Forest Carbon Inventory 2014 at Eight Protected Areas in Bangladesh

Main Report

Bangladesh Forest Department and
Winrock International

March 2015

Climate-Resilient Ecosystems and Livelihoods (CREL)
AID-388-A-12-00007

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Main Report

By

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Contents

Acronyms

ACCF	Assistant Chief Conservator of Forests
ACF	Assistant Conservator of Forests
ACL	Assistant Crew Leader
Ag	Permanent Agriculture
BD	Soil Bulk Density
BFRI	Bangladesh Forest Research Institute
C	Carbon
CCF	Chief Conservator of Forests
CF	Conservator of Forests
CFCI	Consultant Forest Carbon Inventory
CL	Crew Leader
Cm/cm	Centimeter
CMC	Co-management Committee
CMC	Co-management Committee
COP	Chief of Party
CREL	Climate Resilient Ecosystems and Livelihoods
Cum/cum	Cubic meter
CV	Coefficient of variation
CWS	Chunati Wildlife Sanctuary
DAB	Diameter above buttress (0.3 m above upper end of buttress
DBH, dbh, D	Diameter at Breast Height
DCCF	Deputy Chief Conservator of Forests
DCF/DFO	Deputy Conservator of Forests/Divisional Forest Officer
DCOP	Deputy Chief of Party
DF	Degraded forest
F	Forest
FAO	Food and Agriculture Organization (United Nations)
FCI	Forest Carbon Inventory
FD	Forest Department
FRMP	Forest Resources Management Project
G/g	Gram
GBH	Girth at Breast height
GBH, gbh, G	Girth at breast height
GOB	Government of Bangladesh
GPS	Global Positioning System
Ha, ha	Hectare
HNP	Himchari National Park
IPAC	Integrated Protected Area Co-management Project
IUCN	International Union for Conservation of Nature
KHNP	Khadimnagar National Park
KNP	Kaptai National Park
LNP	Lawachara National Park
LRS	Long Rotation Species.
LUS	Land use class
M/m	Meter
Mg	Mega gram (Metric Ton)

MNP	Modhupur National Park
MRV	Measurement, Reporting and Verification
NFI	National Forest Inventory
NRM	Natural Resources Management
OC	Organic Carbon
OD	Oven Dried
ODA	Overseas Development Agency
PA	Protected Area
Pln.	Plantation
PSP	Permanent Sample Plots
REDD+	Reducing Emission from forest Deforestation and forest Degradation
RKWS	Rema-Kalenga Wildlife Sanctuary
R-PP	Readiness Preparation Proposal
Sag	Shifting agriculture
SG	Stump Girth
SNP	Satchari National Park
SOP	Standard Operating Procedures
SRF	Sundarban Reserve Forest
SRS	Short Rotation Species.
T	Ton
Tk	Taka
TL	Team Leader
TOR	Terms of Reference
TSP	Temporary Sample Plots
UN	United Nations
UNDP	United Nations Development Program
UNREDD	United Nations Reducing Emission from Degradation & Deforestation
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USFS	United States Forest Service
VF	Village forest
WI	Winrock International

Executive Summary

The Climate Resilient Ecosystems and Livelihoods (CREL) project, funded by USAID, implemented by Bangladesh Forest Department (BFD) with technical assistance of Winrock International, conducted forest carbon inventory at eight Protected Areas (PAs) of Bangladesh in 2014. The PAs are Khadimnagar National Park (KhNP), Lawachara National Park (LNP), Satchari National Park (SNP), Rema-Kalenga Wildlife Sanctuary (RKWS), Modhupur National Park (MNP), Kaptai National Park (KNP), Chunati Wildlife Sanctuary (CWS) and Himchari National park (HNP). Following IPCC guidelines and lessons from previous forest inventories in the country as well as different SOPs of BFD and Winrock International, concentric circular plots were systematically laid out at 30"X30" intervals. Data were recorded at 2m, 4m, 10m and 17.84m radii plots. Data collected from a total of 377 sample plots in eight PAs covering 34,376 ha and analyzed using MS Excel. This area includes core areas of the PA plus some adjoining area of the Reserved Forests. The CO2 (Mg/ha) estimates were made for five carbon pools, e.g. Trees (seedlings, saplings and live trees), dead wood (standing and lying deadwoods), non-tree vegetation (herbs, shrubs, cane, bamboo, liana etc), litters and soil. The inventory was conducted to establish baselines for forest carbon and biophysical conditions, and the changes that resulted from deforestation and forest degradation. This report describes the methods and results used for CRELs baselines and how those methods and results confirm National REDD+ development as outlined in the 2013 Bangladesh draft R-PP.

The forest carbon inventory resulted in estimates of areas for different Land cover classes, tree recruitments, carbon stocks, deforestation & forest degradation, GHG emissions in the eight selected PAs.The area distribution for different Land Cover Classes were estimated land area are as given in Table a.

Table a: Inventoried Area (ha) estimates for different PAs and land cover classes

Land cover Classes	LNP	SNP	RKWS	KhNP	MNP	KNP	CWS	HNP	Total area (ha)
Forest	1,400	953	4,782	479	2,233	3,786	507	132	14,272
Plantation	-		93	-	578	42	361	15	1,089
Degraded land	509	657		198	-	968	5,873	1,385	9,590
Settlement	310	-	68	1	2,872	271	981	329	4,832
Bare land	-			-	-	-	-	29	29
Rubber	0	92			495				587
Tea	227	104	20	98					449
Agriculture	137	1	555	3	2,083	23	598	128	3,528
Inventoried Area (ha)	2,583	1,807	5,518	779	8,261	5,090	8,320	2,018	34,376

The recruitments in different tree size classes are an indication of forest health; therefore the number of seedlings, saplings and trees per hectare were estimated and are given in Table b.

Table b: Number of seedlings, saplings, trees, stumps per ha

Protected Areas	Seedlings (N/ha)	Saplings (N/ha)	Live trees (N/ha)	Stumps (N/ha)
Lawachara NP	3,130.05	4,880.75	1,426.31	25.16
Satchari NP	3,103.52	1,710.92	894.68	24.00
Rema-kalenga WS	10,338.76	2,867.32	1,419.01	36.03
Khadimnagar NP	884.19	795.77	954.08	12.22
Modhupur NP	30,311.78	4,846.99	1,834.77	11.64
Kaptai NP	939.28	234.82	1,011.63	93.11
Chunati WS	4,366.01	2,165.08	1,035.28	23.06
Himchari NP	2,033.65	2,947.31	168.51	-

The CO2 stocks at different PAs and land cover classes were estimated and are given in Table c. It was observed that the total carbon CO_2 (Mg) stock in eight PAs was **8,001,323** Mg in 2014. The carbon stock varied from 52.8 to 370.7 CO_2 Mg/ha among the PAs. The highest carbon stock was observed at Rema-Kalenga WS (370.7 CO_2 Mg/ha) and lowest at Himchari NP (52.8 CO_2 Mg/ha). The average stock was estimated at 232.8 CO_2 Mg/ha.

Table c. Stock of CO_2 at different cover classes at Forest Carbon inventoried eight PAs.

PA	Live Trees CO2 (Mg/ha)	Dead Trees CO2 (Mg/ha)	Non-trees CO2 (Mg/ha)	Litter CO2 (Mg/ha)	Soil Carbon (Mg/ha)	Total CO2 Mg/ha	Inventoried area (ha)	Total CO2 Mg of the PA
L NP	269.2	3.8	1.5	8.6	40.7	323.8	2,583	836,456
SNP	219.1	0.3	1.0	11.5	33.9	265.8	1,807	480,295
RKWS	319.1	0.0	0.9	5.2	45.6	370.7	5,518	2,045,487
KhNP	264.2	-	0.8	7.1	26.3	298.3	779	232,412
MNP	195.5	-	0.8	6.4	32.2	234.8	8,261	1,939,606
K NP	222.0	3.3	1.0	5.0	27.2	258.5	5,090	1,315,601
CWS	103.8	0.2	10.5	8.9	23.1	146.4	8,320	1,218,037
HNP	37.9	0.4	0.2	0.1	14.2	52.8	2,018	106,605
All PA	191.1	1.0	3.7	6.7	30.3	232.8	34,376	8,001,323

Emission Factors from deforestations for different PAs from conversion of forest to agriculture, settlements and bare lands varied from 0 to 279.01 CO_2 Mg/year with comparatively high 786.2 and 3204.5 CO_2 Mg/year at Chunati WS and Modhupur NP respectively (Table d).

Table d: Deforestation trends in eight PAs

PA	Land cover change	Total Forests in 2001	Total area change (2001-2012)	Annual area change	Rate of Deforestation	Emission Factor (overall eight PAs)	Baseline Annual Emissions
	Forest to:	ha	ha	ha/yr	%	CO2 Mg/ha	CO2 Mg/yr
LNP	Agriculture		7.6	0.63	0.03%	298.8	188.2
LNP	Settlements		2.8	0.23	0.01%	207.5	47.7
LNP	Total	2,149	10.4	0.87	0.04%		236
SNP		229		-			
RKWS	Agriculture		0.4	0.03	0.00%	298.8	9
RKWS	Total	5,755	0.4	0.03	0		8.964
KhNP		481		-			

PA	Land cover change	Total Forests in 2001	Total area change (2001-2012)	Annual area change	Rate of Deforestation	Emission Factor (overall eight PAs)	Baseline Annual Emissions
	Forest to:	ha	ha	ha/yr	%	CO2 Mg/ha	CO2 Mg/yr
MNP	Agriculture		110.2	9.18	0.38%	298.8	2743
MNP	Settlements		47.4	3.95	0.17%	207.5	819.6
MNP	Total	2,389	157.6	13.13	0.55%		3562.6
KNP	Agriculture		4.1	0.34	0.01%	298.8	101.6
KNP	Settlement		3	0.25	0.00%	207.5	51.9
KNP	Total	5,823	7.1	0.59	0.01%		153.5
CWS	Settlement		20.8	1.73	0.16%	207.5	359
CWS	Agriculture		8.5	0.71	0.07%	298.8	212.1
CWS	Total	1,067	29.3	2.44	0.23%		571.1
HNP	Bare soil		2.8	0.23	0.13%	262.6	60.4
HNP	Settlement		2.3	0.19	0.11%	207.5	39.4
HNP	Agriculture		2	0.17	0.09%	298.8	50.8
HNP	Total	182	7.1	0.59	0.33%		150.6
							4,682.75

Two types of degradations were identified from the inventory, one by conversion of forests to degraded forests and another by removal of trees when the stumps were still there. Results show that the conversion of forest to "degraded forest" is the most significant cause of annual GHG emission and loss of forest biophysical condition overall, resulting in approximately 6,487 CO_2Mg/year (Table e).Three PAs did not have any emission from the conversion of forest to degraded forest, which is possibly due to effective forest protection (as the case with Lawachara National Park), or it is replaced with forest loss from agricultural expansion (as is the case with Modhupur National Park).

Table e: Forest degradation by change of land cover class (forest to degraded forests)

PA	Total Forests in 2001	Total area of change (2001-2012)	Annual area change	Rate of Deforestation	Emission Factor	Baseline Annual Emissions
	ha	Ha	ha/yr	%	CO_2 Mg/ha	CO_2 Mg/year
LNP	2,149		-	-		-
SNP	229	5	0.42	0.18%	258	107.5
RKWS	5,755		-	-		-
KhNP	481	2.5	0.21	0.04%	258	53.75
MNP	2,389		-	-		-
KNP	5,823	94.6	7.88	0.14%	258	2,033.90
CWS	1,067	169	14.08	1.32%	258	3,633.50
HNP	182	30.6	2.55	1.40%	258	657.9
All PA	18,075	302	25.14167	0.139096	258	6486.55

The total emissions from extraction of trees by human interference were estimated at 325,031 CO2 Mg from the forests. The annual emissions were not possible to estimate as the age of the stumps were not known Table f).

Table f: Degradation due to human interference (cutting of trees, stumps)

PA	Stumps (N/ha)	Emissions from extraction of trees (CO_2 Mg/ha)	Total CO2 Mg/ha	Per cent of total forest CO_2 stocks	Area of forest (ha)	Total emissions from extraction of trees CO_2 Mg
LNP	30.83	6.43	470.67	1.4%	1,400	8,996
SNP	40.00	18.02	313.71	5.7%	952	17,154
RKWS	31.30	19.00	432.44	4.4%	4,782	90,858
KhNP	15.00	26.44	362.49	7.3%	479	12,663
MNP	19.33	4.03	277.62	1.5%	2,232	9,006
KNP	65.88	48.89	322.74	15.1%	3,786	185,081
CWS	26.19	2.51	197.98	1.3%	507	1,272
HNP	-	-	117.30	0.0%		-
All PAs	31.52	15.98	343.29	4.7%	14,138	325,031

The total area of degraded forest in the CREL PAs is almost 9,589 ha in inventoried area which is almost 28% in the eight PAs. If all this land was reforested into mature forest then a large amount of CO_2 would be sequestered over period that it takes the forest to re-grow. Based on these results the reforestation and effective protection of these lands would be the most significant GHG emission reduction program.

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The authors

1. Introduction and Background

Bangladesh Forest Department (BFD) has been progressing with the implementation of REDD+ (Reducing Emissions from Deforestation and forest Degradation) activities with assistance from Food and Agricultural Organization of United Nations(FAO) and United Nations Development Program (UNDP).Some of the first steps have been development "REDD+ Readiness Roadmap" in December 2012 under the UN-REDD framework, and subsequently in December 2013, developed REDD+ Readiness Preparation Proposal (R-PP) which has a mandate to design and establish National Forest Inventory (NFI). Along with United Nations (UN) agencies, United States Agency for International Development (USAID) has come forward to facilitate implementation of components of the R-PP through a number of programs and through USAID's Climate Resilient Ecosystems and Livelihoods (CREL) project. The CREL project envisages strengthening collaborative management of forest Protected Areas (PAs) with active involvement of BFD and local stakeholders as a follow-up of previous USAID finance Nishorgo Support Project (2003-2008) and Integrated Protected Area Co-management project (IPAC, 2008-2013).

The project took an initiative for conducting forest carbon inventories in a number of Protected Areas (PAs) across Bangladesh. It is anticipated that the Standard Operating Procedure (SOP) for PA level (i.e. sub-national) inventory designs could be taken into account while developing the National Forest Inventory (NFI) under Readiness Preparation Proposal (R-PP2013) implementation in Bangladesh. As part of this activity the CREL project will build capacity of local BFD personnel in forest carbon inventory as well as facilitating development of Measurement, Reporting and Verification (MRV) system in Bangladesh.

This document provides the results of Forest Carbon Inventory 2014 in eight PAs (CREL working sites) following the proposed Standard Operating Procedures (SOP) of Forest Carbon Inventory. One of the primary objectives of writing the SOP was in line with the future NFI for Bangladesh under UNREDD framework. While developing the proposed SOP, extensive consultation with concerned experts from FD, FAO, WI and CREL team were done; as well as review of earlier forest inventory designs with BFD including, Overseas Development Agency, Forest Resources Management Project National Forest and Tree Resources Assessment, Protocols for Measuring & Reporting Carbon Stocks in Mangrove Forests by USDA Forest Service (October 2009), Protocol for Forest Carbon Assessment by USAID's IPAC Project (April 2010), and SOP for Terrestrial Carbon Measurement by Winrock International's Ecosystem Service Unit (2012)were conducted. In particular, the proposed SOP was applied primarily in eight CREL project sites: Himchari National Park (HNP), Chunati Wildlife Sanctuary (CWS), Kaptai NP (KNP), Modhupur NP (MNP), Rema-Kalenga WS (RKWS), Satchari NP (SNP), Lawachara NP (LNP) and Khadimnagar NP (KhNP). Field data collection for this inventory was carried out during Mar-May 2014.

2. Carbon pools for measurements:

There are five carbon pools in a forest. These are1) aboveground and belowground biomass of live trees including seedlings and saplings, 2) Standing and lying dead wood, 3) non-tree vegetation, 4) forest floor (litter), and 5) soil.

Aboveground and belowground biomass: This includes seedlings (all live trees less than breast height (1.3 m); saplings (all live trees reaching breast height (1.3 m), but having a diameter at breast height (dbh)<5.0cm; and all live trees (all live woody stems having a dbh≥5.0 cm). DBH is the stem diameter at 1.3 m above the ground level.

Dead woods (standing and lying): Standing dead woods are dead trees but standing and usually measures as live trees (greater than 5.0 cm DBH and taller than 1.3 m) as well as stumps (when a current height is less than 1.3 m). Lying dead woods refer all woody material on the ground with a diameter ≥10 cm. Lying dead wood is measured using the line-intersect method. The smaller diameter pieces of lying dead woods (diameter <10.0 cm) are considered as litter.

Non-tree vegetation: This includes shrubs, palms, canes, bamboos, lianas, herbaceous vegetation and grasses etc. which consists of a large biomass component in the forests.

Litters: All dead organic surface material (including dead leaves, twigs, dead grasses, and small branches) on top of the mineral soil are considered as litter. Dead woods, on forest floor, with a diameter of less than 10 cm are also considered as litter.

Soil Carbon: Soil Carbon pool has three parameters namely i. soil depth, ii. soil bulk density (BD; mass per volume), and iii. organic carbon (%OC).

3. Forest and Forest Carbon Inventories in Bangladesh

3.1 Important Forest Inventories

Bangladesh has a long history of scientific forest management. The first Forest Management Plan for Sundarbans was written by Curtis (1924) with proper data collection and analyses. The first detailed forest inventory of Sundarbans (Forestal 1960) and Chittagong Hill Tracts (Forestal 1964) was carried out during 1959 to 1963. The inventory of the village forests was carried out by Hammermaster (1981) and others. The Forest Inventory of the Sundarbans Reserved Forest (SRF) was carried out during eighties by Chaffy *et al* (1985) and Revilla and his group during1994-1996 (Anon. 1996). A total of 1200 sample plots were laid out during 1994-96 for collection of inventory data. The Global forest resources assessment 2005 (FAO 2006) was carried out in 2005-2007 covering all over the Bangladesh.

3.2 Forest Carbon inventory in the Sundarbans Reserved Forest (SRF) (2009):

The SRF carbon assessment considered 150 out of these 1200 clustered plots composed of five circular subplots of the SRF inventory of 1994-96. BFD and USFS expatriates adopted this sampling design. These 150 plots were subset of 1200 temporary sample plots systematically laid at one minute intervals. The circular subplots in a plot were laid as a center subplot with four more subplots oriented in cardinal directions(east, west, south, and north), 50m from the center. Each subplot had different sized concentric nested circles e.g. 2 m radius for seedlings and saplings, 4m radius for non-tree vegetation, 10m for trees. In addition 30”X30” square plots for litters, 10m transacts from center for woody debris also laid in each plot. For soil samples 0-30cm and 30-100 cm depth were taken from each plot using one meter long open Faced peat auger. Two 5cm-long samples (for bulk density and %OC) were taken from each of the mid-point of 0-30cm and 30-100 cm depths.

3.3 Forest carbon inventory at six protected areas 2010.

Almost similar to SRF inventory (2009) was adopted, by BFD and IPAC team, in six hill forest PAs at south-eastern part of the country; these includes, Teknaf wildlife sanctuary (TWS), Inani Reserved Forests (IRF), Medakachapia National Park (MNP), Fasiakhali Wildlife Sanctuary (FKWS), Dudpukuria-Dhopachari Wildlife Sanctuary (DDWS), and in Sitakunda eco-park. Since these PAs are different in size and fragmented landuses, a varied number of samples designs were laid out with: TWS (area - 11,615 ha, 54 plots at 45 second interval), IRF (7,700 ha, 56 plots at 40'' interval), MKNP (396 ha, 41 plots 12'' interval), FKWS (1302 ha, 72 plots at 15'' interval), DDWS (4717 ha, 62 plots at 30'' interval) and Sitakunda Eco-Park (800 ha, 35 plots at 50'' interval).

3.4 Forest carbon inventory 2014 at eight protected areas.

The forest carbon inventory 2014 under USAID's CREL project was carried out at eight CREL sites/PAs (Figure 1).

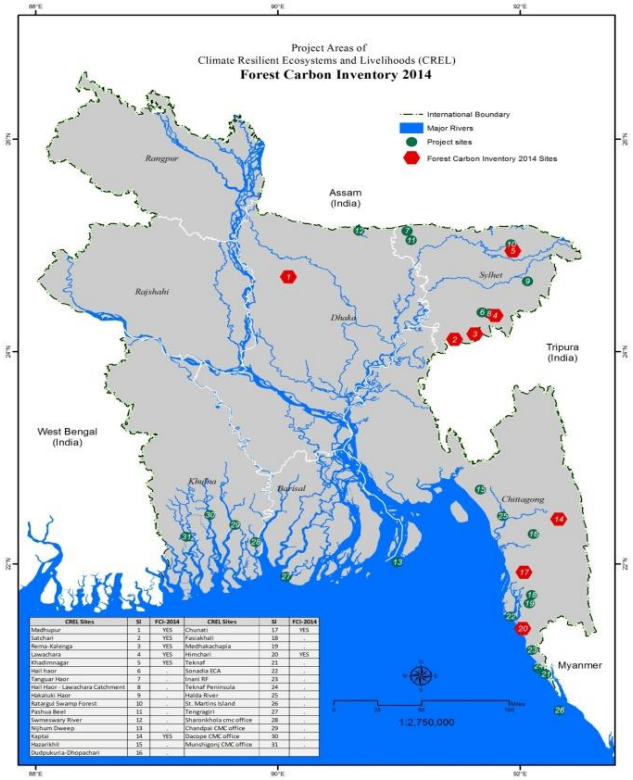

Figure 1. Map showing the CREL sites including Forest Carbon Inventory 2014 PAs.

Brief descriptions of the project sites are given as follows:

3.4.1. Lawachara National Park (LNP):

Lawachara National Park (LNP) is part of the West Bhanugach Reserved Forest and is situated at Kamalgonj Upazila in Moulavibazar District in the North-eastern part of Bangladesh. LNP was first established in 1996 and later expanded to its current area of 1250 hectares. LNP is located about 7 kilometres east of Sreemangal, Moulavibazar in Sylhet Division and is a popular tourist place. LNP is mixed with understory comprising of evergreen and an upper-canopy composed of tall deciduous trees. LNP has approximately 167 plant species, more than 15 species of amphibians, more than 40 species of reptiles, 246 species of birds and 20 species of mammals. The LNP landscape includes about 30 villages comprising 7348 households. Among these, 18 villages are directly adjacent to the park while two villages are located within its boundary.

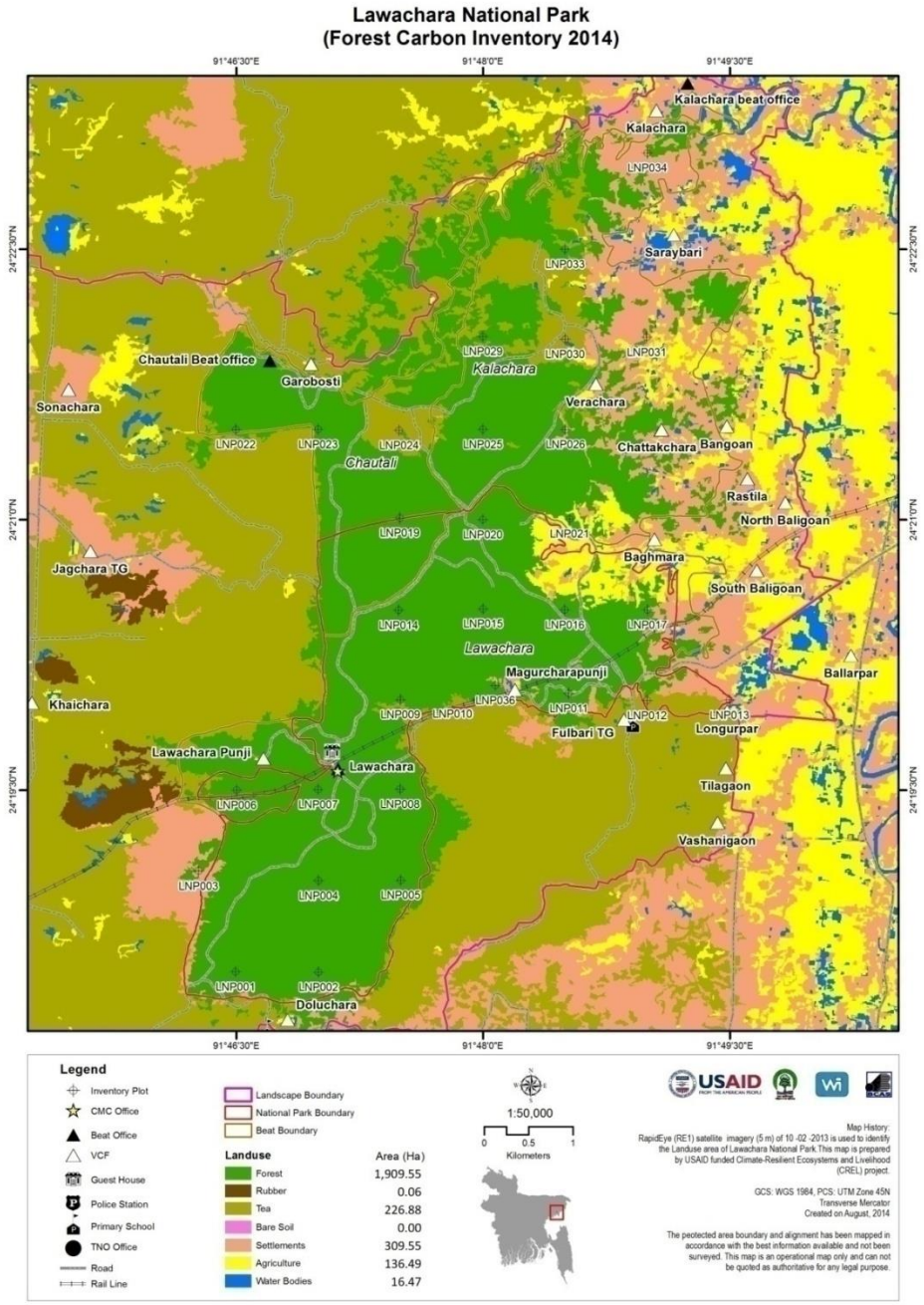

Figure 1. Map of Lawachara National Park

3.4.2. Satchari National Park (SNP)

Satchari National Park (SNP) is situated in the Paikpara Union of Chunarughat Upazila in Habigonj District. SNP stands on the Dhaka-Sylhet old highway and is about 130-140 km northeast of Dhaka, in the SylhetDivision. SNP is governed by the Forest, Act of 1927 as well as the Wildlife Conservation Act of 1974.The tropical evergreen/semi-evergreen vista, established in 2006, comprises an area of 243 hectares as a part of the 6205 ha of the Raghunandhan Hills Reserved Forest. Hillocks, locally called Tillas, are scattered throughout the landscape, ranging from 10-50 meters. A number of small, sandy bedded streams flow throughout the forests, all of which dry out following the end of rainy season in October-November, and are subject to intensive commercial harvesting of sands during the dry season.

SNP originally supported an indigenous vegetation of mixed tropical evergreen forest. However, almost all of the original forest has been removed or substantially altered, turned it into a secondary

forest.About 200 ha of the reserved forest are in natural condition and the remnants were introduced to long and short term social plantations schemes.Bamboo and Cane have been planted in many plantation areas after removing undergrowth vegetation.SNP supports more than 6 species of amphibians, 18 species of reptiles, 149 species of birds and 24 species of mammals.

SNP is surrounded by 10,315 households with a population of about 55,701 (including one Tipra community, an ethnic settlement within the core zone) and 8 tea gardens. The lone Tipra village located within SNP comprises 20 Households. The adjacent areas are covered by tea estates, coffee patches, rubber plantations and rice fields. Other settlements are located approximately 3-8 kms adjacent to the park area. All households inside Tipra settlements are mostly dependent on the forest for their everyday needs of fuel wood, house building materials and vegetables. Many households, mainly the more financially challenged ones, are entirely or partially dependent on the collection on fuel wood, timber and bamboo.

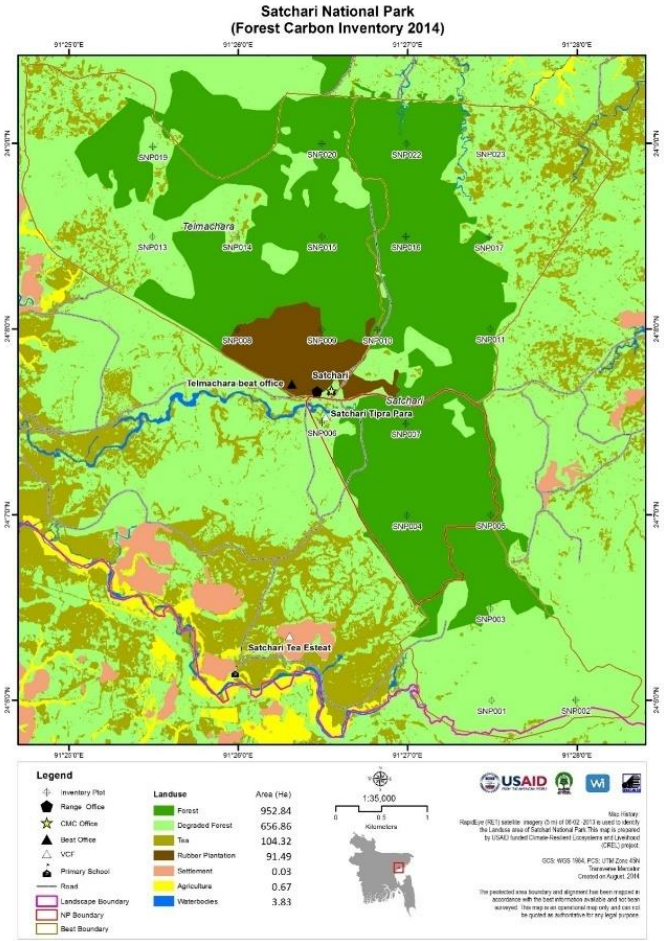

Figure 2. Map of Satchari National Park

3.4.3. Rema-Kalenga Wildlife Sanctuary (RKWS)

Rema-Kalenga Wildlife Sanctuary (RKWS) in Chunarughat and Madhabpur Upazila of Habigonj District is located nearly 130 km northeast of Dhaka. RKWS shares its eastern and southern borders with the Indian state of Tripura. RKWS is governed under the Forest Act of 1927 as well as the Wildlife Conservation Act of 1974.The forest is semi/mixed-evergreen with 1795 ha area, is a part of 6232 ha Tarap Hill Reserve Forest. However, the forest itself has dwindled with paddy cultivated in some areas in between the valleys, particularly in the northern part of the sanctuary. Nearly 400 ha of Tea Estate lands border the Sanctuary on the south-west and approximately 50 ha of Government land (Khans) border the Sanctuary on north-east and are included in the interface landscape zones which complete a 1 km wide buffer strip along the entire Sanctuary boundary.

The forest is semi-evergreen. About 76% of the forest is s till natural condition. Plantations only cover 9% of the forest. It is home to a magnificent assortment of plants, animals and birds and biodiversity of the PA consist of 167 birds, 7 amphibians, 18 reptiles, and 37 species of mammals.

Four different ethnic communities (*Tripura, Shantal, Telegu, and Urang*) live in and around the forest. A village inhabited by the Tipra tribe is located within the Sanctuary. However, there are other villages on the boundary between the reserved forest and the wildlife sanctuary. Around 9,330households have been identified nearby RKWS with an estimated population of 23,000.Adjacent land use includes long-rotational reserved forest, tea estate, converted agricultural lands and Khans land. Human pressure on the sanctuary is in fact buffered by the adjacent reserved part of the forest. However, fuel wood and building materials collected by the adjacent households pose a threat to the biodiversity.

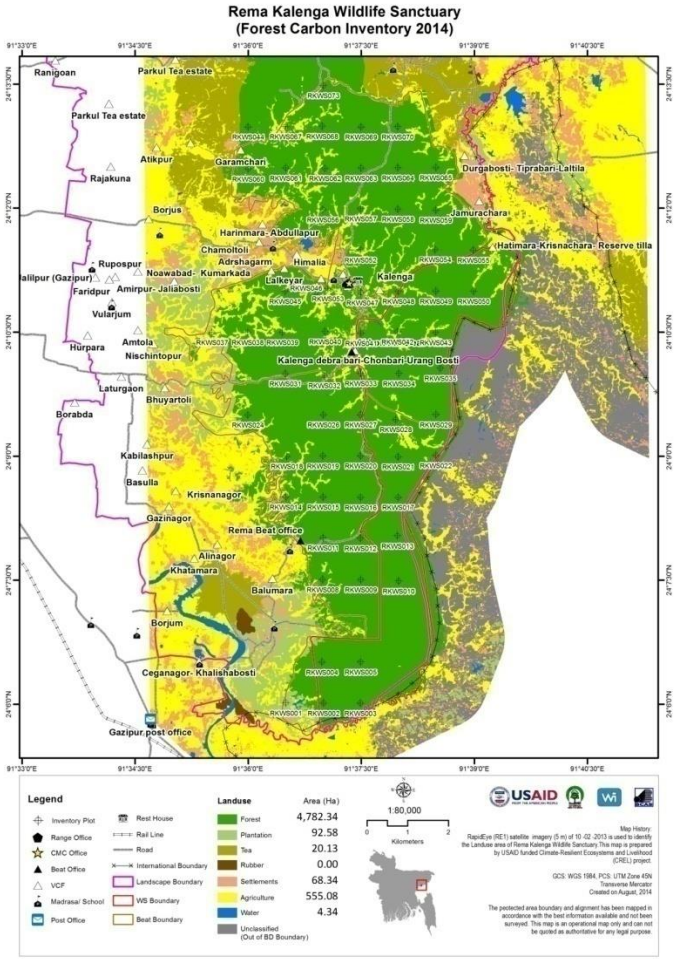

Figure 3.Map of Rema-Kalenga Wildlife Sanctuary National Park

3.4.4. Khadimnagar National Park (KhNP):

The Khadimnagar National Park (KhNP) is situated about 15 km north-east of Sylhet city. The National Park was established in 2006 to preserve the remaining natural hill forests of Khadimnagar under Bangladesh Wildlife Act 1974 with an area of 678.8 ha. Plantations were established in the Khadimnagar Reserved Forest since 1961.The original forests were of local forest bamboo species and subsequently converted into tree plantations with different indigenous tree species. The area is composed of undulating hillocks locally called tilla. The area has also small sandy-bedded streams which generally dry up during dry seasons. The forest has a total of 217 plant species, 20

amphibians, 9 reptiles, 26 animals & 28 species of birds. There is an ethnic Patra community with a population of 12,500 individuals with varying degrees of dependency on forest products.

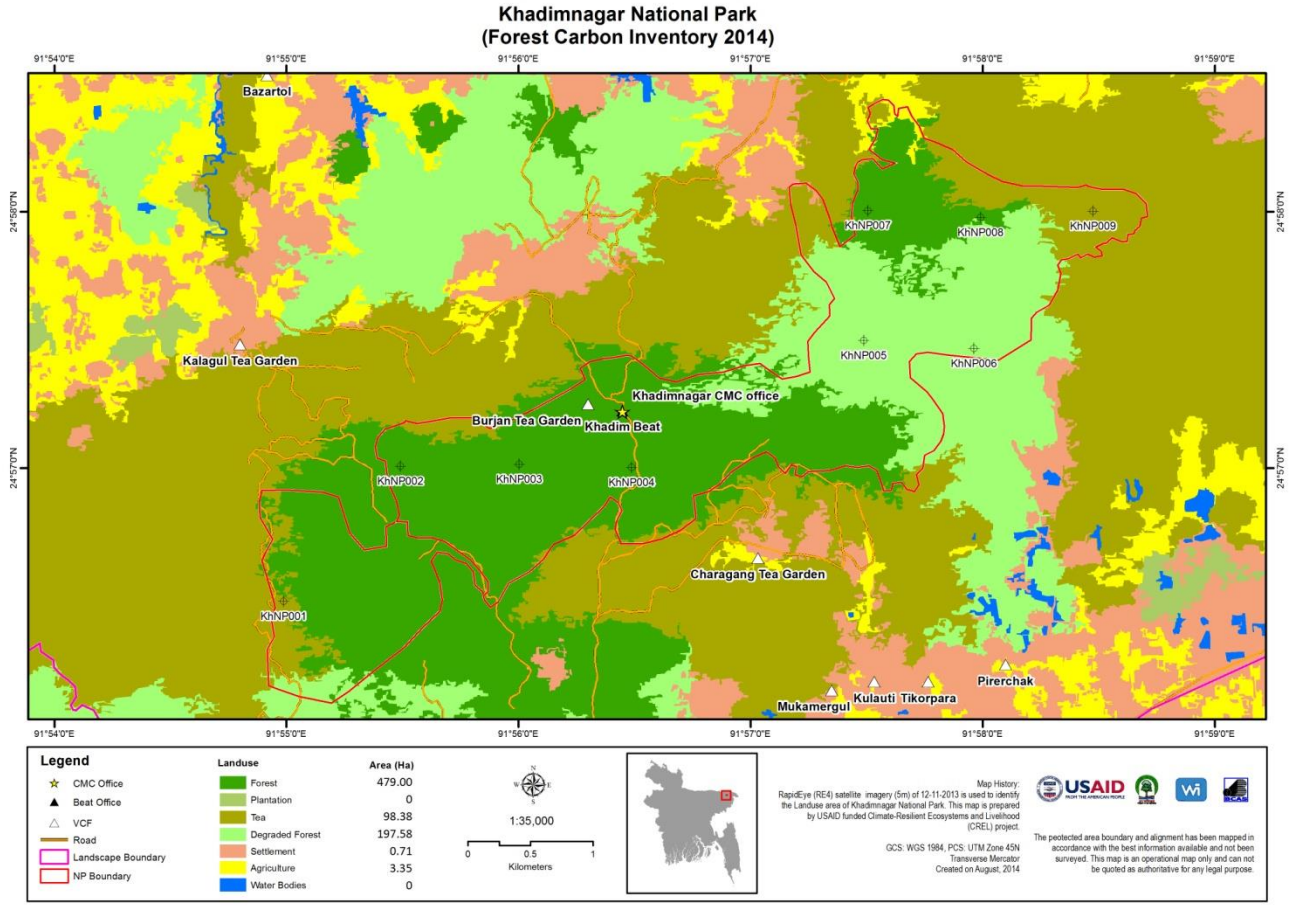

Figure 4.Map of Khadimnagar National Park.

3.4.5 Modhupur National Park (MNP)

Modhupur National Park (MNP) is situated on Dhaka-Mymenshing Road, 125 km Northeast of Dhaka. MNP was established in 1982 following the Wildlife Act of 1974 and was declared a National Park (NP) in 1982.It covers an area of 8436 ha. The Bongshai River that flows through MNP on the southern side of the forest is a part of the old Brahmaputra channel. The area also includes connecting canals, streams, and rivers and is intensively fished with a variety of fishing gear.

The Garo, Koch and Barman communities live in the surrounding area of MNP, comprising a total of 187 villages, with varied degrees of dependency upon the forest. Where communities like the Koch in particular worship nature, the Garo have a deep set belief in the healing powers of local herbs. Fostering this age old tradition of dependency upon the forest has helped these communities develop an inherent understanding of the need for sustainable use of MNP and its resources. Their growing levels of awareness form the backbone of conservation activities.

The Park is deciduous with a slight mixture of evergreen forest, interspersed with hillocks. Topographically the landscape comprises mainly on plain lands and forest patches, which was once a largely dense forest area. Now the land masses surrounding the site and a few patches within the forest are also intensively cropped.4 Rubber plantations also surround the site, collectively containing a total of 7, 314 acres of land with an estimated 1462,800 Rubber trees. The main plant

species of the Park is Sal (*Shorea robusta)*.The number of identified plant species in MNP is 176.Identified fauna species include 4 amphibians, 7 reptiles, 11 mammals and 38 bird species.

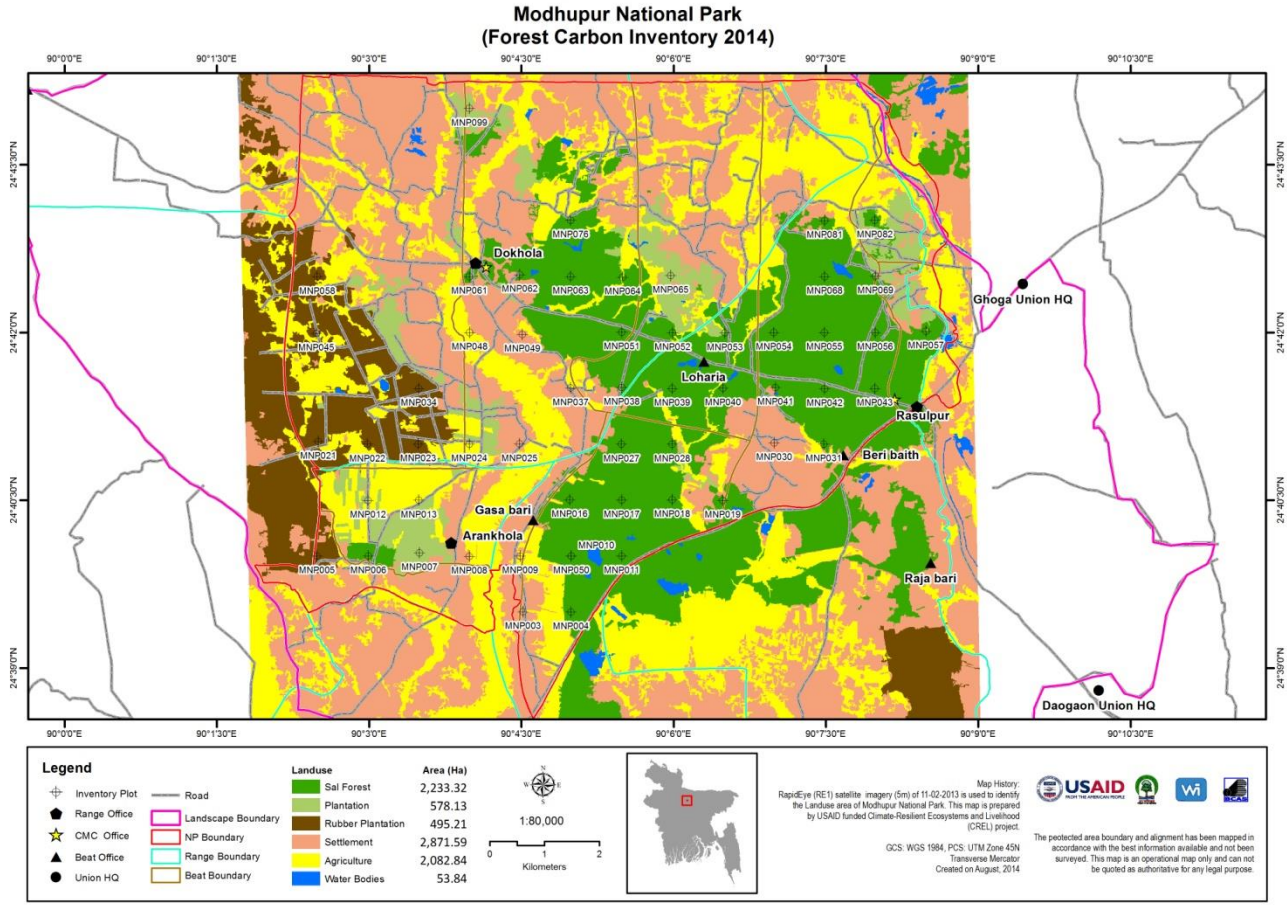

Figure 5.Map of Modhupur National Park

3.4.6 Kaptai National Park (KNP)

Kaptai National Park (KNP), located in the Rangamati Hill District under the Chittagong division, was established in 1999 under the Bangladesh Wildlife Act 1974.The Park comprises an area of 5464 ha. KNP is unique for having the oldest social plantation project in the Indian Sub-continent and was famous for its Burma Teak trees. The area now comprises mainly of hills, valleys and forest, and is still one of the most popular tourism destinations of Bangladesh. The Kaptai Lake is the largest man-made fresh water body in Bangladesh, and other touristic attractions include the Kaptai Hydroelectric project and Karnafully paper Mill Project, both huge contributors to the overall economy of the country.

The surrounding 39 villages comprise of about 1885 households. These communities were most displaced during the building of the Kaptai Dam and Hydroelectric Power Plant in the 1960s, settling on the outskirts or moving to the inner parts of the KNP. They are engaged in a multitude of activities such as agriculture, pond and lake fish culture, vegetable cultivation, and bamboo and handloom products. jhum cultivation (Slash and Burn cultivation) by the ethnic communities like the Marma, and trading vegetable are also popular income options.

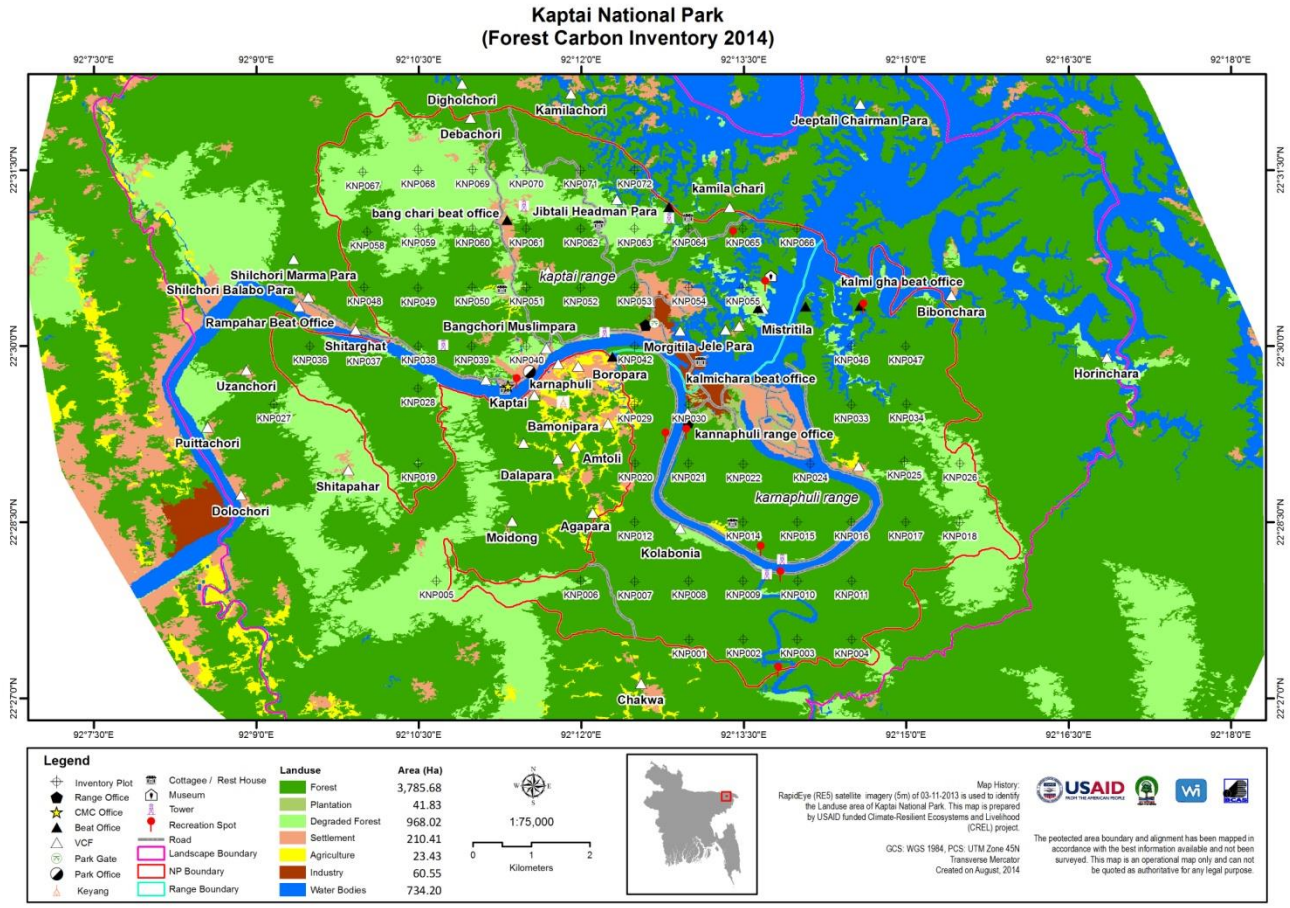

Figure 6.Map of Kaptai National Park

3.4.7 Chunati Wildlife Sanctuary (CWS)

Chunati Wildlife Sanctuary (CWS) was established in 1986, 70 km south of Chittagong City and is managed under the Wildlife and Nature Conservation Division. The total area of CWS is 7764 ha. CWS comprises mainly of secondary growth scrub, and extensive areas of sun grass, including some areas where plantations of exotic trees were initiated.

Around 9400 household with a population of approximately 48,913 people depend on resources (e.g. fuel wood, medicinal plants) from the area. Around 15 villages are very close proximity of CWS with around 70 settlements (paras).Within these settlements nearly one-third of the population is unemployed. Encroachers who settle on -forestlands are mostly people who have affected by riverbank erosion or have become landless due to various reasons. The local agricultural laborers typically find work for only six months a year and even during this time works is not available in a regular basis. Hence steady work is often not a viable option for many locals who otherwise engage in cutting firewood, trees and bamboo and other forest resources for commercial and household gain.

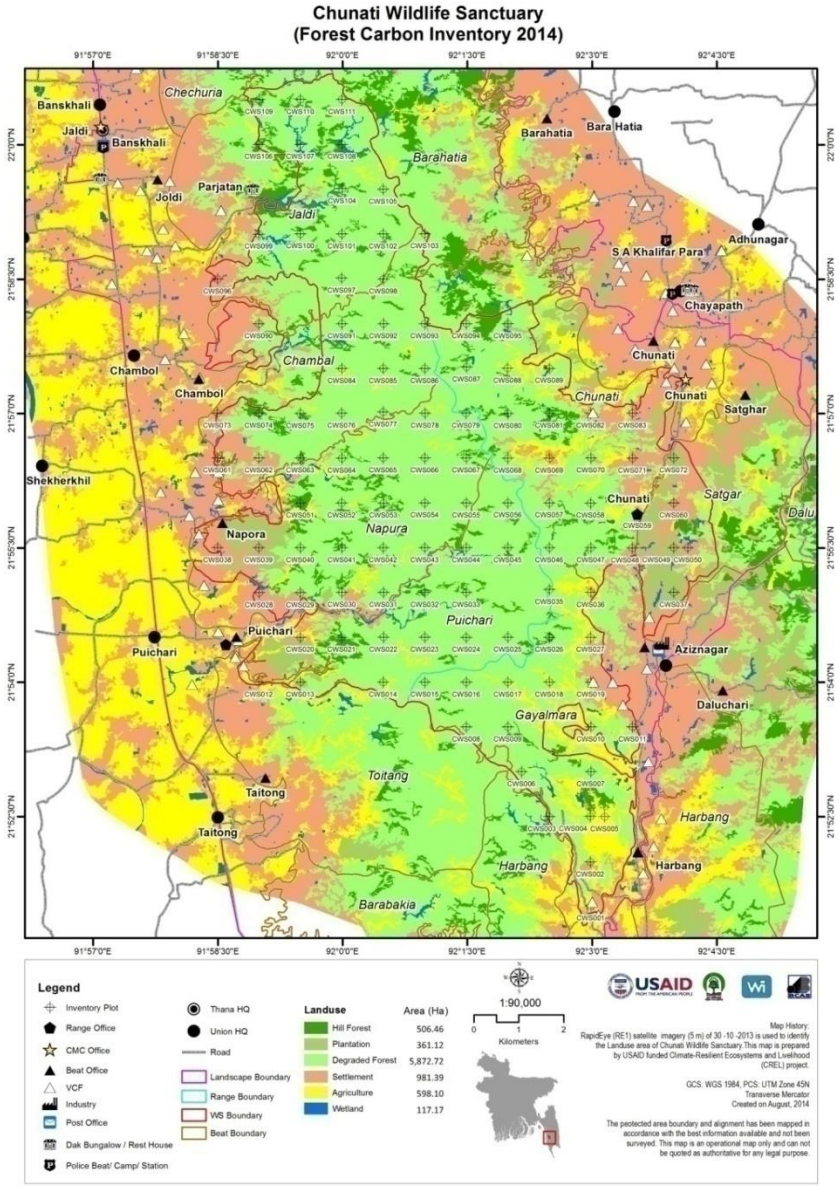

Figure 7.Map of Chunati Wildlife Sanctuary National Park

3.4.8 Himchari National Park (HNP):

Himchari National Park (HNP) is located by the side of the World's longest sea beach of Cox' Bazar. It was declared as National Park in 1980 under the Bangladesh Wildlife Act 1974.The Park comprises an area of 1729 ha with a buffer zone of 130 ha and Landescape area of about 700 ha. It is unique that the sea beach of Cox's Bazar is just along the western site and proposed Inani National Park is in the southern side. The area has got about 130 plant species, 12 species amphibians, 19 species reptiles, 389 species of birds, 35 mammals species.

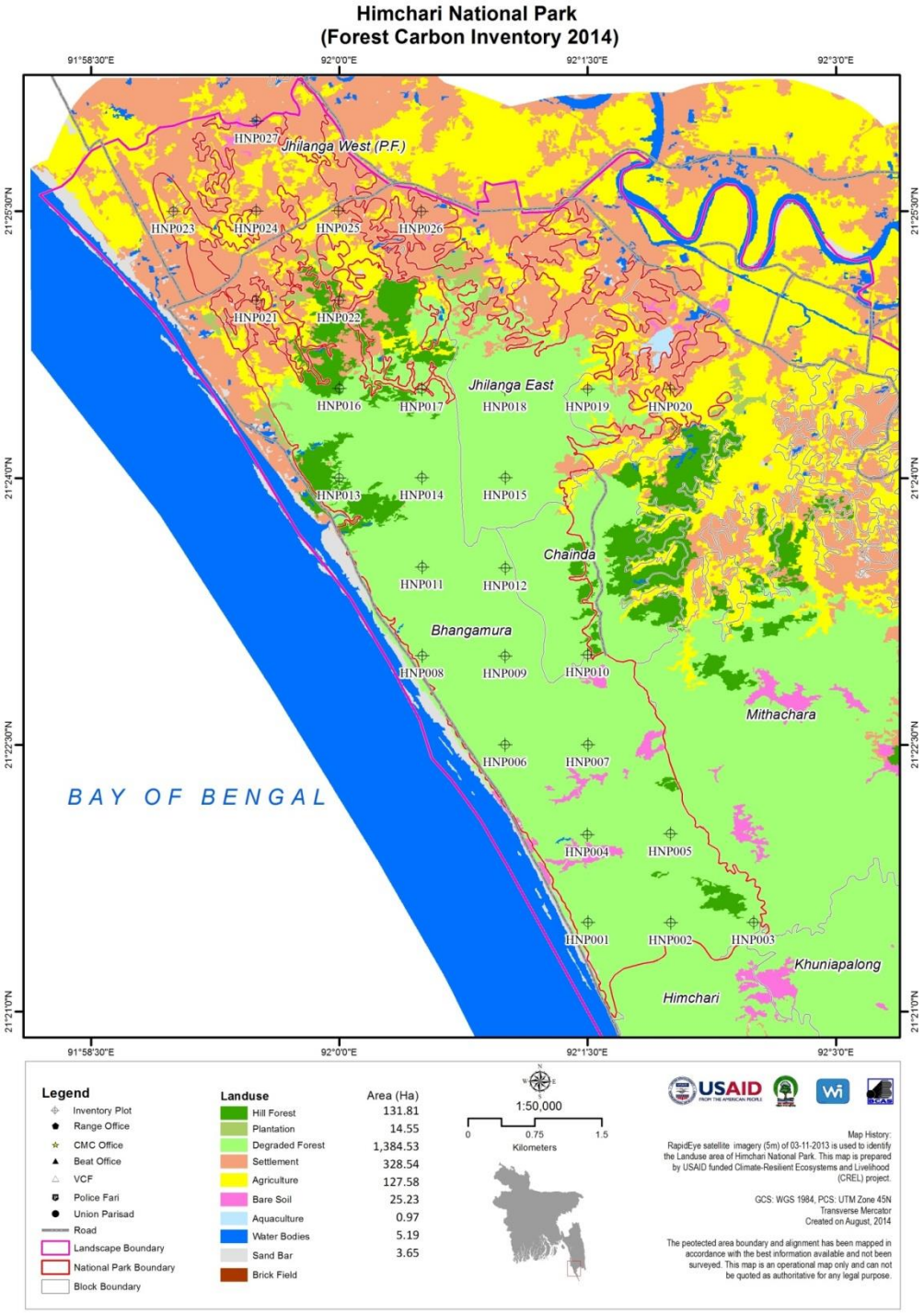

Figure 8.Map of Himchari National Park

4. Objectives of the Forest Carbon Inventory

The objectives of the 2014 forest carbon inventory at eight Pas were to:

1. Develop a Standard Operating Procedures (SOP) for forest carbon inventory,
2. Inventory of forest carbon stocks in different pools of eight PAs that can be used under a REDD+ framework and
3. Develop a biophysical baseline of selected PAs under the CREL project.

5. Definitions and Sampling Design

5.1 Definitions

Forest: Land spanning over more than 0.5 hectares with trees higher than 5 meters 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.

Degraded Forests: Any area of "forest" (see above definition) that has been impacted by human extraction of wood or other vegetation with canopy cover ≤30%

Forest plantations: Forests of introduced species and in some cases of native species established through planting or seeding for production of goods and services, characterized by few species, straight tree lines and even-aged stands

Village forests: The village forests which build up homestead areas contain the houses, ponds, some cultivation fields and forest. The village forest are normally planted though some natural regeneration occurs and which contribute towards the everyday use of villager by supplying food, construction material, fodder and many other ancillary produce.

Settlements/developments: An area of developed land with little to no vegetation, such as a road or village.

Other wooded land: Land not classified as "forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these threshold *in situ*; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.

Permanent agricultures – An area of agricultural land that is not allowed to natural re-growth. This could be an area deemed under continuous agriculture at least once every two years.

Wooded land with shifting cultivation (Fallow): It refers to woody vegetation deriving from the clearing of natural forest for shifting agriculture. The area is generally allowed to naturally re-grow (3-10 years fallow) before being cleared again.

Shrubs: Refers to vegetation types where the dominant woody elements are shrubs i.e. woody perennial plants, generally of more than 0.5 ha area and less than 5 m in height on maturity and without a definite crown. A *shrub* is distinguished from a tree by its multiple stems and shorter height, usually less than 6 m (20 ft) tall.

Herbaceous plants: An herbaceous plant is a plant that has leaves and stems that die down at the end of the growing season. A herbaceous border is a collection of perennial herbaceous plants (plants that live for more than two years and are soft-stemmed and non-woody).

Tea garden: An area identified as a tea garden.

Water bodies: An area of land that is inundated for the whole year or deemed inundated for a period during the year and agriculture may be practiced during dry seasons.

Seedlings: Seedlings includes all live trees less than breast height (1.3 m)

Saplings: Saplings includes all live trees reaching breast height (1.3 m), but having a Diameter at breast height (DBH or D or dbh) <5.0cm.

Trees: Trees includes all live woody stems reaching breast height (1.3 m), having a diameter at breast height of 5.0 cm or greater.

Standing Dead woods: Standing dead woods are dead trees but standing and usually measures as live trees (greater than 5.0 cm DBH and taller than 1.3 m) as well as stumps (when a current height of less than 1.3 m).

Lying dead woods: It refers all woody material on the ground with a diameter ≥10 cm. Lying dead woods is measured using the line-intersect method. However, smaller diameter pieces of lying dead woods are considered as litter.

Stumps: After a tree has been cut and felled, the stump or tree stump is usually a small remaining portion of the trunk with the roots still in the ground.

Litters: All dead organic surface material (including dead leaves, twigs, dead grasses, and small branches) on top of the mineral soil. Dead woods, on forest floor, with a diameter of less than 10 cm are considered as litter.

Soil Carbon: Soil C pool has three parameters namely i. soil depth, ii. Soil bulk density (BD, mass per volume), and iii. Organic carbon concentration (%OC)

Canopy Cover: Canopy Cover is a measure of presence or absence of forest canopy within a plot. It is estimated using densiometer readings at fixed distances from the plot center. This is measured as an average of 4 cardinal (North, South, East & West) readings of imaginary dots of the densiometer.

5.2 Sampling design and sample size

Remaining consistent with previous inventories, it was proposed to follow systematic sampling design at a spacing of 30'' X 30'' within the proposed PAs and their landscape forest reserves. Plots were stratified into major land cover classes prior to the inventory using high resolution satellite imagery. The plots falling in the water bodies were not measured. As best as can be estimated from the high resolution imagery the plots were stratified. The plots centers were plotted at 30'' X 30'' spacing in systematic way in Field Maps on Google Earth as background with 1:15000 scales onto A0 paper size.

To estimate the number of plots needed to achieve the desired statistical precision for forest carbon (i.e. ±6% of the mean at 94% Confidence intervals) four Pas that were sampled in 2010 under the IPAC project were assessed. Based on these inventory results and parameters, sample size (n) is estimated in Table 1.

To estimate the number of plots needed to achieve the desired statistical precision for forest carbon (i.e. ±6% of the mean at 94% Confidence intervals)four PAs that were sampled in 2010 under the IPAC project. These PAs are Dudpukuria-Dhopachari WS, Fasiakhali WS, Medakachapia NP and Teknaf WS. Data of 2010 IPAC inventory were used to estimate the required number of plots with 12% allowable error. The statistical parameters and calculations are given in Table 1.

Table 1: Parameters of sample size (n) estimation for carbon inventory at proposed eight PAs

Statistics	Carbon, Ton/Ha (Live Trees)	Carbon, Ton/Ha (Dead Trees)	Carbon ton/ha (Saplings)	Carbon/ Ha (Seedlings)	Carbon/ Ha (Bamboo)	Carbon/ Ha (Cane)	Woody debris C ton/ha	Carbon/ Ha (Leaf-Litter)	Plant carbon (ton/ha)
st.dev	85.22	0.80	7.63	0.24	16.45	10.10	533.01	0.58	544.31
Mean	69.06	0.68	5.96	0.13	15.13	5.61	330.23	1.56	384.28
N	169.00	57.00	205.00	206.00	73.00	41.00	214.00	222.00	222.00
T	2	2	2	2	2	2	2	2	2
%E	13.11	0.21	1.07	0.03	3.85	3.15	72.87	0.08	73.06
n-estimated	**423**	391	455	976	328	902	724	38	557

The minimum number of sample plots (n) was estimated based on Std. deviation, mean for the live tree carbon (ton/ha) calculated from previous data of Dudpukuria WS, Fasiakhali WS, Medakachapia NP and Teknaf WS using the formula:

n= (t*s/E)^2= (2*85.22/(69.06*0.12))^2=423

Where:
n= the number of sample plots (sample size),
t= the sample statistic from the t-distribution for 94% confidence interval; here t = 2 was used as the sample size for the present sites is not known.
s (std. dev.)= standard deviation estimated from the previous data of four PAs.
E = allowable error, Calculated by multiplying the mean carbon stock by the desired precision, i.e., mean (69.06) * 0.12 (for 12% precision)

It was observed that approximately 423 plots were required to collect data to have an estimate of carbon stock with 12% allowable error. These plots were distributed among the eight PAs in proportion to PA areas. When the plot centres, at 30''X30'' spacing were plotted on maps n=403 plots fallen within the area. All the plots under forest category were taken for data collection. Additional three (3) plots from each of Agriculture and Settlements, Tea and Rubber if available were considered also for data collection. No plots were taken from 'water'. Hence in total 468 plots were initially considered for data collection and finally data were collected from 377 sample plots (Table 3).

Table 2: Number of sample plots for data collection in different land uses at eight Pas

Sl	Protected Area/ Co-management Sites	Inventoried area (ha)	Plots within proposed area (n)	Estimated sample plots (n)
1	Lawachara NP	2,600	42	34
2	Khadimnagar NP	679	9	10
3	Satchari NP	1,810	34	27
4	Rema-Kalenga WS	5,550	72	82
5	Modhupur NP	8,436	54	107
6	Kaptai NP	5,464	68	72
7	Chunati WS	7,764	92	112
8	Himchari NP	2,000	23	24
	Total	34,303	403	468

6. Field Inventory

The training program was organized at Lawachara in between March 18-20, 2014 to carry out the Forest Carbon Inventory. The field inventory team members were trained on the use of field equipment and methods. The trainees learned the Standard Operating Procedures (SOP) of measurements, practiced the use of instruments, and discussed probable questions regarding the inventory process. CREL provided all the logistics required to organize the training program. The experts from CREL, FD & BFRI put their full hearted efforts to make the training towards a successful Forest Carbon Inventory 2014 in the eight Protected Areas (PAs) required for establishing the carbon baseline.

The team leaders, NRM personnel and some of the students had participated in the training. The team leaders worked mostly as recorders and reviewers of data. The foresters and students worked as enumerators. Before starting field work each day, the groups sat together with detailed maps and GPS units to plan for the next plots. Local knowledge of laborers, guards, and FD staff aided the crews' efforts to find suitable routes to plots and minimize hiking time. Generally each group completed 2-3 plots per day, but often this pre-planning activity helped the groups to complete more than 3 plots a day. The field data collection started from March 24, 2014 and continued up to 2nd week of May, 2014.

6.1 Data and Sample Management

Field data were entered into ODK and later computerized spread sheets and backed up electronically in multiple physical locations. Strict precautionary measures were taken in the process of data collection and data entry to minimize error. Completed data forms were checked and reviewed in the field. The data entry was reviewed by BCAS officers. At the end of the inventory, completed data forms were stored in physically secure locations at CREL office. The final electronic data files, including one version with only field-collected numbers and one version with computations have been stored with CREL office and drop box. Soil, litter and herbaceous samples were sent to BFRI, Chittagong for analyses.

6.2 Personnel and Training

The Forest Carbon Inventory field data collection was carried out by five inventory teams. Each team was headed by the concerned Assistant Conservator of Forest (ACF) from the local Forest Division. The other members of the field data collection team were as given below:

CREL NRM Officer/Monitoring Officer/NRM Facilitator -as Deputy Crew/Team Leader-1
Local Forester/Beat Officer– 1
Forestry graduate student- 1
Local Forest Guard -1
Local CMO representative -1
Local labour-1

6.3 Establishment of the sample plots

The plot locations were superimposed on Google maps and classified recent imageries for land uses (e.g. Forests, Degraded Forests, Agriculture, Settlements/developments and Water bodies). The plot locations (latitude &longitude) of the plots for each PA were uploaded to each team's GPS. The team members of the teams approached to the plots with the help of the map and GPS. A set of field data collection forms were designed for data collection and are presented in Appendix-I

The starting points for access to the plots were marked as way points by signs on trees or by recording the GPS co-ordinates. After reaching to the plot center, the plot center was marked with auPVC pipe or a stake driven into the soil. Then, marked three trees that generally surround the plot center and that are as close as possible to plot center with a small dot at DHB height facing plot center, so that they can be used to triangulate plot center in the future if the stake cannot be found.

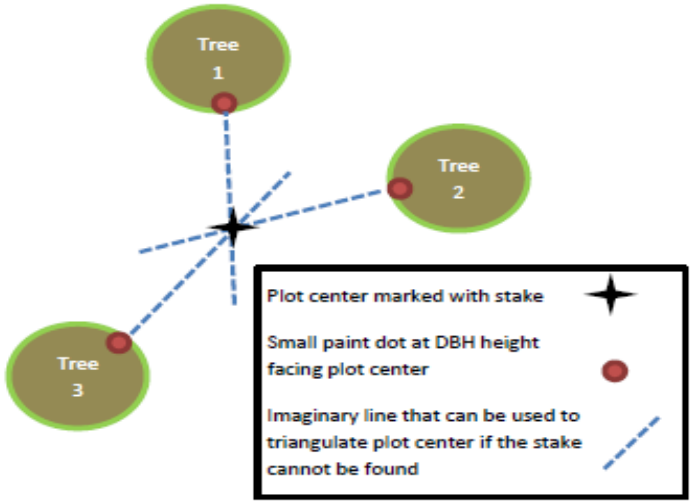

Figure 9.Example of how to mark the 3 trees around plot center so that they can be used to triangulate plot center in the future if the stake cannot be found.

It was decided to take concentric circular plots of radii 2m, 4m, 10m and 17.84m. The plot layout is given in Figure 3.

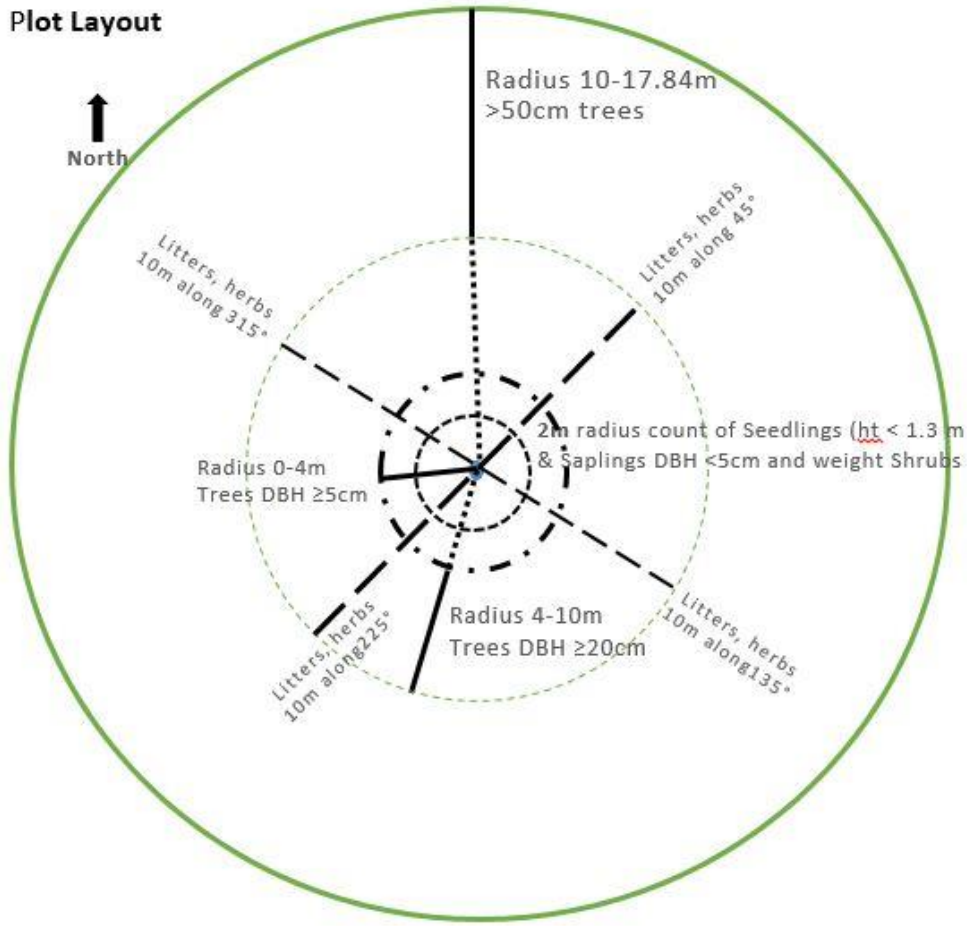

Figure 10.Plot layout for Carbon Inventory 2014 at 8 PAs in Bangladesh

6.4 Parameters recorded/ measured:

The parameters were recorded/ measured from different sample plots are given in Table 4.

Table 3: Forest carbon plot dimensions for data collection from different pools

Parameters	Activities	Plot radius (m)
Seedlings count	Counted the number of live seedlings ≤1.3 m tall for all species.	2
Saplings count	Counted the number of live saplings with DBH≤ 5.0 cm & Height> 1.3 m for all species & recorded the name of the dominant species.	2
Trees DBH	Measured DBH of all trees (including standing dead trees) with DBH > 5.0cm with species name Measured stumps (≥10 cm base diameter) diameter	0– 4
Trees DBH	Measured DBH of all trees (including standing dead trees) with DBH >20.0cm with species name Measured stumps (≥10 cm base diameter) diameter	4 – 10
Trees DBH	Measured DBH of all trees ≥50 cm (including standing dead trees), with species name; Measured Stumps (≥10 cm base diameter)diameter	10 - 17.84
DBH, heights	Recorded data for non-tree woody (Bamboos and canes). Plot radius	2, 4, 10 or

Parameters	Activities	Plot radius (m)
&counts	was variable with intensity of occurrences.	17.84
Palm DBH & height	Measured the height of all palm species, and if available DBH	0 – 10
Trees height	Measured heights of three co-dominant trees	17.84
Lying deadwood	Measured all lying dead wood≥10cm diameter, if it is ≥50% above the ground. Measured along transect line from plot center to 25m at each cardinal direction (45, 135, 225 & 315 degrees)	25m long, 4 transects
Litter	Measured Litter layer from clip plots of 50cmX 50cm square plot; laid out at 10 meters from the center of the plot at four transects at 45, 135, 225 and 315 degrees. Mixed the four samples thoroughly and took a sub-sample (200-300g) for oven-dry weight estimation.	Square clip plot 50cmX 50cm
Grass and herbs	Cut and measured grass and herbaceous vegetation from the square clip plots described above (litter). Mixed the four samples thoroughly and took a sub-sample (200-300g) for oven-dry weight estimation.	Square clip plot50cmX 50cm
Weight of shrubs	In case of plots with shrubs only: Cut all shrubs, took weight of all shrubs and took one sub-sample (200-500g) of the shrubs for oven-dry weight estimation.	2
Soil Organic Carbon	Soil Samples for estimation of organic carbon were taken using soil sampler/pit method at 4 locations (covering valley, slope and flat) to 0-30cm depth. All 4 samples were mixed thoroughly and then took a sub sample (200-300g) for laboratory analyses.	Sample depth 0-30cm
Soil Bulk Density	Soil samples for estimation of bulk density (BD) were taken from two depths (0-15 cm and 15-30 cm). Each bulk density sample was placed in an individual air-tied sample bag for lab analyses.	Sample depths:0-15 cm & 15-30 cm
Canopy cover	Took canopy cover with Densiometer at the end of 10 meters from the plot center at four cardinal directions at due north, east, south & west.	At the end of 10m

Described land and vegetation conditions of plot (Form-1) and if there is anything unique or unusual in the plot or directly surrounding the plot. This could include things such as small streams, trails, large boulder or termite nest, and proximity to a paved road. Took four photos of the plot and recorded the photo numbers on the plot sheet.Each photo was taken facing each of the cardinal direction (N, E, S, W).

6.5 Measurements of Seedlings, Saplings, Trees and Palms.

The number of seedlings was counted and recorded on data Form 2. Similarly, counted the number of saplings (sapling trees with DBH<5 cm and >1.3 m tall) and recorded. The name of the most dominant species was also recorded. Then, measured the trees at different concentric radii plots of different DBH classes. To avoid either miss trees or double recording, measurement began from the North and the first tree was flagged. After a tree is measured, a chalk mark facing the center of the plot was marked to allow the person recording the data to track measured and unmeasured trees.

The DBH was measured on the *upslope* side of the tree. Leaning tree were always measured the height of a measurement (1.3 m) parallel with the tree, *not* perpendicular to the ground. Multi-stem tree were recorded it as if each stem were a different tree on the data sheet with a note that the stems make up one tree. For buttressed tree, if the buttress is shorter than 1.3 m, measured the DBH at the standard (1.3 m) height and if the buttress is taller than 1.3 m, measured the diameter at 30 cm above top of buttress. Marked the height of the measurement with a spot of paint. Tree DBH was measured to the nearest 0.1 cm. The height of trees, palms, and other plants were usually

measured by creating two right triangles. The distance from the object and the person measuring was measured and two angles were measured. The actual height was then calculated using trigonometry during data analysis.

The height has a better relationship with biomass than DBH for palm. Heights of palms were measured and recorded on the data sheet Form 2 for all palms in the 10m plot with bole height ≥1.3m. All smaller palms were ignored.

6.6 Measurements of Stumps from Human Degradation

To estimate the carbon loss due to human interference, measured the base diameter in cm of all stumps with a base diameter ≥10cm within the 17.84m plot & recorded Form 3A.Recorded yes or no if the stump results in a canopy gap in the forest. A canopy gap is a clear opening (no branches or leaf cover) in the forest canopy that would not otherwise be there if the tree had not been cut. If yes, recorded whether the canopy gap is small, medium or large.

1. Small: the gap seems to be no less than 5m across on average. Sunlight would probably not reach the forest floor or only for about an hour per day.
2. Medium: the gap seems to be less than 15m across on average. Sunlight would likely reach the forest floor for more than a few hours.
3. Large: the gap seems to be greater than 15m across on average. Sunlight would likely reach the forest floor for more than a few hours.

6.7 Measurement of Dead Wood

6.7.1Measurement of Standing Dead Wood (not cut by humans)

Standing dead wood refers to trees that have died but are still upright. Measurements of standing dead wood took concurrently with live tree measurements (following the same plot dimensions as live trees) and record in Form-4A. Each standing dead tree was marked as dead on the plot sheet and classified into two classes (see Figure below):

Class 1: Dead tree with branches and twigs and resembles a live tree except for absence of leaves (make sure tree is dead and not deciduous)

Class 2: Trees ranging from those containing small and large branches to those with bole only

By classifying trees into these two simplified classes, a conservative estimate of biomass was taken.

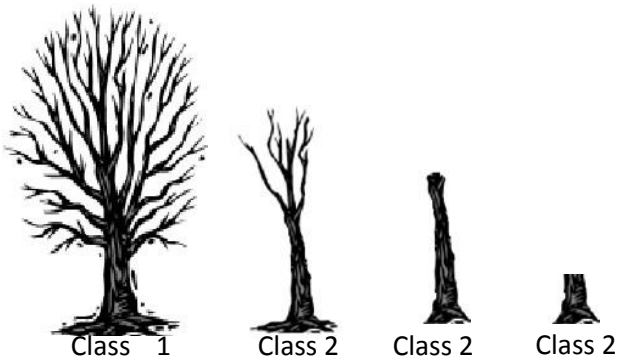

Figure 11.Example of trees in Class 1 and Class 2

Class 1 tree: Followed the same measurement procedures as for the measurement of live trees; including the measurement of tree variables. Marked tree as 'Dead' on datasheet.

Class 2 trees: The biomass of these trees was based on estimating the volume of the remaining tree and multiplying the volume by the wood density. The DBH was measured using methods for live trees. The diameter at the base of the tree (D_{base}) was also measured following height of stem (H). The diameter at top of stump ($D_{top,}$) if possible was also measured.

6.7.2 Measurement of Lying Dead Wood:

Lying dead wood is defined as all woody material on the ground with a diameter ≥10 cm. Smaller diameter pieces of wood were sampled as part of the litter pool.

It is common to locate lying dead wood transects in association with tree plots. Along the four transects. Four 25 m lines at right angles within the land use type along the four cardinal directions were laid out. Along the length of the line, measured the diameter of each intersecting piece of coarse dead wood (≥ 10 cm diameter.

A piece of dead wood was measured if: (a) more than 50% of the log is aboveground, and (b) the sampling line crosses through at least 50% of the diameter of the piece.

If the log is hollow at the intersection point, measured the diameter of the hollow; the hollow portion in the volume estimates was excluded. Each piece was recorded into three density states: sound, intermediate, or rotten. To determine what density class a piece of dead wood fits into, each piece was struck with a machete. If the machete did not sink into the piece (bounces off), classified it as sound. If the machete sinks partly into the piece, and there had some wood loss, classified it as intermediate. If the machete slicked into the piece, if there were more extensive wood loss, and the piece was crumbly, classified as rotten. The volume of lying dead wood and then carbon stocks were estimated using the diameters of each piece of wood and the length of the line transect.

6.8 Measurement of non-tree vegetation

6.8.1 Measurement of bamboos and canes

Non-tree vegetation pool of carbon includes herbs, shrubs, bamboo, cane, lianas etc. The size classes of bamboos were divided into small, medium, and large. Small was based on an average stem size >4cm, medium was based on average stem sized ≤4cm and <8cm, and large ≥8cm.Depending on the intensity of occurrence, measured the DBH and Height of average bamboo culm for each class from 2m or 4 m or 10 m or 17.84m radius were recorded in Form-5.If the bamboos formed a clump the number of stems was estimated to the best of the ability of the field team. The canes were measured similarly.

Figure 12. CCF visits to Forest Carbon Inventory

6.8.2 Measurement of other non-tree vegetation:

The small areas where litter and herbaceous (non-woody) were measured are here referred to as 'clip plots'. A square clip plot frame made of PVC pipe 50 cm x 50 cm were made for sampling. It remained in pieces so that it could construct around existing vegetation. The 'elbows' used to connect two pieces of piping together were glued to one piece of piping.

The weight of an empty polyethylene bag was taken and recorded. Then placed the clip plot at one of the desired four locations, removed all herbaceous plants, put in the polyethylene bag, then took the weight and recoded the weight. This weight was the weight of empty polyethylene bag + the weight of the herbaceous plants. Similarly, weights of the herbaceous plants were taken from remaining three locations and weights were recorded. Then all the four herbaceous plant samples were placed in the bag, thoroughly mixed and a subsample of about 100-150 g was taken. The samples were then labelled with plot ID#, herbaceous plants, date of collection and latter send for estimating oven dried weight.

6.9 Measurement of Litter:

The litter was defined as all dead organic surface material on top of the mineral soil. Some of this material was still be recognizable (dead leaves, twigs, dead grasses, and small branches) and some was unidentifiable decomposed fragments of organic material. Note that dead wood with a diameter of less than 10 cm was included in the litter layer.

Clip plots were used to sample litter and the same clip plots were also used for herbaceous vegetation measurements. The weight of an empty polyethylene bag was taken and recorded. Then placed the clip plot at one of the desired four locations, removed all litters, put the litters in the polyethylene bag, then took the weight and recoded the weight. This weight was the weight of empty polyethylene bag + the weight of the litters. Similarly, weights of the litters were taken from remaining three locations and weights were recorded. Then all the four litter samples were placed in the bag, thoroughly mixed and a subsample of about 100-150 g was taken. The sample was then labelled with plot ID#, litter, date of collection and latter send for estimating oven dried weight.

6.10. Destructive Samples of Seedlings, Saplings, Palms, Bamboos, Shrubs and others

We have volume table and densities of all important tree species in Bangladesh (Appendix II). We used these for estimation of biomasses of trees. But, we do not have equations/models to estimate the biomasses of seedlings, saplings, bamboos, canes& shrubs. We collected destructive samples for estimation of biomasses for these.

6.10.1 Measuring the Weight of an Average Sapling & Seedling

The weight of an empty polyethylene bag was taken and recorded. Then selected one/two representative saplings covering the full range of sizes (from small to large samples) were cut and put in the polyethylene bag (cutting into small pieces if required), then took the weight and recoded the weight. This weight was the weight of empty polyethylene bag + the weight of the saplings. Then a subsample of about 100-150 g was taken. The sample was then labeled with plot ID#, sapling, and date of collection and latter send for estimating oven dried weight.

Similarly, seedlings were cut, weight and properly labelled and latter send for estimating oven dried weight.

6.10.2 Destructive Sampling of non-tree vegetation

The weight of an empty polyethylene bag was taken and recorded. Then, one representative vegetation covering the full range of sizes (from small to large samples) were cut and put in the polyethylene bag (cutting into small pieces if required), then took the weight and recoded the total weight. This weight was the weight of empty polyethylene bag + the weight of the vegetation. Then a subsample of about 100-150 g was taken. The sample was then labeled with plot ID#, vegetation, and date of collection and latter send for estimating oven dried weights.

6.11 Canopy cover

Canopy Cover is a measure of presence or absence of forest canopy within a plot. It is estimated using densiometer readings at fixed distances from the plot center. This is measured as an average of 4 cardinal (North, South, East & West) readings of imaginary dots of the densiometer.

A spherical densiometer was used to estimate canopy cover. The densiometer was hold about 30-40 cm in front of body of the observer and at elbow height, so that head is not visible in the mirror and level the instrument using the level bubble.

In each square of the grid, there are four dots, representing the centre of quarter-square subdivisions of each of the squares (Figure 12). Systematically counted the number of dots NOT occupied by canopy sky at that dot).Recorded this number on the datasheet. Four readings per plot at 10m from plot center in each of the 4 cardinal directions (north, south, east, and west).

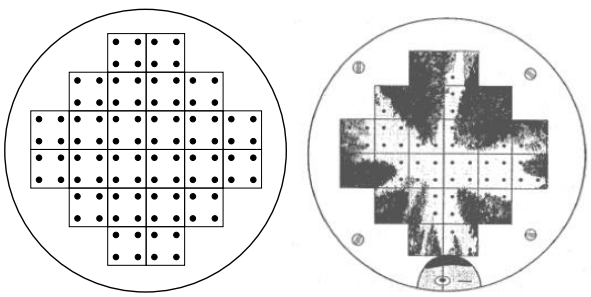

Figure 13. Schematic of densiometer mirror, with the 4 dots depicted in each square. Count the number of dots NOT occupied by the canopy, in the 4 cardinal directions at each subplot.

6.12 Soil % Organic Carbon and Bulk density

Soil carbon was estimated by collecting soil to a depth of 0-30 cm and then analyzing it at BFRI laboratory for carbon content. This information was then combined with a collected bulk density measurement to estimate the average mass of carbon within the soil to a certain depth.

6.12.1 Soil % Organic Carbon

We collected soil samples following Soil pit method. Pits were dug one at top, one at valley, one at slope and the last one on flat locations(covering all different soil carbon deposits), took a uniform thick slice (0-30 cm) of soil from vertical walls of each of four soil pits. The slice was uniform throughout the 30 cm profile. Then mixed all four samples thoroughly to a uniform color and consistency and placed one thoroughly mixed subsample of about 200 gram soil into a labeled sample bag for laboratory analyses. The bag was labeled as % OC with Plot ID number and date of collection.

6.12.2 Soil Bulk Density

Took one the pit for collection of soil sample for estimation of Bulk density. Two estimates of bulk density were taken using a bulk density ring one at 0-15cm depth and a second at 15-30cm depth. When taking samples of bulk density, care was taken to avoid any loss of soil from the ring and any compaction of soil. The goal of the bulk density sample is to get an accurate quantity and density of soil from each layer. Covered the bulk density ring with a piece of wood and hammered the ring into the side of the soil pit (avoid compacting the soil).

When the ring was flush with the side of the soil pit dug around the ring until the soil ring could be removed along with all the soil inside. If soil falls out of the ring, the process was repeated. Carefully placed the soil contained in the bulk density ring into a sample bag and labelled BD1 and BD2 along with Plot ID number.

Therefore, each sampling plot (e.g. tree plot) had three soil samples: 1 bag for soil carbon estimation and two bags for bulk density estimation. We collected soil samples from three plots for each of the major land uses.

6.13 Laboratory Processing of Soils and plant samples

Soils samples were sent to BFRI laboratory for estimation analyses following the standard procedures. The analyzed data were used for soil carbon estimation. The non-tree vegetation sub-samples were also been sent to determine the oven dry weight. These data have been used to estimate the forest carbon and carbon dioxide reserved in the forest.

7. Data compilation:

During the data collection, the data were entered in ODK. But at the end, it was not possible to down load the data. So, data were entered manually in computer following the data collection Forms. The data forms were handy and easy to computer processing. The data compilations were done as given below:

7.1 Live Trees:

1. Above ground Volume (cm^3) = Estimation of volume by using available volume functions table (Appendix II).
2. Wood densities from wood density table (Appendix II).

3. Adjusted plot area (m^2) = COS(RADIANS(Slope in degrees))*PI()*(Plot radius)^2 (The terrain was hilly. So, slope corrections were necessary to get the proper estimates.
4. Plot area expansion factor to hectare = 10000/Adjusted plot area
5. Above ground biomass (g/cm^3) = Volume (cu cm) * Wood density (g/cm^3)*1.2 (a factor to includes biomasses of branches + leaves (factor)
6. Gram biomass to Kilograms: (Kg = No. 5/1000)
7. Plot area expansion factor *biomass (volume*density)*0.5 (to convert biomass to carbon and then divide by 1000 (to convert kilogram to tone, Mg/ha)
8. Above ground CO2= Above ground C*44/12 is the above ground CO2 adjusted (Mg/ha)
9. Below ground CO2 adjusted (Mg/ha) = Above ground CO2 (Mg/ha)*.24
10. The sum of 8 and 9 above gives the total CO2 Mg/ha.

The detailed procedures and results are given in different worksheets of the spread sheet files.

7.2 The Stumps:

For human degradation and loss

1. Estimate the volume of the stumps in cubic centimeters
2. Consider a stump height (say here it is 20 cm)
3. The plot radius for stump plots was 17.84m.
4. Convert the slope in degrees (as it was taken in %) = Degrees(ATAN(slope %/100)
5. Estimated the adjusted plot area as the field is not flat as=COS(RADIANS(DEGREE))*pi()*plot Radius^2
6. Calculate the plot area expansion factor to hectare=10000/Adjusted plot area
7. Estimate the volume per tree by using available volume function for the species, if not found then use function for misc. species
8. Record the wood density.
9. Estimate biomass in kg=PI()*(base diameter/2)^2*stump height/10000
10. C carbon=Biomass in kg*0.5
11. Estimate below ground C stump Mg)= Above ground biomass*0.24
12. Above ground C adjusted (Mg/ha)=Plot area conversion factor to hectare*C of the stump (Mg)
13. Estimate the below ground C adjusted (Mg/ha)= Above ground AC4*W4
14. Above ground CO2 adjusted (Mg/ha)= C biomass*44/12
15. Below ground CO2 adjusted (Mg/ha)= Above ground CO2 adjusted (Mg/ha)*0.24
16. The sum of above 14 and 15 is the total stump CO2 Adjusted (Mg/ha)
17. Estimate the biomass of the tree prior to cutting (Kg)=Volume*density/1000
18. Estimated above ground CO2 adjusted (Mg/ha)=Estimated above ground C with branches and leaves*44/12
19. Below ground CO2 = Above ground CO2 adjusted *0.24
20. Total CO2 is the sum of 18 and 19 above.

7.3 Standing dead wood:

1. Volume(cu cm)=1/3*pi()*(Base diameter/2)^2*stump height in centimeter
2. Adjusted Plot area= COS(RADIANS(DEGREE))*pi()*plot Radius^2
3. Plot area expansion factor to hectare=10000/ Adjusted Plot area
4. Biomass (Kg) above ground including branches and eaves=Volume*density*1.2/1000
5. Above ground C adjusted (Mg/ha)= Plot area expansion factor to hectare*biomass above ground*0.5/1000
6. Above ground CO2 adjusted (Mg/ha)= Above ground C adjusted (Mg/ha)*44/12

7. Below ground CO2 Adjusted (Mg/ha)= Above ground CO2 adjusted (Mg/ha)*0.24

7.4 Lying dead wood:

Lying dead wood is measured using the line-intersect method outlined in Harmon and Sexton (1996)1. Lying dead wood is defined as all woody material on the ground with a diameter >10 cm. Smaller diameter pieces of wood are sampled as part of the litter pool.

7.5 Non-tree Vegetation:

1. Biomass above ground=Number of clump*number of culm/clump*average weight/ culm*conversion factor to estimate oven dry weight from green weight
2. Above ground C adjusted (Mg/ha) = Plot area expansion factor to hectare*above ground biomass* conversion factor to estimate oven dry weight*0.5/1000
3. Above ground CO2 adjusted (Mg/ha) = Above ground C adjusted (Mg/ha) *44/12
4. Below ground CO2= Above ground CO2 adjusted (Mg/ha) *0 .24
5. 3+4 above gives the total

7.6 Saplings & Seedlings:

1. Adjusted plot area (m^2)=Cos(Radians(slope in degrees)*pi()*Plot rarius^2
2. Plot area expansion factor to hectare=1000/ Adjusted plot area
3. C biomass above ground (Kg)=Number of saplings*weight per seedlings*wood density*0.5/1000
4. C below ground = C biomass above ground (Kg)*0.24
5. Above ground C/ha adjusted =Plot area expansion factor to hectare*C Biomass above ground(Kg)/1000

7.7 Litters/Herbaceous:

1. Adjusted plot area (m^2)=Cos(Radians(slope)*pi()*Plot radius^2
2. Plot area expansion factor to hectare=10000/Adjusted plot area
3. C biomass above ground (Kg)=Litter weight/plot*conversion factor to estimate oven dry weight
4. Above ground C adjusted (Mg/ha) = Plot area conversion factor to hectare*C biomass above ground(kg)*0.5/1000
5. Above ground CO2 adjusted (Mg/ha)= Above ground C adjusted (Mg/ha)*44/12
6. Below ground CO2 adjusted (Mg/ha) = Above ground CO2 adjusted (Mg/ha)*0.24
7. 5 + 6 above make the total.

7.8 Species Diversity and Species Richness:

The species diversity indices at different PAs were estimated by Shannon's species diversity index method. The numbers of species observed at individual PAs were divided by the total number of species observed in the eight PAS to get the ration (p). Then this "'p" was used to estimate the Shannon's species diversity index known as H'=-p*ln(p).

Species Richness is a measure of number of species found in a sample population. This species richness index is Menhinicks's index known as "D". The estimation procedure is D= (Number of species found in a PA/√ (Total number of individuals found in the whole population means eight PAs).

8. Results and Discussions:

Based on the Standard Operating Procedures (SOP) developed by the experts from FD, WI Ecosystem Unit, BFRI and CREL; coupled with field data collection from sample plots and remote sensing analysis Forest Carbon Inventory 2014 at eight protected areas were completed. The results are given as follows.

8.1 Land covers areas:

Satellite imagery (RapidEye, 2013) analyses and field inventory sample plots identified nine land cover classes in the PAs inventoried. The area distributions in different land cover classes are given in Table 4.

Table 4: Area (ha) estimates for different PAs and land cover classes

Land cover Classes	LNP	SNP	RKWS	KhNP	MNP	KNP	CWS	HNP	Total area (ha)
Forest	1,400	953	4,782	479	2,233	3,786	507	132	14,272
Plantation	-		93	-	578	42	361	15	1,089
Degraded land	509	657		198	-	968	5,873	1,385	9,590
Settlement	310	-	68	1	2,872	271	981	329	4,832
Bare land	-			-	-	-	-	29	29
Rubber	0	92			495				587
Tea	227	104	20	98					449
Agriculture	137	1	555	3	2,083	23	598	128	3,528
Inventoried Area (ha)	**2,583**	**1,807**	**5,518**	**779**	**8,261**	**5,090**	**8,320**	**2,018**	**34,376**

A total of 377 sample plots were laid out at eight Pas. The number of plots laid out at eight PA by land cover classes are given in Table 5.

Table 5: Distribution of sample plots at different land cover classes based on inventory

Land Use category	LNP	SNP	RKW	KhNP	MNP	KNP	CSW	HNP	Total
Forest	12	5	46	6	30	17	21	1	138
Degraded Forest	3	3	1	2		17	56	20	102
Plantation	12	11	13	1	12	24	26		99
Settlement	1				3	2	4	6	16
Agriculture		1	3		3	1	4		12
Bare Land	1								1
Rubber					7				7
Tea Garden	1								1
Water bodies	1								1
Total	31	20	63	9	55	61	111	27	377

8.2. Biophysical Results:

The numbers of seedlings, saplings, trees, stumps per hectare for different land cover classes at different PAs were estimated and are given in Table 7.In particular, forest areas at Chunati WS, Lawachara NP, Rema-Kalenga WS, Satchari NP and Modhupur NP exhibits a regular trend (inverted j-shape) for seedlings, saplings and trees per ha while Himchari NP, Kaptai and Khadimnagar NP showed irregular pattern of plants in three stages (figure 6).

Table 6: Number of seedlings, saplings, trees, stumps per ha

PA and land cover classes	Seedlings (N/ha)	Saplings (N/ha)	Live trees (N/ha)	Stumps (N/ha)
Lawachara NP	**3,130.05**	**4,880.75**	**1,426.31**	**25.16**
Bare Land	-	-	112.51	-
Degraded Forest	2,917.84	18,568.08	283.58	20.00
Forest	4,774.65	3,382.04	1,976.26	30.83
Plantation	2,254.70	4,177.82	1,318.88	29.17
Settlement	795.77	-	1,903.23	-
Tea Garden	-	-	381.24	-
Satchari NP	**3,103.52**	**1,710.92**	**894.68**	**24.00**
Agriculture	-	-	393.24	-
Degraded Forest	530.52	1,061.03	235.75	10.00
Forest	5,092.96	2,705.63	1,058.82	40.00
Plantation	3,183.10	1,591.55	1,045.36	22.73
Rema-kalenga WS	**10,338.76**	**2,867.32**	**1,419.01**	**36.03**
Agriculture	-	-	53.38	-
Degraded Forest	11,140.85	10,345.07	-	-
Forest	12,118.26	3,321.49	1,602.15	31.30
Plantation	6,366.20	1,346.70	1,195.28	63.85
Khadimnagar NP	**884.19**	**795.77**	**954.08**	**12.22**
Degraded Forest	-	1,989.44	359.60	10.00
Forest	1,326.29	530.52	1,016.61	15.00
Plantation	-	-	1,767.82	-
Modhupur NP	**30,311.78**	**4,846.99**	**1,834.77**	**11.64**
Agriculture	-	-	-	-
Forest	53,184.28	7,665.96	2,499.71	19.33
Plantation	4,509.39	2,785.21	1,135.29	1.67
Rubber	454.73	-	1,203.73	-
Settlement	4,774.65	1,061.03	1,290.50	13.33
Kaptai NP	**939.28**	**234.82**	**1,011.63**	**93.11**
Agriculture	-	-	-	-
Degraded Forest	140.43	187.24	316.16	150.00
Forest	1,966.03	327.67	1,298.39	65.88
Plantation	862.09	198.94	1,358.59	81.67
Settlement	397.89	397.89	827.96	25.00
Chunati WS	**4,366.01**	**2,165.08**	**1,035.28**	**23.06**
Agriculture	-	-	-	5.00
Degraded Forest	809.98	440.52	655.26	20.71
Forest	8,412.48	3,751.51	1,320.98	26.19
Plantation	9,885.97	4,988.90	1,744.94	26.15
Settlement	1,392.61	1,790.49	1,278.03	37.50
Himchari NP	**2,033.65**	**2,947.31**	**168.51**	**-**
Degraded Forest	2,546.48	3,939.08	60.03	-
Forest	3,183.10	-	1,026.54	-
Settlement	132.63	132.63	387.09	-
All PA average	**8,189.50**	**2,577.80**	**1,172.22**	**33.21**

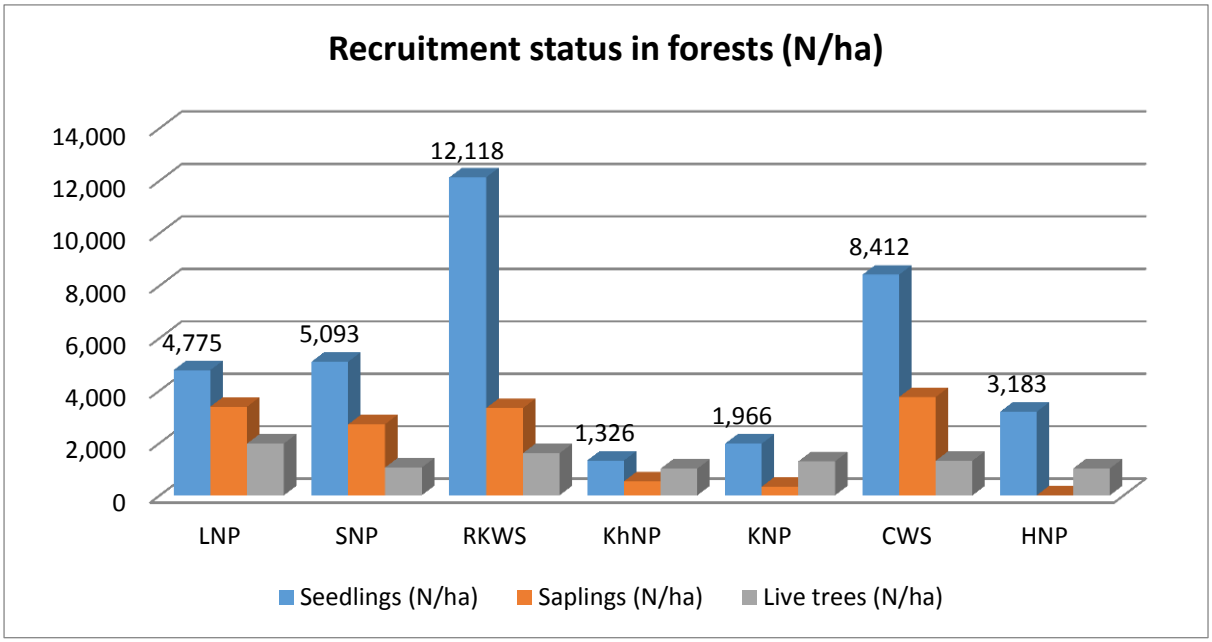

Figure 14. Number of seedlings, saplings and trees in land cover class "Forest "

8.3 Carbon Stocks in PAs

The CO_2 stocks at different PAs and land cover classes were estimated and are given in Table 7. These were further disaggregated by 5 pools and land cover classes and are given in Table 8.It was observed that the total carbon CO_2 (Mg) stock in eight PAs was 8,001,323 Mg. The carbon stock varied from 52.8 CO_2Mg/ha (in Himchari NP) to 370.69 CO2 Mg/ha (in Rema-Kalenga WS) with an average of 232.8 CO_2 Mg/ha among the PAs.

Table 7: Stock of CO_2 (Mg/ha) at different cover classes at Forest Carbon inventoried eight PAs.

Land cover	LNP	SNP	RKWS	KhNP	MNP	KNP	CWS	HNP	CO_2 Mg/ha
Forest	470.7	313.7	432.4	362.5	277.6	322.7	198.0	117.3	343.3
Degraded Forest	98.8	124.1	47.2	79.7		88.8	116.6	29.4	93.2
Plantation	291.9	292.5	249.8	350.9	188.9	351.4	186.0		261.2
Settlement	350.5				163.1	155.4	163.2	120.1	157.7
Agriculture		157.5	55.4		35.2	27.1	18.6		44.2
Bare Land	80.7								80.7
Rubber					246.2				246.2
Tea Garden	160.3								160.3
All land covers	**323.8**	**265.8**	**370.7**	**298.3**	**234.8**	**258.5**	**146.4**	**52.8**	**232.8**

Table 8: Stock of CO_2 at different cover classes and 5 pools at Forest Carbon inventoried eight PAs.

PA and Land cover classes	Live Trees CO2 (Mg/ha)	Dead Trees CO2 (Mg/ha)	Non-trees CO2 (Mg/ha)	Litter CO2 (Mg/ha)	Soil Carbon (Mg/ha)	Total CO2 Mg/ha	Inventoried PA landscapes (ha)	Total CO2 Mg of the PA
L NP	**269.2**	**3.8**	**1.5**	**8.6**	**40.7**	**323.8**	**2,583**	**836,456**
Bare Land	27.8	-	2.3	10.5	40.1	80.7		
Degraded Forest	25.8	25.3	4.1	6.4	37.0	98.8		

PA and Land cover classes	Live Trees CO2 (Mg/ha)	Dead Trees CO2 (Mg/ha)	Non-trees CO2 (Mg/ha)	Litter CO2 (Mg/ha)	Soil Carbon (Mg/ha)	Total CO2 Mg/ha	Inventoried PA landscapes (ha)	Total CO2 Mg of the PA
Forest	411.0	3.3	0.8	11.4	44.2	470.7		
Plantation	241.1	0.3	1.8	8.0	40.7	291.9		
Settlement	308.8	-	-	-	41.8	350.5		
Tea Garden	105.1	-	0.6	3.8	50.7	160.3		
S NP	**219.1**	**0.3**	**1.0**	**11.5**	**33.9**	**265.8**	**1,807**	**480,295**
Agriculture	128.6	-	3.6	2.9	22.4	157.5		
Degraded Forest	79.6	-	1.4	5.1	38.1	124.1		
Forest	259.4	0.4	0.9	13.8	39.3	313.7		
Plantation	247.0	0.3	0.8	12.9	31.5	292.5		
RKWS	**319.1**	**0.0**	**0.9**	**5.2**	**45.6**	**370.7**	**5,518**	**2,045,487**
Agriculture	12.5	-	-	-	42.9	55.4		
Degraded Forest	1.1	-	0.3	1.8	44.0	47.2		
Forest	379.0	0.0	0.7	5.6	47.0	432.4		
Plantation	202.1	-	1.6	5.0	41.1	249.8		
KNP	**264.2**	**-**	**0.8**	**7.1**	**26.3**	**298.3**	**779**	**232,412**
Degraded Forest	40.3	-	-	-	39.4	79.7		
Forest	330.6	-	1.1	9.4	21.5	362.5		
Plantation	313.4	-	0.8	7.7	29.0	350.9		
MNP	**195.5**	**-**	**0.8**	**6.4**	**32.2**	**234.8**	**8,261**	**1,939,606**
Agriculture	-	-	-	1.3	34.0	35.2		
Forest	238.6	-	0.7	7.7	30.5	277.6		
Plantation	147.1	-	0.3	4.3	37.1	188.9		
Rubber	201.5	-	2.2	6.8	35.8	246.2		
Settlement	138.6	-	0.3	5.9	18.3	163.1		
KNP	**222.0**	**3.3**	**1.0**	**5.0**	**27.2**	**258.5**	**5,090**	**1,315,601**
Agriculture	-	-	-	-	27.1	27.1		
Degraded Forest	57.9	0.3	0.6	2.6	27.2	88.8		
Forest	276.8	8.4	2.2	8.0	27.3	322.7		
Plantation	316.9	2.0	0.4	5.0	27.1	351.4		
Settlement	123.5	2.9	0.9	1.7	26.4	155.4		
CWS	**103.8**	**0.2**	**10.5**	**8.9**	**23.1**	**146.4**	**8,320**	**1,218,037**
Agriculture	-	-	0.7	4.8	13.0	18.6		
Degraded Forest	75.4	0.2	6.4	7.4	27.1	116.6		
Forest	149.6	0.0	12.3	14.0	22.0	198.0		
Plantation	139.4	0.3	20.4	8.8	17.1	186.0		
Settlement	132.6	0.5	2.7	6.8	20.6	163.2		
HNP	**37.9**	**0.4**	**0.2**	**0.1**	**14.2**	**52.8**	**2,018**	**106,605**
Degraded Forest	11.8	-	0.2	0.2	17.2	29.4		
Forest	101.1	-	-	-	16.2	117.3		
Settlement	114.5	1.7	0.0	-	3.8	120.1		
All PA	**191.1**	**1.0**	**3.7**	**6.7**	**30.3**	**232.8**	**34,376**	**8,001,323**

This inventory shows the CO_2 stocks per hectare for each of the PAs sampled in this inventory (Table 9) along with error bars representing 80% confidence level are given in Table 10 and Figure 8. The confidence interval ranges from mean±15 (at Chunati WS) to 84 (at KNP) for the different PAs.

Table 9: Mean CO_2 (Mg/ha) stock with Confidence Level (all land cover classes)

PA	n	Mean, CO2 Mg/ha	Std. Dev	SE	t	CI (+/-) at 90%
Lawachara NP	31	323.8	242.6	43.6	1.310	57.1
Satchari NP	20	265.8	161.7	36.2	1.328	48.0
Rema-Kalenga WS	63	370.7	198.3	25.0	1.296	32.4
Khadimnagar NP	9	298.3	180.4	60.1	1.397	84.0
Modhupur NP	55	234.8	127.0	17.1	1.297	22.2
Kaptai NP	61	258.5	241.6	30.9	1.296	40.1
Chunati WS	111	146.4	121.7	11.5	1.290	14.9
Himchari NP	27	52.8	85.9	16.5	1.315	21.7
Total	**377**	**232.8**	**195.8**	**10.1**		

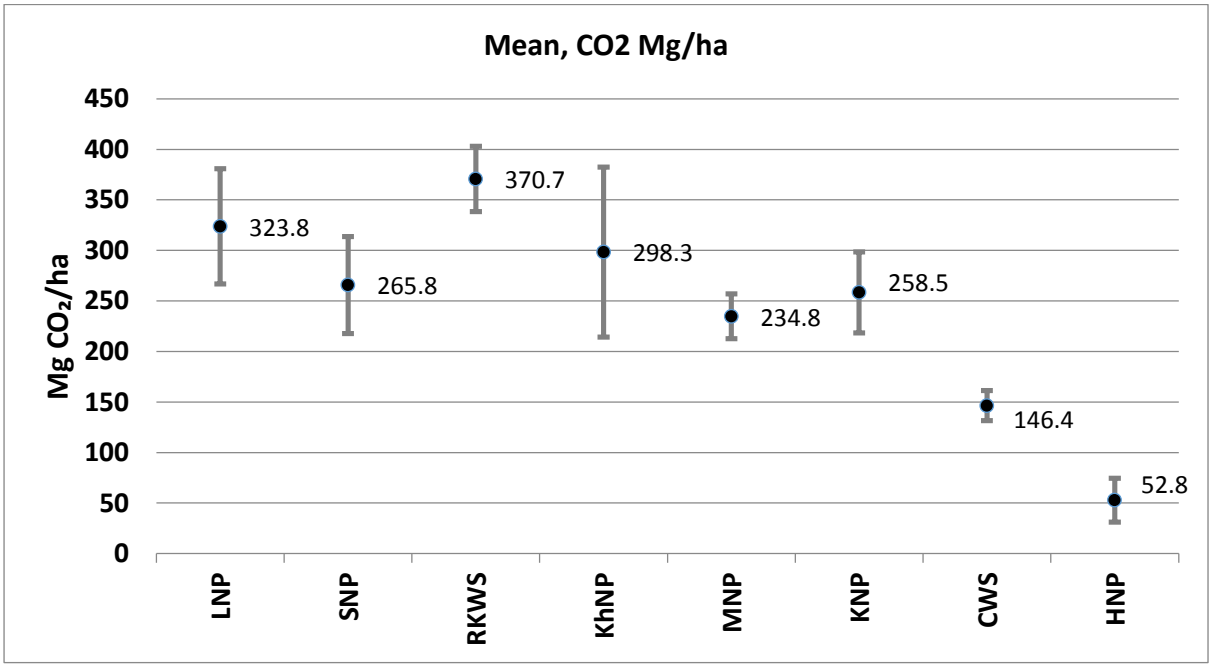

Figure 15. Mean CO2 stocks for eight PAs with error bars showing 90% confidence level

8.4 Species diversity:

Species diversity indices at different PAs were estimated by Shannon's diversity index method. The number of species observed at each PA and total number of species observed in the eight PAs were used to estimate Shannon's diversity index (Table 11 and figure 9). RKWS, Chunati WS, Kaptai NP and Lawachara NP has highest species diversity followed by Modhupur NP and SNP and while Himchari NP and Khadimnagar NP has low diversity. The species richness were also estimated for each PA with the formula

D = Number of species observed in a PA/ √(Total number of individuals observed in the samples of eight PA) and are also given in Table 10.

Table 10.Shannon's species diversity and Species richness at the eight PAs in 2014

PA	Number of Species	Number of individual observations	p=number of spp in the PA/Total number of spp	Diversity Index,H' =-p*ln(p)	Species richness
Lawachara NP	60	230	0.29	0.36	1.25
Satchari NP	31	92	0.15	0.28	0.65
Rema-Kalenga WS	85	498	0.41	0.37	1.77
Khadimnagar NP	10	40	0.05	0.15	0.21
Modhupur NP	33	567	0.16	0.29	0.69
Kaptai NP	61	312	0.29	0.36	1.27
Chunati WS	73	535	0.35	0.37	1.52
Himchari NP	11	24	0.05	0.16	0.23
Total	**208**	**2,298**		**2.33**	

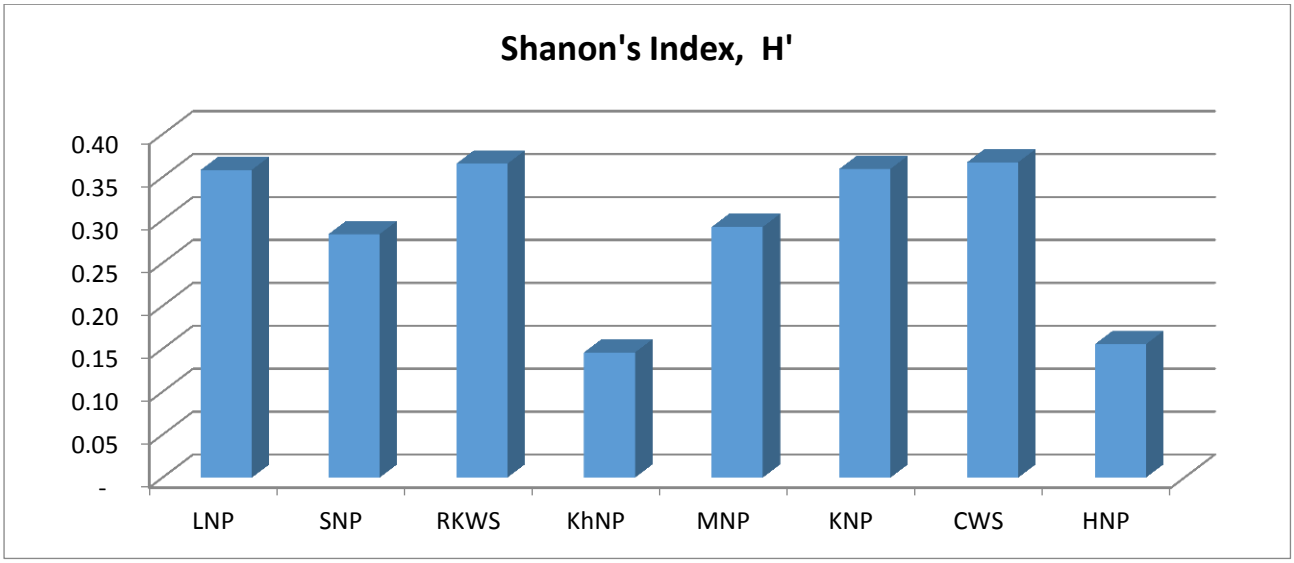

Figure 16. Shannon's species diversity in the inventoried eight PAs in Bangladesh

8.5. Emissions from deforestation and forest degradation

In GHG accounting, land cover change i.e. deforestations and forest degradations, due to anthropogenic pressures are important. This inventory, coupled with Global Forest Loss-gain data (Hansen et. al. 2013) landsat imageries during 2001-2012, calculated annual land cover change and estimated emission factors for eight PAs. Emission factors are calculated as the difference between the forest CO_2 stocks before land use change and after land use change (i.e. post-deforestation). Emissions occur when the conversion results in a decrease in carbon stocks. In contrast, sequestration can occur when a unit of land is converted to higher carbon stocks, for example when degraded land is allowed to re-grow into forest, or an agricultural area is planted with trees. Table 11 shows the rate of deforestation and emission factors for eight PAs.

Table 11: Deforestation trend in eight PAs

PA	Land cover change	Total Forests in 2001	Total area of change (2001-2012)	Annual area change	Rate of Deforestation	Emission Factor (overall 8 PAs)	Baseline Annual Emissions
	Forest to:	ha	ha	ha/yr	%	CO2 Mg/ha	CO2 Mg/yr
LNP	Agriculture		7.6	0.63	0.03%	298.8	188.2
LNP	Settlements		2.8	0.23	0.01%	207.5	47.7
LNP	Total	2,149	10.4	0.87	0.04%		236
SNP		229		-			
RKWS	Agriculture		0.4	0.03	0.00%	298.8	9
RKWS	Total	5,755	0.4	0.03	0		8.964
KhNP		481		-			
MNP	Agriculture		110.2	9.18	0.38%	298.8	2743
MNP	Settlements		47.4	3.95	0.17%	207.5	819.6
MNP	Total	2,389	157.6	13.13	0.55%		3562.6
KNP	Agriculture		4.1	0.34	0.01%	298.8	101.6
KNP	Settlement		3	0.25	0.00%	207.5	51.9
KNP	Total	5,823	7.1	0.59	0.01%		153.5
CWS	Settlement		20.8	1.73	0.16%	207.5	359
CWS	Agriculture		8.5	0.71	0.07%	298.8	212.1
CWS	Total	1,067	29.3	2.44	0.23%		571.1
HNP	Bare soil		2.8	0.23	0.13%	262.6	60.4
HNP	Settlement		2.3	0.19	0.11%	207.5	39.4
HNP	Agriculture		2	0.17	0.09%	298.8	50.8
HNP	Total	182	7.1	0.59	0.33%		150.6
							4,682.75

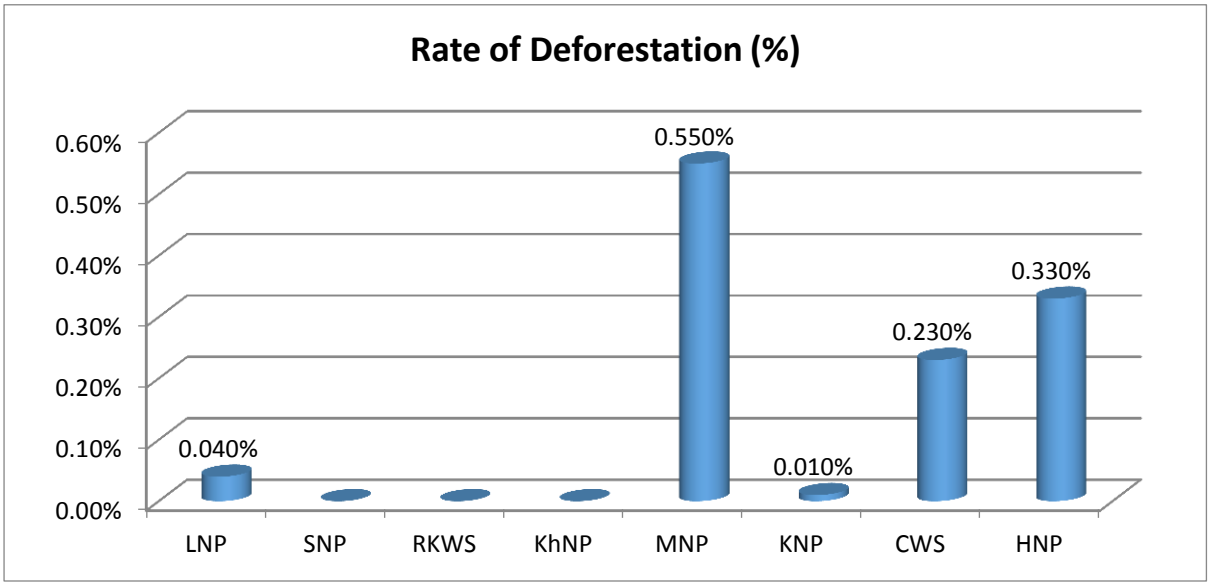

Figure 17. Rate of deforestation at eight PAs in Bangladesh

Inventoried PAs, alike other forest reserves in the country are constantly affected by extractions of forest resources, in particular removal of saplings and poles in addition to cane, bamboo and fuel wood. In most cases forests are being converted as shrub lands where trees often cannot grow above 5cm DBH. In this inventory, stumps were measured from the sample plots and degradation from tree removals are estimated, based on the relation of stump basal diameter to tree DBH and subsequent calculation of CO_2 Mg/ha extracted. It is found that Kaptai NP has the highest stump measurements. However, at Himchari NP no stumps are found and this PA is the most degraded one whereas stumps are being removed. The estimates of emissions from extraction of trees are given in Table 12.

$$\text{Biomass extracted (Mg/ha)} = \text{Biomass of sample tree(Mg/ha)} - \text{Biomass stump(Mg/ha)}$$

Table 12: Forests degradation due to human interference (cutting of trees, stumps)

PA	Stumps (N/ha)	Emissions from extraction of trees (CO_2 Mg/ha)	Total CO2 Mg/ha	Per cent of total forest CO_2 stocks	Area of forest (ha)	Total emissions from extraction of trees CO_2 Mg
LNP	30.83	6.43	470.67	1.4%	1,400	8,996
SNP	40.00	18.02	313.71	5.7%	952	17,154
RKWS	31.30	19.00	432.44	4.4%	4,782	90,858
KhNP	15.00	26.44	362.49	7.3%	479	12,663
MNP	19.33	4.03	277.62	1.5%	2,232	9,006
KNP	65.88	48.89	322.74	15.1%	3,786	185,081
CWS	26.19	2.51	197.98	1.3%	507	1,272
HNP	-	-	117.30	0.0%		-
Total	**31.52**	**15.98**	**343.29**	**4.7%**	**14,138**	**325,031**

An estimate have been prepared to have an idea of emissions by land cover change and are given in Table 13.

Table 13: Emission factor, by land cover classes (unit, CO_2 Mg/ha)

		Converted to						
	Land cover	**Forest**	**Degraded Forest**	**Plantation**	**Settlement**	**Rubber**	**Agriculture**	**Tea Garden**
Converted from	**Forest**	-	250.1	82.1	185.6	97.1	299.0	183.0
	Degraded Forest	(250.1)	-	(168.0)	(64.6)	(153.1)	48.9	(67.1)
	Plantation	(82.1)	168.0	-	103.4	14.9	216.9	100.9
	Settlement	(185.6)	64.6	(103.4)	-	(88.5)	113.5	(2.5)
	Rubber	(97.1)	153.1	(14.9)	88.5	-	202.0	86.0
	Agriculture	(299.0)	(48.9)	(216.9)	(113.5)	(202.0)	-	(116.0)
	Tea Garden	(183.0)	67.1	(100.9)	2.5	(86.0)	116.0	-

Example of how to use Table 13: If one hectare of forest is converted to degraded forest then there is an emission of 250.1 CO_2 Mg/ha. If one hectare of agricultural land is converted to forests, there will be a sequestration of 299.0 CO_2 Mg/ha.

8.6. Discussions

This report provides the results from the CREL forest inventory in 2014. The analyses of the results also provide important recommendations and contributions to Bangladesh's National REDD+ development.

The analysis of forest degradation suggests that degraded forests are a significant cause of GHG emissions and loss of quality biophysical condition for forests in Bangladesh. As part of the inventory CREL also measured some common non-forest land cover types in Bangladesh, enabling preliminary *emission factors* that could be the basis for further national scale inventory.

Integrated with the forest inventory CREL developed a unique set of metrics for assessing the biophysical condition of forest and other land cover types, including tree recruitment, species richness, and general structure related to live biomass, dead biomass and soil organic matter that can give an indication of forest health and resiliency.

By combining the data for GHG emissions and changes in forest biophysical condition with baseline land cover change maps, the CREL project is able to establish baselines for eight PAs. The methods and results provide important contributions to Bangladesh's R-PP and National REDD+ development.

Some important findings from this report are:

1. Estimated carbon stocks for forest and non-forest lands that enable a preliminary estimate of emission factors for deforestation in Bangladesh.
2. Estimated carbon stocks and emissions from the conversion of forest to degraded forest. This provides the first estimation of the impact of forest degradation in Bangladesh that we are aware of.
3. A unique assessment of the relative impact and emission from illegal tree cutting in eight forest protected areas based on an inventory of tree stumps. This helps to quantify the threat and impact of tree cutting on exiting protected forests.
4. Degradation appears to be the most significant threat to forest GHG emission and loss of biophysical condition.
5. Degraded forest needs to be mapped with higher degree of accuracy for a REDD+ program in Bangladesh. From our experience higher resolution data is not the best solution and it is advised to look at other data sources like Radar.
6. Plantation forest is also an important component of Bangladesh's forests. These can be very hard to map with RS therefore manual digitization should be considered as a viable option.

Data archives: Lists of spread sheets submitted along with the report.

Khadimnagar National Park (KhNP), Lawachara National Park (LNP), Satchari National Park (SNP), Rema-Kalenga Wildlife Sanctuary (RKWS), Modhupur National Park (MNP), Kaptai National Park (KNP), Chunati Wildlife Sanctuary (CWS) and Himchari National park (HNP).

Archive: ***RIMS Unit, Forest Department and C:\Users\Ruhul\Dropbox\CREL_Bangladesh\FCI2014***

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Appendix I: Field Forms

Form 1 CREL Forest Carbon Inventory 2014: Plot Setup and Description

Name of PA:_____PlotID:_____Range:_____Beat:_____Block:_____

Mouza: _____ Union:_____ _____ Upazila_____

Team Leader:_____ Data recorded by:_____ # people in team: _____

GPS in DD MM SS.ss: Lat (N)_____ Long. (E)_____GPS Accuracy (±m) ____

Plot location _____

Entry Waypoint/nearest landing:_____

Date:_____/_____/_____Start Time:_____ End time:_____ Total Time: _____

Land use category (circle one):

Forest	Degraded forest	Shrub land	Plantation forest	Village forest	Settlement/ developed	Permanent Agriculture	Shifting Cultivation	Tea garden	Wet -land

Topography (circle one):

Depression	Flat	Low hills	High hills	Valley

Disturbance Evidence (circle one):

No disturbance	Forest fire	Illicit timber removal	Encroachment	Grazing	Fuel wood removal	Sun grass removal	Other (specify)

Storm Cyclone damage:

No evidence	Low (<30%)	Medium (30-70%	High (>70%)

Disease:

No evidence	Low (<30%)	Medium (30-70%	High (>70%)

Dominant wildlife (describe evidences noticed in the plot):

Red listed Flora and Fauna:

Invasive species:

Notes:

Data Entry (name, date, notes)

Entry Review (name, date, notes)

Form 2 CREL FCI2014: Measurement of Seedlings, Saplings, Trees and Palms

Name of PA:_____ Plot ID:_____Slope (%): _____ Photo Number(s):N_____E_____S_____W_____

Seedlings Plot Dimension radius 2.0 m; Saplings Plot Dimension radius 2.0 m:
# of Seedlings: _____ # of Saplings: ___Dominant Species Name _____

Live Tree Measurements: Nested Plots

Plot radius: small, 4.0m Tree diameter: small, ≥5.0cm		
Tree #	Species	DBH (cm)

Plot radius: medium, 10.0m Tree diameter: medium, ≥20.0cm		
Tree #	Species	DBH (cm)

Plot radius: medium, 17.84m Tree diameter: medium, ≥50.0cm		
Tree #	Species	DBH (cm)

Co-dominant Trees and Palms where height is measured						
Tree #	Species	Height (m)	Clinometer angle		Eye to tree (m)	Equipment Used
			+	-		

Data Entry (name, date, notes)

Entry Review (name, date, notes)

Form 3: CREL FCI2014: Measurement of Stumps and Canopy Cover

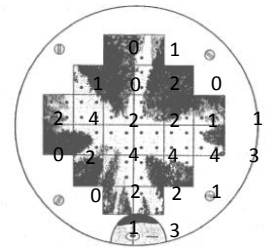
Name of PA: _____Plot ID #:_____

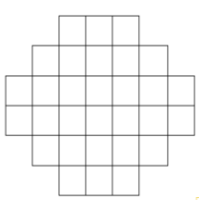
Form 3A: CREL Carbon Inventory: Stumps from human degradation

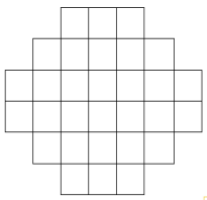
Stump ID#	Base diameter (cm)	Does the cut tree result in any gap in the canopy (YES/NO)	If YES comment on if the gap is small, medium, or large	Sample Tree DBH (cm) *tree of similar or same species with similar base diameter*		
				Species	DBH (cm)	Base dia (cm)

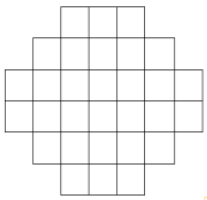
Form 3B Canopy cover

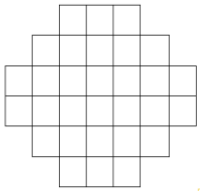
The spherical densiometer consists of 24 ¼" squares engraved onto a concave mirror. Each square of the grid must be subdivided mentally into 4 smaller squares and represented by an imaginary dot in the center of each of the smaller squares (see Example). Four canopy cover readings should be taken, each 10m from plot center at due North, East, South, and West. Count the number of dots NOT occupied by canopy (where you can see sky at that dot). Record this number on the datasheet.











Record the number of dots NOT occupied by canopy (You can see sky at

North reading Sum of dots _____

East reading Sum of dots _____

South reading Sum of dots _____

West reading Sum of dots _____

Data Entry (name, date, notes)

Entry Review (name, date, notes)

Form 4: CREL FCI2014: Standing Dead & Lying Wood Measurements and Soil Samples:

Form 4A: Standing Dead Wood Measurements

Name of PA: _____Plot ID #:_____

Diameter at base, at 0.15 m; (cm)	DBH at 1.3 m; (cm)	Diameter at top (cm) (if measured directly)	Height (m) (if measured directly)	Height Measurement			
				Clinometer angle		Distance from eye to tree (m)	Height of eye (m)
				+	-		

Form 4B: Lying Dead Wood Measurements		
(wood greater than 10 cm diameter) Transect length (m) = __25 m___		
Diameter (cm)	Density Class (S/I/R)	Hollow Diameter (cm)

S=Solid, I=Intermediate, R=Rotten

Form 4C: Soil

Soil type (circle): **clay, sandy-clay, loam, Sandy-loam, silty-clay, silty-loam;**

Other soil type_____

Soil % C

Sample ID # _____

Sample method: _____

Sampledepth (cm): _____

Bulk density

Sample ID# _____

Sample method: _____

Sample volume (cm^3): _____

Sampledepth (cm): _____

Sample ID# _____

Sample method: _____

Sample volume (cm^3): _____

Sample depth (cm): _____

Data Entry (name, date, notes)

Entry Review (name, date, notes)

Form 5: CREL FCI2014: Non-Tree Woody Vegetation: Bamboos

Name of PA:_____ Plot ID:_____

Plot radius 2, 4 or 10 m will depend on intensity of occurrence

Clump #	Species Small, medium and large	Average DBH (cm) of the culm	Height (m)	Average Height (m) of the culm				Number of Culms/Stems in the clump (n)	Plot radius (m)
				Clinometer angle (%)		Distance from eye to tree (m)	Height of eye (m)		
				+	-				

Bamboo: Small (diameter< 4cm), Med. (diameter 4-8cm) and Large (diameter>8cm)

Data Entry (name, date, notes)

Entry Review (name, date, notes)

Form 6: CREL FCI2014: Destructive harvest samples & sub-samples

(Seedlings, Sapling, Bamboo, Cane, Palm, Shrub, litter and herbaceous vegetation)

Name of the PA: **Plot ID.**:

Data sheet for destructive harvest samples & sub-samples

Sample ID	Species	DBH (cm)	Height (m)	Sample			Sub-sample		
				Weight of bag (g)	Weight of bag+ material (g)	Weight of sample (g)	Weight of bag (g)	Weight of bag+ material (g)	Weight of sample (g)
	Bamboo: Small (diameter< 4cm)								
	Bamboo: Med. (diameter 4-8cm)								
	Bamboo: Large (diameter>8cm)								
	Litter 1	-	-						
	Litter 2	-	-						
	Litter 3	-	-						
	Litter 4	-	-						
	Grass & Herbaceous 1	-	-						
	Grass & Herbaceous 2	-	-						
	Grass & Herbaceous 3	-	-						
	Grass & Herbaceous 4	-	-						
	Shrubs	-							
	Seedlings (2 numbers)	-							
	Saplings (2 numbers)	-							
	Palm								

Data Entry (name, date, notes) Entry Review (name, date, notes)

Appendix-II: List of volume equation and wood density

Sl	Species	Scientific name	Reference	Volume equation	Wood Density
	Minjiri	*Cassia siamea*	Latif*et al.* 1995	$\ln(V_{ob})$=- 8.602 + 2.4038×ln(D)	
1	Akashmoni	Acacia auriculiformis	Latif*et al.* 1995	ln(V)=-8.208+2.2389*ln(D)	0.70
2	Arjun	T*erminalia arjuna*	Rahman et al. 2001	ln(V)=2.222144*ln(G)-11.1885	
3	Banderhola	*Duabanga grandiflora*	Latif et al. 195b	ln(V)=2.4987*ln(D)-9.2929	0.54
4	Base dia-DBH	Dipterocarpus turbinatus	Latif et al. 1985b	DBH (cm)=0.792437*base dia (cm)	
5	Bhadi	Mise Sp.	Latif et al. 1985b	ln(V)=2.08627*ln(D)-7.574983	0.65
6	Bohera	Terminalia ballerica	Latif et al. 1985b	ln(V)=2.1338*ln(D)-8.0446	0.78
7	Chapalish	Artocarpus chaplasha	Latif et al. 1984c	ln(V)=2.24074*ln(D)-8.179774	0.49
8	Chundul	Tetrameles nudiflora	Latif et al. 1985b	ln(V)=2.0291*ln(D)-7.077637	0.36
9	Civit	Swintonia floribunda	Latif et al. 1985b	ln(V)=2.14002*ln(D)-7.631146787	0.61
10	Dhakijam	Syzygiium grande (Plantations)	Latif et al. 1984b	$V = 0.00552016 - 0.0028213 \times D + 0.00078431 \times D^2$	0.79
11	Dhakijam	Syzygiium grande (natural)	Latif et al. 1985b	V=-0.275876+0.009951*D+0.0005876*D^2	0.79
12	Eucalyptus	Eucalyptus camaldulesnsis	Latif et al. 1999	ln(V)=2.297689*ln(G)-11.177929	0.68
13	Gamar	Gmelina arborea	Latif et al. 1984c	ln(V)=2.1472*ln(D)-7.9022697	0.44
15	Garjan	*Dipterocarpus Turbinatus*	Latif et al. 1984a	ln(V)=2.35556*ln(D)-8.5116354	0.78
16	Jackfruit	Artocarpus heterophyla	Latif&Zahir 2000	ln(V)=2.18203*ln(G)-11.06320	0.49
17	Jam	Syzigium cumini	Latif et al. 1985b	V=0.00506138D^2+0.00217385-0.00111102*D	0.67
18	Jarul	Lagarastroemia Spp	Latif et al. 1985b	ln(V)=2.08627*ln(D)-7.574983	0.61
19	Kadam	Anthocephalus chinensis	Latif et al. 1985b	ln(V)=2.32592*ln(G)-11.6329	0.47
20	Kanak/Banak		Latif et al. 1985b	ln(V)=1.6912*ln(D)-6.3428	0.72
21	Koroi	*Albizia procera*	Latif*et al.* 1999	ln(V)=2.463398*ln(G)-12.093533	0.73
22	Mahogany	*Swietenia macrophylla*	Latif et al. 1999	ln(V)=2.460647*ln(G)-12.045383	0.67
23	Mangium	*Acacia mangium*	Latif*et al*. 1993	$\ln(V_{ob})$ =- 8.209 + 2.2178×ln(D)	0.56
24	Mango	Mangifera indica	Latif&Zahir 2000	ln(V)=2.24506*ln(G)-11.27269	0.54

Sl	Species	Scientific name	Reference	Volume equation	Wood Density
25	Neem	Azadracta indica	Latif and Zahir 2001	ln(V)=2.25814*ln(G)-11.33340	0.76
26	Pitraj	*Aphanamixis polystachya*	Latif et al. 1985b	ln(V)=2.4781*ln(D)-9.2157	0.54
27	Rain Tree	Samania saman	Latif*et al.* 2000	ln(V)=2.5086408*ln(G)-12.287524	0.59
28	Rubber wood	Hevea brazelenisis	Zahir (in press)	ln(V)=-10.5628+2.1502*ln(G)	0.56
29	Sal	Shorea robusata	Latif et al. 1992	ln(V)=2.51789*ln(D)-9.1727759	0.82
30	Simul	Bombex ceiba	Latif et al. 1985b	ln(V)=2.3088*ln(D)-8.4630	0.67
31	Sissoo	*Dalbergia sissoo*	Latif et al. 1999	ln(V) = -12.14678171+2.49978991×ln(G)	0.74
32	Teak/Shegun	*Tectona grandis*	Latif et al. 1985a	ln(V)=2.12337*ln(D)-7.566916	0.61
33	Urium	Mangifera sylvastica	Latif et al. 1985b	ln(V)=2.337*ln(D)-8.5703	0.54
34		Mixed SPP	Latif et al. 1985b	ln(V)=2.08627*ln(D)-7.574983	0.67

Appendix –III: List of Species and tree counts at each PA

PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N
CWS	**535**	**HNP**	**24**	**KhNP**	**40**	**KNP**	**312**	**LNP**	**230**	**MNP**	**567**	**RKWS**	**498**	**SNP**	**92**
Aam	15	Amra	1	Champa	3	Assar	7	Aam	4	Aam	1	Aam	1	Akashmoni	6
Akashmoni	171	Arjun	1	Chikrashi	2	Agar	5	Agar	3	Ajoki	5	Agar	6	Amra	1
Alena	3	Chandul	1	Dumur	1	Ashok	1	Akashmoni	48			Akashmoni	16	Awal	4
Analagula	1	Coconut	5	Jam	1	Badi	9	Awal	4	Akashmoni	63	Amloki	2	Belpoi	1
Arshol	2	Gujibula	1	Badi	4	Batna	17	Jalpai	1	Badi	2	Amra	4	Biskut	1
Badi	4	Jam	2	Kakra	1	Bohera	4	Bohera	8	Bhahula	1	Awal	11	Bohera	1
Barizzara	1	Kanthal	4	Sal	8	Bon Badam	1	Bollos	1	Bilati gab	1	Badi	1	Bon kodom	1
Batna	4	Kecho	1	Teak	16	Bon Jalpai	1	Bonak	10	Bislong	2	Badrak	5	Chapalish	10
Bhandigula	2	Koroi	1	Udal	2	Bormala	2	Boroi	1	Bohera	4	Bal	1	Civit	1
Bohera	6	Mouch	1	Dhakijam	2	Buikumra	1	Chalta	2	Bokain	1	Baranga	4	Dumur	5
Bon supari	2	Aam	6			Bura	1	Chapalish	23	Bot	1	Bel poi	3	Gamar	2
Bormala	10					Chapalish	4	Dewa	2	Datoi	1	Bellom	1	Jam	1
Borta	2					Chundul	1	Dumur	10	Dhapor	1	Bohera	34	Jarul	1
Bura	21					Civit	2	Ekush	3	Eucalyptus	1	Bon jolpai	1	Kankar	1
Chagollaidda	2					Darmara	9	Garjan	10	Jam	6	Bon lichu	3	Kawa Jam	1
Chapalish	7					DhakiJam	2	GuaChamir	2	Jarul	4	Bon pisli	3	Kolapati	1
Chatian	3					Dumur	24	Gulli	3	Kaikka	1	Bon supri	6	Koroi	1
Dewa	1					Gamar	16	Tejpata	1	Kanchan	1	Bonak	32	Kurcha	2
Dharmara	3					GandhoNarikel	1	Hingra	1	Kanthal	2	Bonmala	1	Laldumur	2
Dharmcra	1					Garjan	7	Jam	10	Khapaisa	2	Bormala	3	Maitaawal	1
Dumur	47					Goda	1	Jambura	3	Khudi jam	2	Bot	4	Malkanakoroi	3
Eucalyptus	9					Godha	1	Jarul	6	Mahogany	1	Bot awal	1	Mangium	4
Faisshom	1					Gun	2	Jhara	2	Neur	3	Boti jam	1	Pichla	1
Gamar	25					Gutgutia	6	Jolpai	1	Rubber	100	Butia	1	Sada Jam	1
Garjan	17					Harba	4	Kakra	9	Sal	324	Butu jam	2	Shilkoroi	3

PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N
Goda	2					Hatipita	1	KaloDumur	1	Sasra	1	Champa	3	Teak	16
Guava	11					Hijja	1	Kaw	1	Shida	1	Chundul	1	Varenga	2
Guicca	5					Jam	4	Khami	1	Shindhuria	5	Chapalish	45	Eucalyptus	8
Gutgatiya	1					Jarul	12	Koroi	1	Singra	1	Chatim	1	Jaw	8
Hargoja	2					Kadam	2	Korom	1	Tal gach	1	Cholamugur	4	Badi	1
Haritaki	1					Kalibol	1	Kuma	1	Tarokata	1	Dewacham	5	Simul	1
Horina gala	1					Keron	1	kumari	1	Teak	26	Dhawcham	1		
Jam	12					Kerong	2	La1 Dumur	2	Telsur	1	Dishi	1		
Jolpai	1					Komkui	1	Lal Guia	1			Dumur	9		
Kadam	3					Koroi	6	Lud	1			Fula jam	1		
Kalanaricha	3					Kumira	1	Malakana	3			Gamar	12		
Kalodumur	2					Kuruch	1	Moskor	1			Garjan	22		
Kanthal	3					Lotkon	4	Naor	2			Gorug	1		
Kata koroi	4					Menda	3	Pichni	1			Guburia	1		
Kaw	1					Minjiri	1	Pichondi	2			Hargoja	22		
Kechua	6					Moch	4	Pisti	3			Hingra	1		
Khanshak	1					Modon	3	Pittosul	1			Huria	3		
Khorala	1					Pasula	1	Rata	5			Jalna	4		
Koroi	9					Pechigola	1	Rongi	1			Jam	21		
Kuruk	11					Pharula	1	Sadaawal	2			Jarul	17		
Kurukh	3					Pitali	3	Simul	1			Jolpai	1		
Laldewri	2					Pitraj	2	Singra	2			Kadam	3		
Lawa	2					Rain Tree	1	Sonalu	1			Kaimala	1		
Litchi	4					RoktoVerala	4	Bon jambura	4			Kakra	16		
Madar	1					Rongi	6	Dhakijam	1			Kalakurcha	1		
Mandar	1					Sheon	1	Gamar	1			Kata kuar	1		
Minjiri	1					Sheori	2	Jaw	1			Kaw	3		
Moch	1					Shuruj	5	Badi	2			Kewatudi	4		

PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N
Naricha	13					Simul	1	Kanthal	3			Khami	5		
Painna	2					Teak	89	Mahogany	2			Koimela	2		
Pitali	1					Tejbol	1	Mangium	6			Korai	5		
Puigga	1					Udal	9	Rubbar	1			Kudi jam	3		
Puti jam	6					Verala	4	Roktan	1			Kumini	1		
Rupgheh	1					Aam	4	Eucalyptus	4			Kumli	1		
Sal	8											Kurcha	1		
Shuijja	1											Laldumur	9		
Supari	7											Lohakat	7		
Suruj	1											Lud	6		
Teak	17											Mahogany	1		
Telsur	2											Mandar	1		
Udol	2											Mangium	3		
Uriga	2											Mini jarul	8		
Vatgula	2											Neur	3		
Vijja	1											Oloipati	1		
Achargola	11											Orish	1		
Chakuakoroi	1											Pisli	5		
Mahogany	1											Pitali	2		
												puria	2		
												Rata	11		
												Sadapati	1		
												Sal	15		
												Sheowra	5		
												Simul	3		
												Sit	1		
												Sopriawal	1		
												Tairol	1		

PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N	PA/Species	N
												Tentul	1		
												Teak	33		
												Thona	6		
												Vetkoi	1		