanctuary	6-2-5 Carbon Inventory FSWS 12.8.2010.xls	Forest	Hill	2010	yes	wgs84 (guessed)
CREL TWS	Teknaf Wildlife Sanctuary	6-2-7 Todd_Teknaf C Inventory-15.5.11_tanim.xls	Forest	Hill	2010	yes	wgs84 (guessed)
FD-NFA	Forestry department National forest assessment	based on tree csv from R training.xlsx	National	Mixed	2007	yes	wgs 84
FD-SAL	Forestry department Sal forests	sal1N.mdb	eco zone	Sal	2001	partial	wgs 84
FD-SRF	Forestry department Sundarban Reserved Forest	SRF C-Analysis_Final (2010).xls	eco zone	Sundarbans	2010	yes	wgs84 (guessed)
FD-97-hill	Forestry department FI 97 hill forests	CHTINV.ZIP COXBAZAR.ZIP SYLHET1.ZIP	eco zone	Hill	1997	yes	wgs84 (guessed)
FD-97-coastal	Forestry department FI 97 coastal forests	BHOLA.ZIP CCOINV.ZIP NOAKHALI.ZIP PATINV.ZIP	eco zone	Coastal	1997	yes	wgs84 (guessed)
FD-97-sundarban	Forestry department FI 97 Sundarbans forests	SUNDATA1.ZIP + rec3.xlsx	eco zone	Sundarbans	1997	yes	wgs84 (guessed)

Entity code	No. of plots	Plot size*(ha)*	No of subplots	Shape	Radius if subplot is circle (m)	Subplot size (ha)	Nested subplot?	Min dbh (cm)	Max dbh (cm)	tree height measured?	Dead trees measured?	Seeding and/or sampling counts?	Forest floor measure-ments?	No trees
CREL INP	56	0.15708	5	circle	10	0.03	no	7	127	partial	yes	yes	Litter and soil	361
CREL SRF	32	0.15708	5	circle	10	0.03	no	10	89.2	partial	yes	yes	Litter and soil	391
CREL DDSW	62	0.15708	5	circle	10	0.03	no	0.2	710	partial	yes	yes	Litter and soil	2128
CREL FKWS	72	0.15708	5	circle	10	0.03	no	0.3	96.7	partial	yes	yes	Litter and soil	1821
CREL TWS	54	0.15708	5	circle	10	0.03	no	10	122	partial	yes	yes	Litter and soil	434
FD-NFA	251	2	4	rectangular	No	0.50	no	3	231	all	NA	NA	NA	38988
FD-SAL	4000	0.02	1	circle	5.64 or 7.98	0.02	no	9	75	partial	no	no	mo	23809
FD-SRF	150	0.15708	5	circle	10	0.03	no	0.1	170	partial	yes	yes	Litter and soil	21621
FD-97-hill	3208	0.190065	5	circle	11	0.04	yes	0.9	120	partial	no	no	no	88424
FD-97-coastal	610	0.190065	5	circle	11	0.04	yes	2.3	57.8	partial	no	no	no	38909
FD-97-sundarban	1202	0.190065	5	circle	11	0.04	yes	2	117	partial	no	no	no	149066

APPENDIX 6: DECENTRALIZED OFFICE AND DUTY STATIONS FOR THE BFI

Sl	Selected DO	Division Name	Range Name	Name	Distance to zone	Nearest Zone	Distance to legal forest	Nearest Legal Forest
1	Yes	Chittagong North	Hathazari	Hathazari Range Office	2766.27	Hill	5702.029	Hill
2	Yes	ChittagongNorth	Olinagar	Olinagar Range Office	481.2386	Hill	0	Hill
3	Yes	Chittagong North	Mirsarai	Mirsarai Range Office	1988.279	Hill	1812.308	Hill
4	Yes	ChittagongNorth	Sitakunda	Sitakunda Range Office	919.8001	Hill	1135.328	Hill
5		ChittagongNorth	Hazarikhil	Hazarikhil Range Office	-	-	-	-
6	Yes	Chittagong North	Karerhat	Karerhat Range Office	0	Hill	0	Hill
7	Yes	Chittagong North	Narayanhat	Narayanhat Range Office	1012.309	Hill	4082.988	Hill
8		Chittagong North	Narayanhat	Narayanhat Range Office	-	-	-	-
9		Chittagong North	Mirsarai	Mirsarai Range Office	-	-	-	-
10		Chittagong North	Bariyadhala	Bariyadhala Range Office	-	-	-	-
11		Chittagong North	Kumira	Kumira Range Office	-	-	-	-
12	Yes	Chittagong North Forest Division	Chittagong North Town	Chittagong North Town Range Office	5216.519	Hill	7925.486	Coastal
13	Yes	Chittagong North	Icchamoti	Icchamoti Range Office	1266.639	Hill	2204.702	Hill
14	Yes	Chittagong North Forest Division	Kalurghat	Kalurghat Range Office	9844.747	Hill	12367.29	Coastal
15	Yes	Chittagong South	Patiya	Patiya Range Office	1783.657	Hill	5251.887	Hill
16	Yes	Chittagong South Forest Division	Barobakia	Barobakia Range Office	0	Hill	13.80368	Hill
17	Yes	Chittagong South	Padua	Padua Range Office	154.9496	Hill	4604.568	Hill
18	Yes	Chittagong South	Dohajari	Dohajari Range Office	909.9385	Hill	1055.464	Hill
19	Yes	Chittagong South	Chunati	Chunati Range Office (CTG South)	0	Hill	0	Hill
20		Chittagong South	Chunati	Chunati Range Office (Wildlife)	-	-	-	-
21		Chittagong Wildlife Division	Bashkhali Eco-Park	Bashkhali Eco- Park Range Office	-	-	-	-
22	Yes	Chittagong South	Jaldi	Jaldi Range Office	0	Hill	0	Hill
23	Yes	Chittagong South	Bashkhali	Bashkhali Range Office	0	Coastal	1596.552	Coastal
24	Yes	Chittagong South	Chhanua	Chhanua Range Office	0	Coastal	5265.876	Coastal
25	Yes	Chittagong South	Khurshia	Khurshia Range Office	479.598	Hill	771.4599	Hill
26	Yes	Chittagong South	Kalipur	Kalipur Range Office	0	Hill	55.66238	Hill
27	Yes	Lama	Lama Division	Lama Forest Division Office	73.24399	Hill	0	Hill
28	Yes	Lama	Matamuhari	Matamuhari Range Office	0	Hill	0	Hill
29	Yes	Lama	Tain	Tain Range Office	0	Hill	0	Hill
30	Yes	Lama	Lama Sadar	Lama Sadar Range Office	-	-	-	-
31	Yes	Chittagong Hill Tracts (South)	Alikhiang	Alikhiang Range Office	0	Hill	0	Hill
32	Yes	Chittagong Hill Tracts (South)	Changrachari	Changrachari Range Office	0	Hill	0	Hill
33	Yes	Chittagong Hill Tracts (South)	Farua	Farua Range Office	0	Hill	0	Hill
34	Yes	Rangamati (Jhum Control)	Tinkonia	Tinkonia Range Office	0	Hill	0	Hill
35	Yes	Chittagong Hill Tracts (North)	Pablakhali	Pablakhali Range Office	0	Hill	0	Hill

36	Yes	Chittagong Hill Tracts (North)	Sisok	Sisak Range Office	0	Hill	0	Hill
37	Yes	Chittagong Hill Tracts (North)	Baghaihat	Baghaihat Range Office	0	Hill	0	Hill
38	Yes	Chittagong Hill Tracts (North)	Masalong	Masalong Range Office	0	Hill	0	Hill
39	Yes	Chittagong Hill Tracts (North)	Naraichari	Naraichari Range Office	633.2382	Hill	0	Hill
40	Yes	Rangamati (Jhum Control)	Hajachari	Hajachari Range Office	618.1912	Hill	0	Hill
41	Yes	Rangamati (Jhum Control)	Merung	Merung Range Office	618.1912	Hill	0	Hill
42	Yes		Kaptai	Kaptai Range Office	0	Hill	0	Hill
43	Yes	Patuakhali Coastal Division	Patharghata	Patharghata Range Office	0	Coastal	91.62017	Coastal
44	Yes	Patuakhali Coastal Division	Mohipur	Mohipur Range Office	0	Coastal	2235.344	Coastal
45	Yes	Patuakhali Coastal Division	Patuakhali	Patuakhali Range Office	9720.589	Coastal	24997.3	Coastal
46	Yes	Patuakhali Coastal Division	Char Montaz	Char Montaz Range Office	69.93774	Coastal	1659.988	Coastal
47	Yes	Patuakhali Coastal Division	Galachipa	Galachipa Range Office	0	Coastal	4187.892	Coastal
48	Yes	Patuakhali Coastal Division	Dashmina	Dashmina Range Office	3065.052	Coastal	5028.168	Coastal
49	Yes	Noakhali Coastal Division	Nalcchira	Nalcchira Range Office	0	Coastal	3026.244	Coastal
50	Yes	Noakhali Coastal Division	Nalchira	Nalchira Range Office	0	Coastal	2112.112	Coastal
51	Yes	Noakhali Coastal Division	Sagoria	Sagoria Range Office	0	Coastal	2774.954	Coastal
52	Yes	Noakhali Coastal Division	Habibiya	Habibiya Range Office	0	Coastal	10723.14	Coastal
53	Yes	Noakhali Coastal Division	Chor bata	Chor bata Range Office	0	Coastal	8041.467	Coastal
54	Yes	Noakhali Coastal Division		Noakhali DFO Office	5954.621	Coastal	28568.12	Coastal
55	Yes	Chittagong Coastal Division	Urirchar	Urirchar Range Office	2574.043	Coastal	17.89363	Coastal
56	Yes	Noakhali Coastal Division	Jahajmara	Jahajmara Range Office	0	Coastal	1937.871	Coastal
57	Yes	Chittagong Coastal Division	Sandwip	Sandwip Range Office	1050.141	Coastal	6242.738	Coastal
58		Chittagong Coastal Division	Mirsarai	Mirsarai Range Office	-	-	-	-
59		Chittagong Coastal Division	Sitakunda	Sitakunda Range Office	-	-	-	-
60		Chittagong Coastal Division	Bashkhali	Bashkhali Range Office	-	-	-	-
61		Chittagong Coastal Division	Chhanua	Chhanua Range Office	-	-	-	-
62		Cox'sbazar South Division	Inani	Inani Range Office	-	-	-	-
63	Yes	Cox'sbazar South Division	Shilkhali	Shilkhali Range Office	0	Hill	18.12247	Hill
64	Yes	Cox'sbazar South Division	Teknaf	Teknaf Range Office	3296.232	Coastal	315.389	Hill
65	Yes	Cox'sbazar South Division	Whykheong	Whykheong Range Office	0	Coastal	0	Hill
66	Yes	Cox'sbazar South Division	Ukhia	Ukhia Range Office	0	Hill	812.5278	Hill
67		Cox'sbazar North Division	P.M. Khali	P.M. Khali Range Office	-	-	-	-
68	Yes	Cox'sbazar South Division	Panerchara	Panerchara Range Office	0	Hill	0	Hill

69	Yes	Cox'sbazar South Division	Dhoapalong	Dhoapalong Range Office	234.0992	Hill	757.11	Hill
70	Yes	Cox'sbazar South Division	Rajarkul	Rajarkul Range Office	274.6531	Hill	1339.838	Hill
71	Yes	Cox'sbazar North Division	Baghkhali	Baghkhali Range Office	0	Hill	2249.194	Hill
72		Cox'sbazar North Division	Joarianala	Joarianala Range Office	-	-	-	-
73		Cox'sbazar North Division	Meherghon a	Meherghona Range Office	-	-	-	-
74		Cox'sbazar North Division	Fulchari	Fulchari Range Office	-	-	-	-
75		Cox'sbazar North Division	Eidgaon	Eidgaon Range Office	-	-	-	-
76	Yes	Cox'sbazar North Division	Fashiakhali	Fashiakhali Range Office	0	Hill	0	Hill
77		Chittagong North Forest Division	Chittagong North Town	Chittagong North Town Range Office	-	-	-	-
78		Cox'sbazar Chittagong North Division	Kalurghat	Kalurghat Range Office	-	-	-	-
79		Chittagong South Forest Division	Barobakia	Barobakia Range Office	-	-	-	-
80	Yes	Chittagomg Wildlife Division	Bashkhali Eco Park	Bashkhali Eco Park Range Office	0	Hill	0	Hill
81	Yes	Chittagong South Forest Division	Jaldi	Jaldi Range Office	-	-	-	-
82		Chittagong South Forest Division	Kalipur	Kalipur Range Office	-	-	-	-
83		Chittagong North Forest Division	Mirsarai	Mirsarai Range Office	-	-	-	-
84	Yes	Chittagong North Forest Division	Bariyadhala	Bariyadhala Range Office	153.7937	Hill	0	Hill
85	Yes	Chittagong North Forest Division	Kumira	Kumira Range Office	0	Hill	1353.483	Hill
86	Yes	Bhola Coastal Division	Bhola	Bhola Range Office	12538.22	Coast al	30045.45	Coastal
87	Yes	Bhola Coastal Division	Char Fashion	Char Fashion Range Office	0	Coast al	9072.148	Coastal
88	Yes	Bhola Coastal Division	Lalmohon	Lalmohon Range Office	0	Coast al	9549.483	Coastal
89	Yes	Bhola Coastal Division	Daulat Khan	Daulat Khan Range Office	0	Coast al	13930.12	Coastal
90	Yes	Bhola Coastal Division	Dhal Char	Dhal CharRange Office	0	Coast al	345.5874	Coastal
91	Yes	Bhola Coastal Division	Char Kukri Mukri	Char Kukri Mukri Range Office	0	Coast al	1145.222	Coastal
92	Yes	Bhola Coastal Division	Manpua	Manpura Range Office	0	Coast al	2738.408	Coastal
93	Yes	Cox's Bazar South Forest Div.	Inani	Inani	0	Hill	595.4421	Hill
94		Cox's Bazar South Forest Div.	Shilkhali	Shilkhali	-	-	-	-
95		Cox's Bazar South Forest Div.	Teknaf	Teknaf	-	-	-	-
96		Cox's Bazar South Forest Div.	Whykheong	Whykheong	-	-	-	-
97		Cox's Bazar South Forest Div.	Ukhia	Ukhia	-	-	-	-
98		Cox's Bazar South Forest Div.	Panerchara	Panerchara	-	-	-	-
99		Cox's Bazar South Forest Div.	Dhoapalong	Dhoapalong	-	-	-	-
100		Cox's Bazar South Forest Div.	Rajarkul	Rajarkul	-	-	-	-
101	Yes	Cox's Bazar North Forest Div.	P.M.Khali	P.M.Khali	0	Hill	3889.285	Hill

102	Yes	Cox's Bazar North Forest Div.	Bagkhali	Bagkhali	0	Hill	2249.194	Hill
103	Yes	Cox's Bazar North Forest Div.	Joarianala	Joarianala	0	Hill	9.36357	Hill
104	Yes	Cox's Bazar North Forest Div.	Meherghona	Meherghona	0	Hill	0	Hill
105	Yes	Cox's Bazar North Forest Div.	Fulchari	Fulchari	0	Hill	326.9197	Hill
106	Yes	Lama Forest Division	Lama	Lama DFO	86.56701	Hill	0	Hill
107	Yes	Cox's Bazar North Forest Div.	Eidgarh	Eidghar	0	Hill	0	Hill
108	Yes	Cox's Bazar North Forest Div.	Eidgaon	Eidgaon	0	Hill	0	Hill
109		Cox's Bazar North Forest Div.	Fashiakhali	Fashiakhali	-	-	-	-
110	Yes	Tangail Forest Division	Dokkhola	Dokkhola Range office	0	Sal	0	Sal
111	Yes	Tangail Forest Division	Aryankhola	Aryankhola Range office	0	Sal	0	Sal
112	Yes	Rangpur		Rangpur DFO Office	34210.21	Sal	20734.1	Sal
113	Yes	Rangpur Social Forest Division	Mitha Pukur	Mitha Pukur Range Office	16555.3	Sal	0	Sal
114	Yes	Rajshahi Social Forest Division	Paikbanda	Paikbanda Range Office	32949.67	Sal	12726.55	Sal
115	Yes	Mymensingh Forest Division	Rasulpur	Rasulpur Range office	0	Sal	196.9524	Sal
116	Yes	Mymensingh Forest Division	Bhaluka	Bhaluka Range office	0	Sal	0	Sal
117	Yes	Mymensingh Forest Division	Modhu Tilla	Modhu Tilla Range Office	0	Sal	0	Sal
118	Yes	Mymensingh Forest Division	Rangtia	Rangtia Beat Office	0	Sal	0	Sal
119		Mymensingh Forest Division	Bali Juri	Bali Juri Beat Office	-	-	-	-
120		Mymensingh Forest Division	Rangtia	Rangtia Range Office	-	-	-	-
121	Yes	Mymensingh Forest Division	Bali Juri	Bali Juri Range Office	0	Sal	0	Sal
122	Yes	Dinajpur Forest Division	Charkai	Charkai Range Office	1610.405	Sal	3027.456	Sal
123	Yes	Dhaka Wildlife Division	Bhawal	Bhawal Range office	0	Sal	0	Sal
124	Yes	Dhaka Wildlife Division	Bhurulia	Bhurulia Range office	0	Sal	0	Sal
125	Yes	Dhaka Wildlife Division	National Park	National Park Range office	0	Sal	0	Sal
126		Dhaka Wildlife Division	Bangabandhu Safari Park	Bangabandhu Safari Park Range office	-	-	-	-
127	Yes	Dhaka Forest Division	Rajendrapur	Rajendrapur Range office	-	-	-	-
128	Yes	Sundarban East Forest Division	Chandpai	Chandpai RO	0	Sundarbans	0	Sundarbans
129	Yes	Sundarban West Forest Division	Nalian	Khulna RO, Nalian	780.0424	Sundarbans	787.1067	Sundarbans
130	Yes	Sundarban West Forest Division	Burigoalini	Satkhira RO, Burigoal	362.9451	Sundarbans	307.96	Sundarbans
131	Yes	Sundarban East Forest Division	Sarankhola	Sarankhola RO	0	Sundarbans	0	Sundarbans
132	Yes	Sylhet	Satchari	Satchari Range Office	0	Hill	0	Hill
133	Yes	Sylhet	Raghunandan	Raghunandan Range Office	0	Hill	0	Hill

134	Yes	Sylhet	Moulavibazar Wild Life Sanctuary	Moulavibazar Wild Life Division Office	0	Hill	359.8372	Hill
135	Yes	Sylhet	Moulavibazar Wild Life (Sreemangal)	Moulavibazar Wild Life (Sreemangal) Range Office	162.7581	Hill	454.6605	Hill
136	Yes	Sylhet	Kalenga	Kalenga Range Office	0	Hill	0	Hill
137	Yes	Sylhet	Rajkandi	Rajkandi Range Office	2119.244	Hill	2567.342	Hill
138	Yes	Sylhet	Kulaura	Kulaura Range Office	0	Hill	3.45652	Hill
139	Yes	Sylhet	Juri	Juri Range Office	227.4232	Hill	4338.858	Hill
140	Yes	Sylhet	Borolekha	Borolekha Range Office	3012.115	Hill	3251.1	Hill
141	Yes	Sylhet	Sunamgonj	Sunamgonj Range Office	43443.83	Village	43443.83	Village
142	Yes	Sylhet	Sari	Sari Range Office	0	Hill	13974.79	Hill
143	Yes	Cox's Bazar North Forest Div.		Cox's Bazar Forest Div.	0	Hill	0	Hill
144	Yes	Bandarban Pulpwood Division		Bandarban Pulpwood Forest Division		Hill		Hill
145	Yes	Chittagong Hill Tracts (South)						
146	Yes	Khagrachari Forest Division		Khagrachari Forest Division		Hill		Hill
147	Yes	Dhaka Forest Division	Dhaka	Dhaka Forest Division		Sal		Sal
148	Yes	Sundarban East Forest Division	Bagerhat	Sundarban East Forest Division		Sundarbans		Sundarbans
149	Yes	Sundarban West Forest Division	Khulna	Sundarban West Forest Division		Sundarbans		Sundarbans
150	Yes	Bhola Coastal Division	Bhola	Bhola Coastal Division		Coastal		Coastal
151	Yes	Patuakhali Coastal Division	Patuakhali	Patuakhali Coastal Division		Coastal		Coastal
152	Yes	Noakhali Coastal Division	Maijdee	Noakhali Coastal Division		Coastal		Coastal
153	Yes	Rajshahi Social Forest Division	Rajshahi	Rajshahi Social Forest Division		Village		village
154	Yes	Rangpur Forest Division	Rangpur	Rangpur Forest Division		Village		village
155	Yes	Pabna Social Forest Division	Pabna	Pabna Social Forest Division		Village		village
156	Yes	Jessore Forest Division	Jessore	Jessore Forest Division		Village		village
157	Yes	Barisal Coastal Forest Division	Barisal	Barisal Coastal Forest Division		Village		village
158	Yes	Sylhet Forest Divison	Sylhet	Sylhet Forest Divison		Village		village
159	Yes	Comilla Social Forest Division	Comilla	Comilla Social Forest Division		Village		village
160	Yes	Mymensingh Forest Division	Mymensingh	Mymensingh Forest Division		Village		village

161	Yes	Dhaka Social Forest Division	Dhaka	Dhaka Social Forest Division		Village		village
162	Yes	Faridpur Social Forest Division	Faridpur	Faridpur Social Forest Division		Village		village

APPENDIX 7: DETAILED COSTS CONSIDERED FOR THE BFI DESIGN PROCESS

TABLE 15: AVERAGE DISTANCE FROM DO TO PLOT (BASED ON THE ZONE MAP)

Zones	Total	Hill	Sal	Sundarbans	Coastal	Village
Total Area (ha)	14441514	1787564	427738	548232	804903	10872975
Road length (m)	115313281	7799262	1921052	99964	8586078	96906489
Total Area (ha)	14441514	1787564	427738	548232	804903	10872975
Road density (m/ha)	7.98	4.36	4.49	0.18	10.67	8.91
Average land area covered DO	134967	29793	38885	137058	34996	278794
Average maximum distance from DO to plot (m)	16640	12131	38990	33532	10110	18637
Maximum distance from DO to plot (m)	38401	28463	92532	73273	23507	42751
Average distance from DO to plot (m)	8320	6066	19495	16766	5055	9319
Shortest road network to run the average maximum distance	18121	14783	25036	37198	9298	18620
Factor to multiply times the straight-line distance between plots to compute average travel distance along roads	2.18	2.44	1.28	2.22	1.84	2.00

* DO offices that are less than 5 km from a forest type can be used to measure it, except for the swamp where the nearest DO is at 43 km.

TABLE 16: AVERAGE DISTANCE FROM DO TO PLOT (BASED ON THE LEGAL FOREST MAP)

Legal Forest Boundary	Total	Hill	Coastal	Sal	Sundarbans	Village
Total Area (ha)	14441514	1641503	61497	285338	580708	11872367
Road length (m)	115313281	6555348	47240	1390269	103671	107216318
Total Area (ha)	14441514	1641503	61497	285338	580708	11872367
Road density (m/ha)	8	4	1	5	0	9
Average land area covered DO	134967	27358	2674	25940	145177	304420
Average maximum distance from DO to plot (m)	16640	12215	9329	32888	38990	15779
Maximum distance from DO to plot (m)	38401	28785	22350	72226	92532	36310
Average distance from DO to plot (m)	8320	6108	4664	16444	19495	7890
Shortest road network to run the average maximum distance	18121	14871	6945	36583	25036	14931
Factor to multiply times the straight-line distance between plots to compute average travel distance along roads	2.18	2.43	1.49	2.22	1.28	1.89

* DO offices that are less than 5 km from a forest type can be used to measure it, except for the swamp where the nearest DO is at 43 km.

In order to assess the time to walk from the road to the plot, a map of the distance to road was prepared.

The average distance between roads to plot was calculated for each ecological zone.

TABLE 17: AVERAGE DISTANCE TO WALK FROM ROAD TO PLOT (M)

Legal Boundary	**Total**	**Hill**	**Coastal**	**Sal**	**Sundarbans**	**Village**
Average distance from the road to the plot (km)	4.58	1.96	3.79	0.43	20.83	0.46
Maximum distance from road to plot (km)	25.15	20.86	17.77	3.98	59.38	47.97
Average walking speed to plot (km/hr)	-	3	4	5	3	5
Average distance from plot (km/hr)	-	3	4	5	3	5

	Total	Hill	Coastal	Sal	Sundarbans	Village
Average distance from the road to the plot (km)	4.06	1.85	0.64	0.42	20.94	0.46
Maximum distance from road to plot (km)	19.27	20.86	11.91	3.92	59.38	18.59
Average walking speed to plot (km/hr)	-	3	4	5	3	5
Average walking speed returning from plot (km/hr)	-	3	4	5	3	5

Table 18 represents the costs related to transportation from the decentralized office to the plot and between the plots.

TABLE 18: COSTS FOR TRANSPORT

Transportation mode	Bus	Jeep	Accommodation boat - Big boat	Micro bus	CNG Taxi	Van	Country boat	Engine boat (fixed cost)
Hill								
Rate (km/hr)	30	30	5.7	15	15	20	6	8
Cost/km	5	7	3	5	6	6	3	10
Fixed Cost/Day	0	9000	35000	18000	2500	1500	5000	14000
% of distance travelled by mode	0	0	0	70	20	10	0	0
Sal								
Rate (km/hr)	30	30	5.7	15	15	20	6	8
Cost/km	5	6	3	5	6	6	3	10
Fixed Cost/Day	0	7000	35000	10000	2500	1500	4000	20000
% of distance travelled by mode	0	0	0	80	10	5	5	0
Sundarbans								
Rate (km/hr)	30	30	5.7	15	15	20	6	8
Cost/km	5	6	3	5	6	6	3	10
Fixed Cost/Day	0	7000	35000	10000	2500	1500	5000	44000
% of distance travelled by mode	0	0	80	0	0	5	15	0
Coastal								
Rate (km/hr)	30	30	5.7	15	15	20	6	8
Cost/km	5	6	3	5	6	6	3	10
Fixed Cost/Day	0	7000	35000	15000	2500	1500	5000	20000
% of distance travelled by mode	0	0	0	40	15	5	0	40
Village								
Rate (km/hr)	30	30	5.7	15	15	20	6	8
Cost/km	5	6	3	5	6	6	3	10
Fixed Cost/Day	0	12000	35000	10000	2500	1500	4000	20000
% of distance travelled by mode	0	0	0	80	10	5	5	0

On-plot measurement

The figures presented in Table 19 are used to calculate the cost related to field measurements.

TABLE 19: COSTS RELATED TO PLOT MEASUREMENTS

On-plot (measurement)	Hill	Sal	Sundarban	Coastal	Village
Hours to talk with public, establish and GPS the center point of the plot including plot level attributes and reference trees	1.00	0.50	1.00	0.70	2.00
Time to navigate from one subplot to the next	0.50	0.40	0.20	0.20	0.50
Time to walk back	0.50	1.00	0.40	0.50	1.00
Subplot shape (Circular or Rectangular)					
Hours to measure a Subplot (area attributes)	Time in minutes to measure each tree by size class				
Hours to measure 1 ha subplot of Trees >30 cm	5.0	4.0	5.0	5.0	5.0
Hours to measure 1 ha subplot of Trees >10 cm	4.0	3.0	3.0	3.0	4.0
Hours to measure 1 ha subplot of Trees >2.5 cm	3.0	2.0	2.0	2.0	3.0
Hours to measure 1 ha subplot of Trees >1 cm	2.0	1.0	1.0	1.0	2.0
All Trees Nested subplot					
All Trees >10 cm Nested subplot	Hours to measure 100 m transect of Dead wood				
Hours to measure 1 m subplot of Dead wood	0.20	0.15	0.50	0.25	0.15
Hours to measure a Soil Sample	Hours for botanical specimen collection per plot				
Hours for botanical specimen collection per plot	0.75	0.75	1.00	1.00	0.75
Time each day for other matters (editing, specimen handling, equipment cleaning, etc.)	3.0	3.0	3.0	3.0	2.5

** Based on Sundarban and FAO inventories

Assessment of the costs for soil carbon analysis

Soil samples will be composite soil samples collected in the centre of each plot. In the case there are different land features; composite sampling will be collected.

Cost for the soil analysis includes sample processing Bulk density, Organic carbon and Texture. Cost for the dead wood analysis includes Sample processing and organic carbon.

For collecting the botanical specimens, we need one wooden frame and 4kg used newspaper for one plot. Storing in the herbarium and identification of the specimen will be performed by the national herbarium. 200 BDT is considered for the identification of one specimen. We consider that on average, 20 specimens need to be identified for each plot. The cost analysis does consider that the samples will be sent via courier to Dhaka for their processing and analysis.