# Climate-Resilient Ecosystems and Livelihoods (CREL)
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# Standard Operating Procedures (SOP) for Forest Carbon Inventory, Bangladesh

**Bangladesh Forest Department**
**and**
**Winrock International**

**October 2014**

This Standard is developed with expert review from Forest Department, Protocols for Measuring & Reporting Carbon Stocks in Mangrove Forests by USDA Forest Service (October 2009), Standard Operating Procedures for Terrestrial Carbon Measurement by Winrock International's Ecosystem Service Unit (2012), Protocol for Forest Carbon Assessment by USAID's IPAC Project (April 2010), National Forest, Tree Resources Assessments (2005-2007) by FAO of the UN, Bangladesh and SOP 2014 of CREL.

# Standard Operating Procedures (SOP) for Forest Carbon Inventory Bangladesh

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# 1. Introduction and Background

Bangladesh Forest Department (FD) has been progressing with the implementation of REDD+ activities with assistance from FAO and UNDP. Some of the first steps have been development of the "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 UN agencies, USAID has come forward to facilitate implementation of components of the R-PP through a number of programs including 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 Forest Department and local stakeholders as a follow-up of previous USAID finance Nishorgo Support Project (2003-2008) and Integrated Protected Area Co-management project (2008-2013).

The project took an initiative for conducting forest carbon inventories in a number of Protected Areas (PA) across Bangladesh. It is anticipated that this 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 Forest Department personnel in forest carbon inventory as well as facilitating development of Measurement, Reporting and Verification (MRV) system in Bangladesh.

While developing this protocol, extensive consultation with concerned experts from FD, FAO, WI and CREL team was done; as well as review of earlier forest inventory designs with Bangladesh Forest Department including, Overseas Development Agency (ODA inventory 1984), Forest Resources Management Project (FRMP inventory 1996) National Forest and Tree Resources Assessment (2005-2007), 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) are conducted.

## 1.1. Definitions of land cover

**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.

**Bamboo or mixed Bamboo/broadleaved forest:** Forest in which more than 75% of the canopy covers consists of bamboo or more than 50% bamboo in mixture with broadleaved species

**Degraded Forests**

- Any area of "forest" (see above definition) that has been impacted by human extraction of wood or other vegetation.
- Any area of land that has been declared a forest, does not meet the forest definition (see above), but could regenerate into forest if human activities (e.g. cutting of saplings trees and other wood extraction) were abated or stopped. These lands are commonly dominated by dominated by shrubs, and in some references have been terms "shrublands."

**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** – An area of trees that is or can reach a forest definition (see above definition), but is planted within a village.

**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.

**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.

**Tea garden**– An area identified as a tea garden.

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

## 1.2. Carbon pools for measurements

Five carbon pools in a forest e.g. 1) aboveground and belowground biomass of live trees including seedlings and saplings, 2) non-tree vegetation, 3) dead wood, 4) forest floor (litter), and 5) soil.

Trees aboveground and belowground biomass: 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 dbh<5.0cm; and trees (all live woody stems having a diameter at breast height of 5.0 cm or greater). Diameter at breast height (dbh) is the stem diameter 1.3 m above the ground. Tree: includes seedlings, saplings, and trees >5cmDBH. Trees include above ground biomass (ABG) stem, branches and leaves, and below ground biomass (BGB) roots.

Non-tree vegetation: includes, depending on ecosystem, shrubs, leafy palms, cane, bamboo etc. which consists a large biomass component in the forests.

Dead woods (standing and lying): Standing dead woods are dead trees but standing. 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. Smaller diameter pieces of lying dead woods are considered as litter.

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).

## 1.3. Other measurements:

Canopy Cover: The measurement of percent canopy cover from trees that are >5m height. This does not include any other woody vegetation such as shrubs or cane.

Stumps: the measure of basil diameter of trees that have been cut by humans and extracted from the forest.

# 2. History of Forest inventories in Bangladesh

Based on the sampling designs in recent forest/carbon inventories, this Standard Operating Procedures (SOP) aims to portray national forest inventory and corresponding design for protected areas under CREL project. To be mentioned, earlier forest inventories namely, Canadian Forestal Forestry and Engineering International Limited inventory in Sundarbans, Rainkhiang and Kassalong reserved forests during 1961-1963; Overseas Development Administration (ODA) of U.K. inventory in Sundarbans during 1980-85; Village Forest inventory in 1981; World Bank financed FRMP inventory in Sundarbans, Chittagong, Cox's Bazar and Sylhet during 1996-97, etc. are comprehensive ones which carry long history of forest inventories in Bangladesh. In general, this SOP adopts a refined design from earlier designs and national stratifications of land use used in recent past forest carbon inventories where forest carbons had special focus.

**National forest and tree resources assessment 2005-07:** Forest Department, FAO & local experts followed a global approach for systematic sampling whereby each sampling unit was designated as a "Tract" (1km X 1km) and identified 299 tracts over the country which are laid out at10 minutes longitude and 15 minutes latitude intervals (figure 1). Each Tract comprises of 4 Plots with a dimension 20m x 250m (0.5 ha) and three sub-plots (having a diameter of 3.99 m; i.e. 50 $m^2$) at 5m, 125m and 245m from the plot starting point along the Plot central axis. A remote sensing component with wall-to-wall Landsat TM imageries used for land use classification for the country. The study also enumerated above ground carbon in forests (96 t C/ha), cultivated lands (9 tC/ha), villages (72 tC/ha) and urban areas (46 tC/ha) and inland water (1 tC/ha).

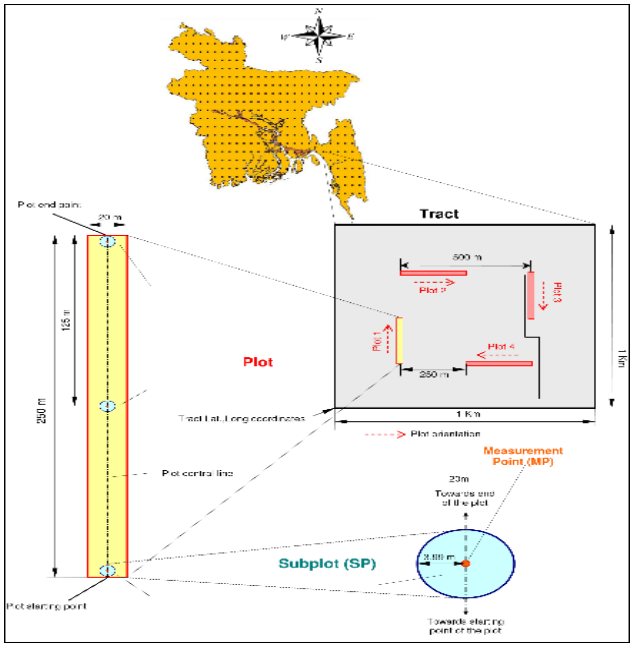


Figure 1.National forest and tree resource assessment 2005—07; diagram of sampling design and plot layout.

**Forest Carbon inventory in the Sundarbans RF (2009):** The SRF carbon assessment, alike earlier forest inventory (WB financed FRMP inventory 1996), considered 150 clustered plot composed of five circular subplots (Figure 2). Forest Department and USFS expatriates adopted this sampling design. These 150 plots are subset of 1200 temporary sample plots (of 1996 inventory) systematically laid in 1 minute interval. The circular subplots in a plot arelaid as a center subplot with four more subplots oriented in cardinal directions(east, west, south, north), 50m from the center. Each subplot has different sized concentricnested circles e.g. 2 m radius for seedlings and saplings, 4m radius for non-tree vegetation, 10m for trees. In addition 30cmX30cm 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 1m 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 30-100cm.

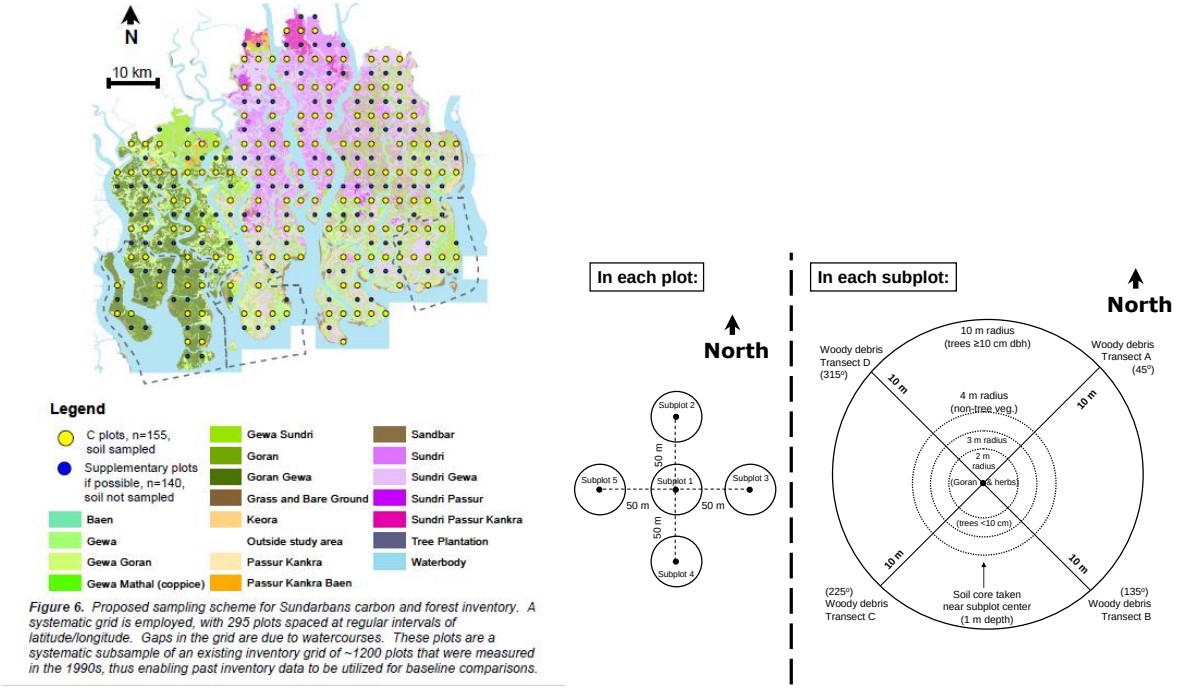


*Figure 6. Proposed sampling scheme for Sundarbans carbon and forest inventory. A systematic grid is employed, with 295 plots spaced at regular intervals of latitude/longitude. Gaps in the grid are due to watercourses. These plots are a systematic subsample of an existing inventory grid of ~1200 plots that were measured in the 1990s, thus enabling past inventory data to be utilized for baseline comparisons.*

Figure 2: Forest carbon inventory for the Sundarbans RF, sampling design (left side) and clustered plot layout (right side).

**Forest Carbon inventory in hill forest protected areas (2010):** Almost similar to SRF inventory (2009) was adopted, by Forest Department and IPAC team, in 6 hill forest PAs at south-eastern part of the country; these includes, Teknaf wildlife sanctuary (TWS), Inani Reserved Forests (IFR), Medakachapia National Park (MNP), Fasiakhali Wildlife Sanctuary (FKWS), Dudpukuria-Dhopachari Wildlife Sanctuary (DDWS), and in Sitakunda eco-park (Figure 3). Since these PAs are different in size and fragmented land uses, 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).

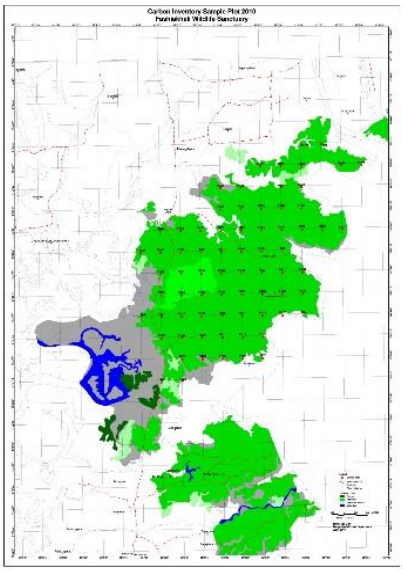

Figure **3**: Example of Fasiakhali WS, IPAC PA sampling design in 2010. The plot layout followed the same methods outline in other PAs. The sampling intensities used in different forest inventories in Bangladesh are summarized in Table 1.

Table 1: Sampling intensity of previous forest (Carbon) inventories in Bangladesh

| Inventories | Radius (m) | plot area (sqm) | Cluster-plot area (ha) | No. of plot | Plot interval | Total inventory area (ha) | total area inventoried (ha) | sampling intensity |
|---|---|---|---|---|---|---|---|---|
| SRF Carbon inventory (2009) | 10 | 314.16 | 0.16 | 150 | 2'X4' | 23.56 | 600,000(411,000) | 0.00004% |
| FRMP inventory (1996) in SRF | 10 | 314.16 | 0.16 | 1,200 | 1'X1' | 188.50 | 600,000 | 0.00031 % |
| NFA 2007-Nationwide | 20mX250m | 5,000.0 | 0.50 | 296 | 10'X 15' | 148.00 | 14,757,000 | 0.00001 % |
| Teknaf WS inventory (2010) | 10 | 314.16 | 0.16 | 54 | 45"X45" | 8.48 | 11,615 | 0.00073 % |
| Inani RF inventory(2010) | 10 | 314.16 | 0.16 | 56 | 40"X40" | 8.80 | 7,700 | 0.00114 % |
| Medakachapia NP inventory (2010) | 10 | 314.16 | 0.16 | 41 | 12"X12" | 6.44 | 396 | 0.01626 % |
| Fasiakhali WS inventory (2010) | 10 | 314.16 | 0.16 | 72 | 15"X15" | 11.31 | 1,302 | 0.00869 % |
| Dudpukuria WS Inventory (2010) | 10 | 314.16 | 0.16 | 62 | 30"X30" | 9.74 | 4,717 | 0.00206 % |
| Sitakunda RF Inventory (2010) | 10 | 314.16 | 0.16 | 35 | 50"X50" | 5.50 | 800 | 0.00687 % |
| Chunati WS CDM (2006) | 5.64 | 99.93 | 0.05 | 218 | | 10.89 | 7,822 | % |

# 3. Description of the Inventory sites

*Add a short description of the proposed site*

# 4. Objectives of the Proposed Carbon Inventory

*Add objectives*

# 5. Sampling Design

*Add a short description*

## 5.1. Estimation of Sample Size (n)

The formula for estimation of sample size may be used as given below:

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 a desired confidence interval; here t = 2 may be used as the sample size for the present sites is not known.

s (std.dev.)= standard deviation estimated from the previous new data.

E = allowable error, Calculated by multiplying the mean carbon stock by the desired precision, i.e., mean *desired precision

Distribution of sample plot for field data collection: Sould be given in proposed area of inventory

## 5.2. Parameters to be recorded/measured:

The parameters to be recorded/ measured from different sample plots may be as given in Table 5.

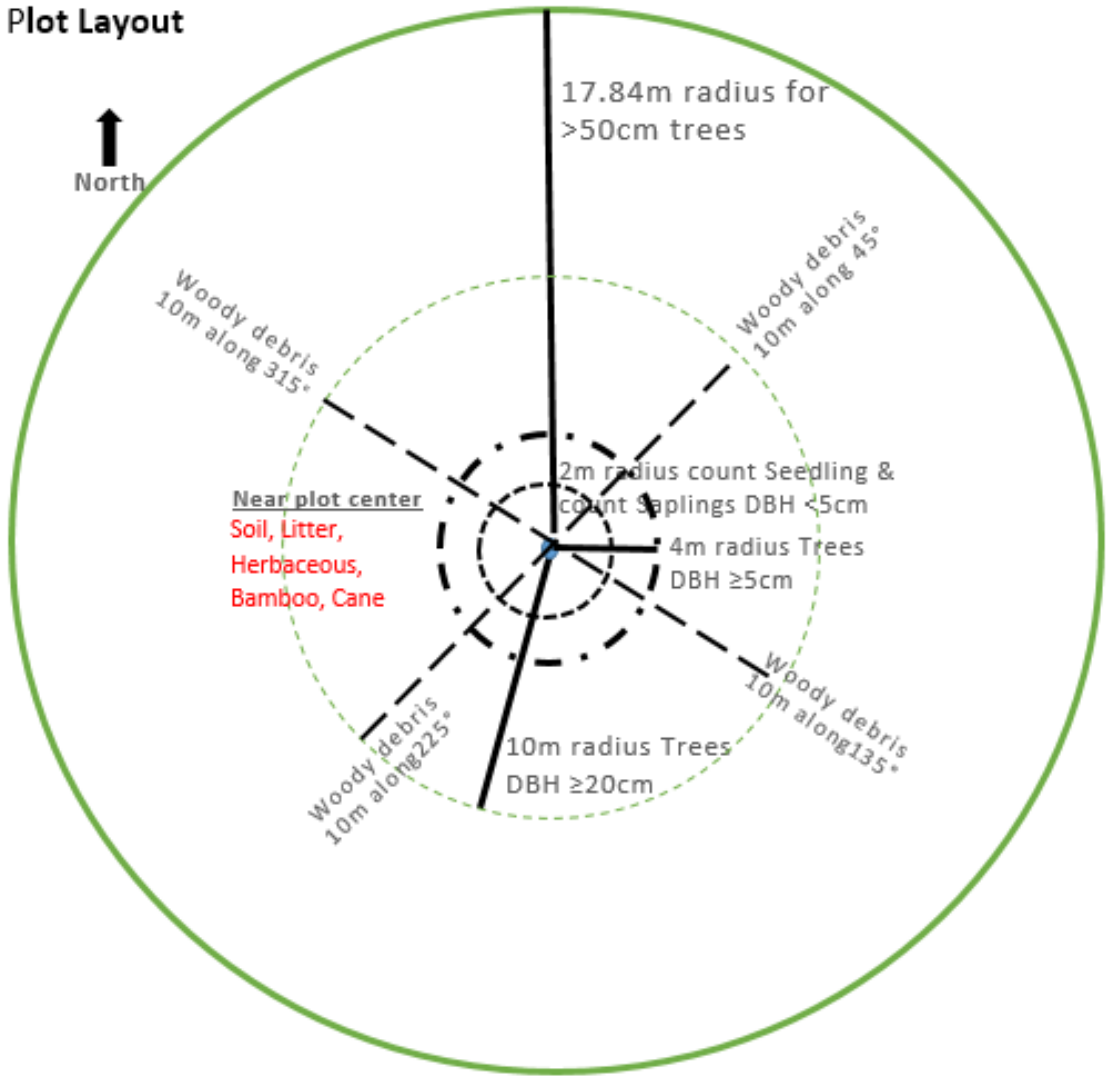


Table 2: Forest Carbon Plot Dimensions for different pools

| Parameters | Activities | Proposed plot radius (m) |
|---|---|---|
| Marking Plot center | Mark plot center, mark three trees around the plot center even if the marking of the plot centre is missing;<br>Photograph of the plots along four cardinal directions; | |
| Seedlings count | Count the number of live seedlings ≤1.3 m tall for all the species. | 2 |
| Saplings count | Count the number of live saplings with DBH≤ 5.0 cm & Height> 1.3 m for all the species & record the name of the most dominant species. | 2 |
| DBH, heights & counts of Bamboos | Record data for bamboos by select size class (small, medium or large) and count the number of culms in each size classes | 4 |
| Trees DBH | Measure DBH of all trees (including standing dead trees) with DBH > 5.0 cm with species name<br>Tree measure, DBH, Stumps (≥10 cm base diameter; with dbh of similar base diameter, if available), standing dead wood. | 4 |
| Palm DBH & height | Measure the height of all palms, species, and if available DBH | 10 |
| Trees DBH | Measure DBH of trees (including standing dead trees) with DBH≥20.0 | 10 |

| Parameters | Activities | Proposed plot radius (m) |
|---|---|---|
| | cm with species name | |
| Trees DBH | Measure DBH of trees ≥50 cm (including standing dead trees), with species name;<br>Tree measure, DBH, Stumps (≥10 cm base diameter; with dbh of similar base diameter, if available), standing dead wood. | 17.84 |
| Stumps | Stumps (≥10 cm base diameter; with dbh of similar base diameter, if available), standing dead wood. | 17.84 |
| Degradation | Measure the base diameter (bd) of all stumps ≥10 cm base diameter that have been cut by humans and extracted from the forest (i.e. stumps). | 17.84 |
| Trees height | Measure heights of three co-dominant trees | 17.84 |
| Lying deadwood | Measure all lying dead wood≥10cm diameter, if it is≥50% above the ground. Measure along transect line from plot centre to 25m at each cardinal direction (45, 135, 225 & 315 degrees) | 25m long, 4 transects |
| Litter | Measure 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. Mix the four samples thoroughly and take a sub-sample (100-150 g) for oven-dry estimation. | 5-cm Square clip plot |
| Grass, herbs | Cut and measure grass, and herbaceous vegetation from the square clip plots described above (litter). Mix the four samples thoroughly and take a sub-sample (200-300g) for oven-dry estimation. | 50cm Square clip plot |
| Weight of shrubs | In case of plots with shrubs only: Cut all shrubs, take weight of all shrubs and take one sub-sample (200-300g) of the shrubs for oven-dry weight estimation. | 2 |
| Soil Organic Carbon | Soil Samples for organic carbon will be taken using soil sampler/pit method at 4 locations (covering valley, slope and flat) to 0-15 cm and 15-30cm depth. All 4 samples should be mixed thoroughly (till of consistent texture and color) and then take a sub sample (200-300g) in a sample bag. | Sample depth 30cm |
| Soil Bulk Density | Soil Samples for bulk density one locations at 2 depths (0-15 cm and 15-30 cm). Each bulk density sample must be placed in an individual sample bag for lab analysis. | Sample depths0-15 cm & 15-30 cm |
| Canopy closer | Take canopy cover with Densiometer at 10 m from the centre at four cardinal directions N, E, S and W | |

## 5.3. Personnel, logistics and equipment requirement

### Personnel

For data collection nessessary number of teams may be required (one of these will work as control team for data verification). The compositions of the teams may be composed as given below:

Team Leader – 1: For data recording and over all supervision of the team works
Dy. Team Leader-1: For taking the records of the non-tree vegetation, stumpsetc.
Forester/Beat Officer– 1: For measurements of plot dimensions with team leader and tree measurements
Student- 1: Assisst the Dy Team Leader for measurements and reccodings
Forest Guard -1: Assist Team leader and Dy. Team Leader (May be engaged for ODK data entry)
Local CMO representative (CPG/Eco-guide/NS/VCF)-1: Assist data collections.
Local labour-1: Assist to go the plot and data collleection.

## Logistics

One four wheel drive vehicle
Road maps
Plot location maps printed to correspond with plot IDs stored on the GPS
Food, water and first aid

## Equipment

The list of equipment required is given in Table 6 and Table 7.

Table 3: Field Equipment List for Forest Carbon Inventory (From USA)

| Sl | Equipment | Quantity /team | Total Qty | Use/Info | Description |
|---|---|---|---|---|---|
| 1. | DME (Haglof DME 201 Cruiser - Complete Unit) | 2/team | 12 | Circular tree plots - or can decide to do square plots | Haglof DME 201 Cruiser - Complete Unit |
| 2. | Haga Altimeter | 2/team | 12 | | |
| 3. | Laser range finder (Opti-Logic 400XL Laser Rangefinder, feet/yards/meters) | 1/team | 6 | tree heights, standing dead trees, canopy gap opening. Not sure if essential for this project | Opti-Logic 400XL Laser Rangefinder, feet/yards/meters |
| 4. | Metric Diameter tape measure (Lufkin Chrome-Clad 3/8" Wide line is chrome-clad steel with black graduations. Claw hook, hand crank rewind and vinyl covered steel case. Case dimensions: 3-1/2" x 1") | 3/team | 18 | tree plots | Lufkin Chrome-Clad 3/8" Wide line is chrome-clad steel with black graduations. Claw hook, hand crank rewind and vinyl covered steel case. Case dimensions: 3-1/2" x 1" |
| 5. | Hanging scale - 100 g (Model 40300 - Capacity 100g x 2g, Length 22 cm) | | 6 | | |
| 6. | Hanging scale - 300 g (Model 40300 - Capacity 300g x 2g, Length 22 cm) | 1/team | 6 | weigh subsamples | Model 40300 - Capacity 300g x 2g, Length 22 cm |
| 7. | Hanging scale - 2 kg (Model 42500† - Capacity 2,500g x 20g, Length 22 cm) | | 6 | weigh saplings, shrubs, non-tree vegetation. Size needed depends on how large understory vegetation is | Model 42500† - Capacity 2,500g x 20g, Length 22 cm |
| 8. | Compass (Silvapolaris) | 1/team | 6 | Clip plots, square plots, safety | Silvapolaris |
| 9. | Densitometer (Convex Model A) to determine forest over story density or canopy cover | 1/team | 6 | Not sure need. Would only be used if want to estimate canopy cover | grsgis.com/densitometer/index.htm |
| 10. | Measuring Tape 50 m (Metric Open Reel, Graduated Both Sides Meter, cm, 2 mm one side - Meter, cm, 5 mm other side ,50m, OTR-50 mm ) | 1/team | 6 | | Metric Open Reel, Graduated Both Sides Meter, cm, 2 mm one side - Meter, cm, 5 mm other side ,50m, OTR-50 mm |

| Sl | Equipment | Quantity /team | Total Qty | Use/Info | Description |
|---|---|---|---|---|---|
| 11. | Measuring Tape - 30 m (Metric Open Reel, Graduated Both Sides Meter, cm, 2 mm one side - Meter, cm, 5 mm other side ,50m, OTR-30 mm) | 1/team | 6 | | Metric Open Reel, Graduated Both Sides Meter, cm, 2 mm one side - Meter, cm, 5 mm other side ,50m, OTR-50 mm |

Table 4: Field Equipment List for Forest Carbon Inventory (LOCAL PURCHASE)

| Sl. | Equipment | Quantity /team | Total Qty | Use/Info |
|---|---|---|---|---|
| 1 | Digital Camera | 1/team | 6 | Already available with CREL |
| 2 | GPS (Garmin 78S) with additional pair of rechargeable battery | 1/team | 6 | Already available with CREL; Garmin78S with SIRF® GPS Receiver and 64MB SD Card |
| Consumables | | | | |
| 3 | First Aid Kit | 1/team | 6 | |
| 4 | Equipment backpacks | 3+/team | 15 | to carry equipment, lunch, and water into field |
| 5 | Cover for Nexus Tabs | 2/team | 12 | |
| 6 | Clippers | 2/team | 12 | to cut understory vegetation for clip plots, litter |
| 7 | Machete (locally made Dao) | 1/team | 6 | |
| 8 | Stakes for plot center | 464 nos. | | A local wooden poles taller than average thick understory vegetation will be used to mark the plot center |
| 9 | Bright colored paint (orange/red) with a Brush | 2 lbs/team | 12 lbs | |
| 10 | Clip board | 1/team | 6 | Readymade Aluminum Portable Desk |
| 11 | Cloth bags for sample (soil, litter, seedlings, clip plot) collection. | 5/site | 4250 | Soil bags. Can make locally w/ draw string. Make at least ~40 cm long x 15 cm wide |
| 12 | Non-stretching, light weight, durable, thin nylon rope | 1kg/team | 6 kg | Non-stretching nylon rope to locate the distance from the centeralong with DME. |
| 13 | Hammer (wooden handle with iron weight) | 1/team | 8 | for permanent plots |
| 14 | Piece of wood to place over hammer | 1team | 8 | for permanent plots |
| 15 | Chalk sticks | 2box/team | 12 | to mark measured trees |
| 16 | Durable plastic tarp ~2 m x 2 m (Terpal) | 1/team | 6 | to put equipment on while measuring plot |
| 17 | Clip Plot (pvc) each with 200cm pipe + 4 corner joints | 2/team | 12 | For clip plots: non-tree vegetation and litters |
| 18 | Hand Saw | 1/team | 6 | cut dead wood density samples, cut shrubs |
| 19 | Permanent Marker (black) | 5/team | 30 | |
| 20 | Pens | 1 dozen/team | 6 | |
| 21 | Pencils | 1 dozen/team | 6 | |
| 22 | Note book | 4 No. /team | 24 | |
| | Iron pipe (each with dia-5 cm, length 7cm) | 2 no. /.team | 8 | To take soil bulk density samples |
| 24 | Digital weight scale 5kg | 1 no. /team | 6 | |

**Inventory schedule**

*The proposed Carbon Inventory schedule should be added*

## 5.4. Distribution of Responsibilities

The seven personnel of the team will form two groups to ensure proper distribution of works amongst the team members. The first group will be formed with the team leader, student, one of the CREL personnel, Forester and the Forest Guard (FG) for tree, bamboo, cane & palm measurements. The second group will be formed by remaining two personnel of the team for sample collection & measurements (Seedling, sapling, clip plots, litter, soil samples etc.)

## 5.5. SOP for Field Measurements

### 5.5.1 Establishment of the sample plots

For identification of sample plots for field checking, it is necessary that the starting points for access to the samples are marked by signs on trees or by stakes driven into the ground. The starting points and as well as the lines of access will be shown on the maps and recorded in GPS. The team will proceed along the grid line with the help of GPS and other measuring equipment.

The plot locations will be superimposed on Google maps and classified recent imageries for land uses (e.g. Forests, Degraded Forests, Agriculture, Settlements and Water bodies). The plot locations (latitude &longitudes) of the plots for each team will be uploaded to each team's GPS. The team members of the teams will approach to the plots with help of the map and GPS as follows:

1. Navigate to predetermined latitude and longitude using a GPS.
2. Walk an additional 10 steps in the direction of travel for choosing the plot center.
3. At the plot center, mark a 'waypoint' on GPS and record GPS coordinates, accuracy, elevation, and waypoint number on data sheet. To record a GPS location, place the GPS at the plot center and let it record for > 5 minutes prior to saving 'waypoint'.
4. Measure the slope using a clinometer. If the slope is greater than 10% record the exact slope for later correction of plot area.
    1. Two people are required to measure slope.
    2. The person with the clinometer shall identify the eye-level sight of the partner.
    3. The person with the clinometer should stand in the center of the plot and the partner should go to the edge of the larger nested plot.
    4. The person with the clinometer standing in the center of the plot shall then aim at the eye-level location in the partner and record the angle reading displayed in the clinometer. This angle is the slope angle and could be recorded as degrees (unit should be delineated in field sheets).
5. Describe land and vegetation conditions of plot (see Appendix 1, 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.
6. Take 4 photos of the plot and record the photo numbers on the plot sheet (Form 2).Each photo should be taken facing each of the cardinal direction (N, E, S, W) take each photo 2m from plot center so that the plot center stake (or pole) is visible in the photo.
7. Mark center of the plot by driving 30cm long metal rebar stake into the ground till just 10-20cm are left above the ground. Mark the top of the stake with brightly colored paint or a visible plastic cap. Then, mark 3 trees that generally surround the plots center (i.e. even spaced around plot center) and that are as close as possible to plot center with a small dot at exactly DHB height, the dot is exactly facing plot center.

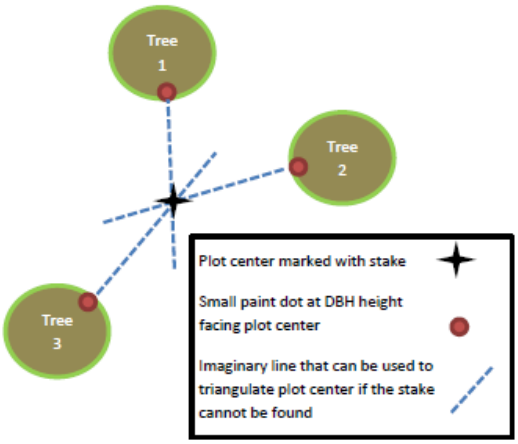


Figure 4: Example of how to mark the 3 trees around plot center so that they can be used to triangulate plot center in the future if the stake cannot be found.

The goal for marking the 3 trees is so that if the plot center is removed or lost it can be found by using the 3 trees to triangulate the plot location. It is very important to establish a plot center that can be found again during future inventories. Because this inventory is measuring degradation, it is also very important to minimize the evidence of the plot measurement (e.g. big marks on all the trees) which will dissuade local activities that result in degradation. This will be used to identify the plot center during any third-party verification or quality checks.

### 5.5.2. Identification of plot boundary with DME

Place the DME stand in the center point of the plot. In areas with dense vegetation, it is recommended that a piece of bright colored flagging be placed on branches above the DME stand to increase visibility. Because the DME is essential for establishing circular plots, extra batteries should always be carried into the field. Alternatively, a rope/cord and/or a tape measure may be used to identify the boundary of circular plots. If a rope is used, the length of the rope must be measured prior to each plot establishment with a tape measure as many ropes are made out of material that stretches over time or when wet.

### 5.5.3 Measurements of Tree, Seedlings and Saplings

- Stand at the plot center with one end of a tape and the CREL personnel with other end of the tape and guide the tree measuring persons whether in or out of the plot measuring the tree. The team leader will record tree data (seedling & sapling count number, diameter at breast height (DBH) of all trees, height of three co dominant trees measured and the student will record the data, the Forester will measure and mark trees. The recorder should stand in the center of the plot being measured. He should track those measuring the trees and should try and ensure that no trees are missed. These members will also record the data of bamboos, canes&, palms. A 1.3 m long pole should be used to mark the DBH point.
- To avoid either missed trees or double recording, measurement should begin to the North and the first tree should be flagged. After a tree is measured, a chalk mark facing the center of the plot should be placed on tree to allow the person recording the data to track measured and unmeasured trees.
- Count the number of seedlings (defined as seedling height ≤1.3 m)and record the number on data Form 2. Similarly, count the number of saplings (sapling trees with DBH<5 cm and >1.3 m tall) and record the number on data Form 2. Record the name of the most dominant species and record on data Form 2.

*Diameter at breast height (DBH) measurement:*

1. Always place tree pole and measure DBH on the *upslope* side of the tree

2. Leaning tree: Always measure the height of a measurement (1.3 m) parallel with the tree, *not* perpendicular to the ground. Therefore, if the tree is leaning, measure underneath the lean, parallel with angle of tree. If a tree is not straight, a tape measure must be used to measure the bole distance from ground to DBH.
3. Multi-stem tree: If the tree is multi-stemmed with forking below the point of measurement (e.g. 1.3 m), measure the diameter on each stem. Record it as if each stem were a different tree on the data sheet, but with a note that the stems make up one tree.
4. Buttressed tree
    - If the buttress is shorter than 1.3 m, measure the DBH at the standard (1.3 m) height.
    - If the buttress is taller than 1.3 m, measure the diameter at 30 cm above top of buttress. Mark the exact height of the measurement with a spot of paint. This spot of paint will ensure that if the tree needs to be re-measured in the future it will be clear where the DBH was measured.

DBH measurements are illustrated in Figure 8.

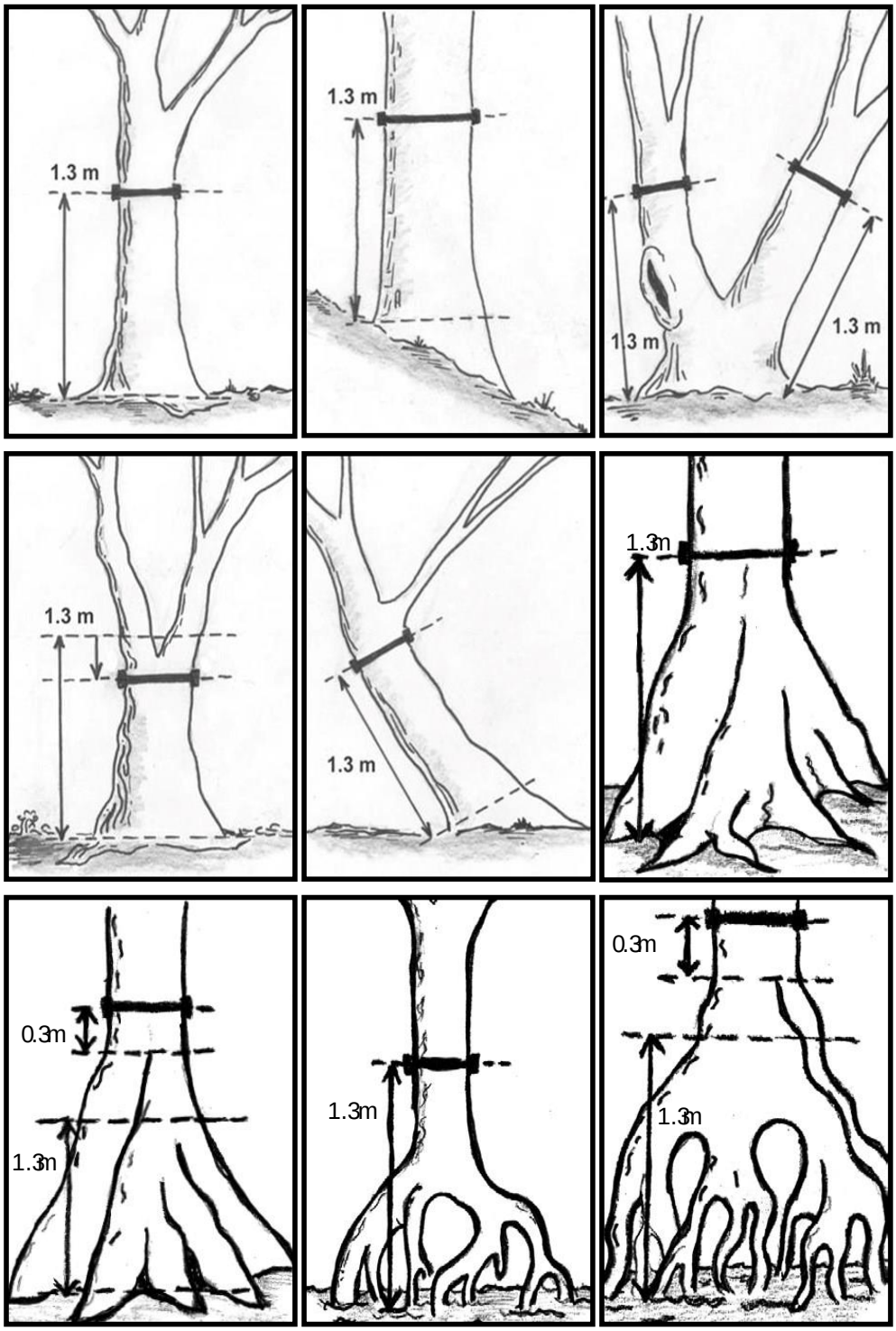


Figure 5: Proper placement of diameter tape (SOP WI 2012).

Tree DBH should be measured to the nearest 0.1 cm. If the diameter tape has a hook, push the hook into the bark of the tree slightly to secure it and pull the tape to the right. The diameter tape should always start left and be pulled right around the tree, even if the person taking the measurement is left-handed. As the diameter tape wraps around the tree and returns to the hook the tape should be above the hook. The tape should not come around the tree below the hook. The tape should not be upside down; the numbers must be right side up (Figure 9). Place chalk mark on the tree to indicate to crew members that the tree has been measured.

Figure 6: Measurement of diameter using a diameter tape and tree pole (SOP, WI, 2012)

Other tree parameters: The volume/biomass tables are based on DBH or DBH &total height of the tree. So, measure the total height of three co-dominant trees.

**Boundary trees**: Occasionally trees will be close to the border of the plots. The plots are relatively small and will be expanded to estimate biomass carbon on a per hectare basis. **It is therefore very important to carefully decide if a tree is in or out of a plot**. Extra care should be taken with boundary trees to assure they are in or out of the plot; this may involve using a measuring tape stretched from plot center to exactly the mid-point of the tree. To definitively determine whether the tree is in or out of the plot, use a tape measure to measure out from the plot center to the base of the boundary tree. If the plot is on sloped ground, make sure the measurement follows the slope. If 50% of the base of the trunk is within the boundary of the nest, the tree is in. If more than 50% of the base of the trunk is outside of the boundary, it is out and should not be measured.

When all of the trees in the plot have been measured, there should be a double check to see that all of the trees have been measured.

*Measurement of Heights*

The height of trees, palms, and other things is usually done by creating two right triangles. The distance from the object and the person measuring is measured and two angles are measured. The actual height is then calculated using trigonometry during data analysis.

1. Walk around the tree and find the best location to view the top of the tree.
2. Stand far enough away from the tree so that the top of the tree is less than 90 degrees above the line of sight.
3. Measure total tree height (see Figure below):
   - Always stand up-slope of the tree. Standing down-slope of the tree should only take place when no other option exists.
   - Using clinometer, measure the angle in % to top of the canopy of the tree (a%)
   - Using clinometer, measure the angle in % to base of the tree (b%)
   - Using Laser Range Finder or measuring tape, measure distance from eye of person measuring tree to the tree ($dis_{tree}$) in meters. Be certain that the distance measured is horizontal and not along the slope. Record the horizontal distance to the nearest 0.01 meter
4. Repeat measurements in another location, thus measuring tree height in two locations.
5. If you are not able to stand far enough from the tree so that the top of the tree is less than 90% above you, then take the measurements (a) and (b) in degrees (units on left side of clinometer). CAREFULLY NOTE ON THE DATA SHEET THE CHANGE IN UNITS! Tree height must be calculated differently if degrees are used!

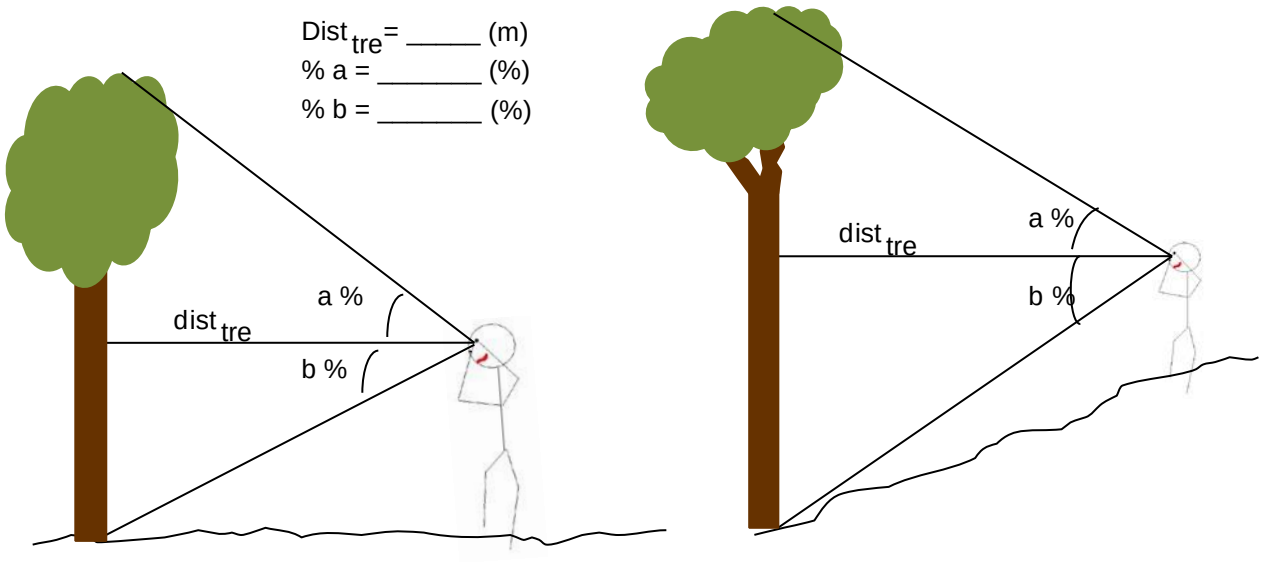


Figure 7: Tree height field measurements

*Seedlings and Saplings*

The biomass of trees smaller than the minimum size tree applicable to the allometric equation can be estimated using alternative approaches. In this SOP these smaller trees are divided into two groups seedlings and saplings.

Seedlings are all young trees with height ≤1.3 m
Saplings are all young trees DBH<5 cm and >1.3 m tall

Count the number of seedlings and saplings in the 2 meter radius plot and record on data sheet. (After field data collection, the number of saplings will be combined with the average sapling weight to estimate total sapling biomass (see 'SOP Destructive sampling of trees, saplings, palms, and bamboo')).

Record the dominant species of seedlings and saplings. Record on From 2

*Measurement of Palms*

Allometric equations for palms will be based on height and DBH. For palms, unlike trees, the height has a better relationship with biomass than DBH. All palms in the 10m plot ≥1.3m in height shall be measured and recorded on the plot sheet Form 2. All smaller palms will be ignored.

Measure palms at the same time as trees.

Measure all palms taller than 1.3 m within the 10m nested plot.

Measure the height and DBH of the palm and record on From 2

Record the palm species.

### 5.5.4 Stumps from Human Degradation

Measuring degradation from illegal fuel wood or timber harvest is difficult due to the uneven distribution and frequency from this type of human degradation. Commonly degradation occurs more frequently the closer to human infrastructure and areas where there is greater need for wood products. Ideally to measure degradation a sampling design would be developed that takes these spatial parameters into account. However, this SOP is using a simple systematic grid sampling design; therefore it is not taking these spatial parameters specifically into account. To measure degradation:

- Measure base diameter in cm of all stumps with a base diameter ≥10cm at 15 cm above the ground if available otherwise at top of the stump within the 17.84m plot & record in Form 3A.
- List the stump ID as S01, S02, S03, …

- Indicate 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, indicate if the canopy gap is small, medium or large.
- 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.
- 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.
- 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.
- Identify a sample tree that has not been cut (a live tree) within or near the plot that has a similar/same base diameter. As best as possible try to identify a tree that is also a similar or same species. Measure that trees DBH at 1.3m height and species (following SOP section 3.5.1) and record in the same line as the stump measurement on the plot sheets (Form 3A).The goal of measuring the "sample tree" is to get a proxy measurement of what the stumps DBH was before being cut, so that we can estimate the biomass lost when that tree was cut.

### 5.5.5 Canopy cover

Canopy cover measurements may aid in leveraging remotely sensed data to track forest degradation.

A spherical densiometer is used to estimate canopy cover.

It should be held 30-40 cm in front of your body and at elbow height, so that your head is not visible in the mirror.

Level the instrument using the level bubble.

In each square of the grid, imagine that there are four dots, representing the center of quarter-square subdivisions of each of the squares (Figure 11).Systematically count the number of dots NOT occupied by canopy (where you can see sky at that dot).Record this number on the datasheet.

Make four readings per location at 10m from plot center in each of the 4 cardinal directions (north, south, east, and west).

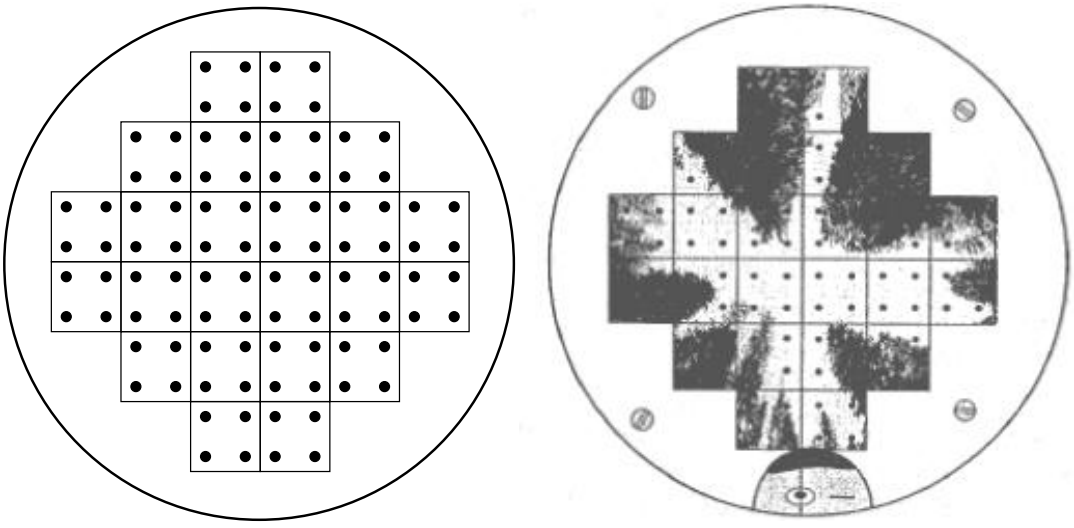

Figure 8: Schematic of densiometer mirror, with the 4 dots depicted in each square. Count the number of dots NOT occupied by the canopy, in the 4 cardinal directions at each subplot.

## 5.5.6 Measurement 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 take place concurrently with live tree measurements (following the same plot dimensions as live trees) and record in Form-3A. Each standing dead tree should be 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 will be taken.

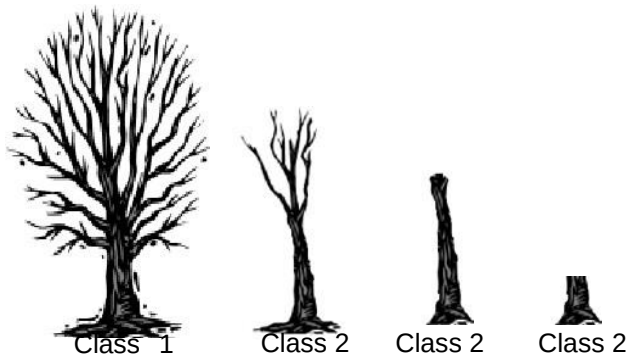


Figure 9: Examples of trees in Class 1 and Class 2.

**Class 1 tree:** Follow the same measurement protocols as for the measurement of live trees; including the measurement of tree variables (e.g. DBH, H) (see SOP Measurement of Trees). If species/genus specific allometric equations require different field measurements, rules must be included in this SOP stating which field measurements will be made for which type of dead tree (for example – for all Class 1 dead trees, the 'other' tree allometric equation will used and DBH of dead trees will be measured.) If nested plots are used, only dead trees of the appropriate size (e.g. DBH) should be measured for each nest. Mark tree as 'Dead' on datasheet.

**Class 2 trees:**

1. The biomass of these trees is based on estimating the volume of the remaining tree and multiplying the volume by the wood density.
2. Measure DBH using methods for live trees. .
3. Measure the diameter at the base of the tree. ($D_{base}$)
4. Measure height of stem (H) using a clinometer
5. Measure diameter at top of stump ($D_{top,}$) if possible otherwise does not and writes NA on datasheet.

## 5.5.7 Measurement of Lying Dead Wood

Lying dead wood is defined as all woody material on the ground with a diameter $\geq$10 cm. Smaller diameter pieces of wood are 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
Lay out four 25 m lines at right angles within the land use type.

Along the length of the line, measures the diameter of each intersecting piece of coarse dead wood ($\geq$ 10 cm diameter) (see Figure below).Calipers work best for measuring the diameter. When measuring the diameter of dead wood it is not always possible to place a tape around the log. It can also be dangerous because logs are

usually home to snakes, spiders, etc.If you are going to measure the diameter of the piece of dead wood with a diameter tape, make sure the route is clear before placing your hand underneath the log.

Figure 10: Use of calipers to measure the diameter of lying deadwood

A piece of dead wood should only be 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—see figures below. Some examples are displayed in the Figure below.

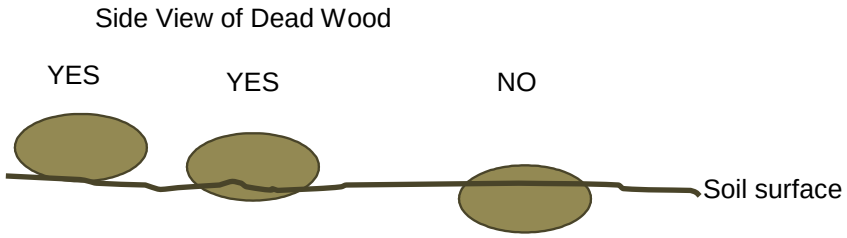


Figure 11: Schematic of which dead wood should be measured. The first two logs should be measured because the log is more than 50% above ground, but the third log should not be measured. The horizontal line represents the soil surface.

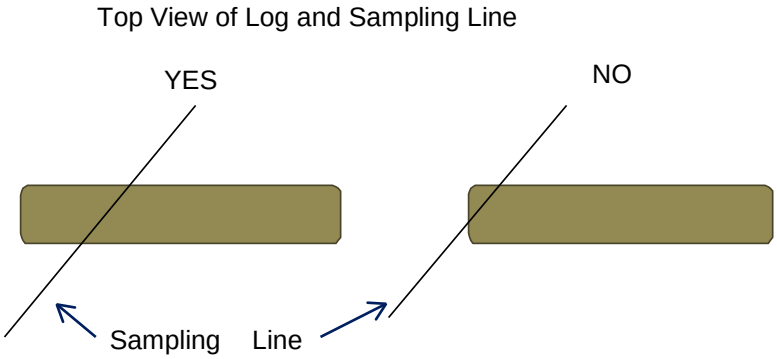


Figure 12: Schematic of which dead wood should be measured. The first log should be measured because the sampling line crosses more than 50% of the diameter of the log. Conversely, the second log should not be measured because the sampling line does not cross more

If the log is hollow at the intersection point, measure the diameter of the hollow; the hollow portion in the volume estimates is excluded.

Assign each piece to one of three density states: sound, intermediate, or rotten. To determine what density class a piece of dead wood fits into, each piece will be struck with a machete. If the machete does not sink

into the piece (bounces off), classify it as sound. If the machete sinks partly into the piece, and there has been some wood loss, classify it as intermediate .If the machete sticks into the piece, if there is more extensive wood loss, and the piece is crumbly, classify as rotten. Record on data sheet.

The volume of lying dead wood and then carbon stocks will be estimated using the diameters of each piece of wood and the length of the line transect.

### 5.5.8. Soil % Organic Carbon and Bulk density

Soil carbon is estimated by collecting so il to a certain depth and then analyzing it in a laboratory for carbon content. This information is then combined with a collected bulk density measurement to estimate the average mass of carbon within the soil to a certain depth[5].

Bangladesh Forest Research Institute (BFRI) has been select for soil analysis and taking oven dry weights of other samples. This Division of the Institute is mandated and is carrying out these tasks since long.

*Soil % Organic Carbon*

We will collect soil samples following Soil pit method. Pits will be dug one at top, one at valley, one at slope and the last one on flat locations (covering all different soil carbon deposits) as given below:

- Dig soil pits 30 cm deep; making sure that one of the walls facing the sun is perpendicular to the soil surface.
- Using the shovel take a slice of soil from vertical walls of the soil pit one from 0-15 cm and other from 15-30 cm. The slice should be uniform throughout.
- Repeat steps a & b at the other 3 sampling locations.
- Mix all four samples of 0-15 cm depth thoroughly to a uniform color and consistency. It is important to take special care to remove pieces of litter and charcoal from samples at any sites. Simillarlly mix the samples of 15-30 cm depth and take a second sample.
- Place one thoroughly mixed subsample of about 200 gram soil into a labeled sample bag.
- .
- Label the sample SOC, Plot ID# (e.g. SOC, LNP001)

[5]An assessment must be made to ensure the soil laboratory applies commonly accepted standard procedures for sample preparation (e.g., mixing and sieving), drying temperatures, and method for carbon analysis. In addition, the soil laboratory may have a minimum soil sample weight requirement for soil processing. For bulk density determination, make sure the lab dries the samples in an oven at 105°C for a minimum of 48 hours. For soil carbon determination, the material is sieved through a 2-mm sieve and then thoroughly mixed. The dry combustion method using a controlled-temperature furnace (e.g., a LECO CHN-2000 or equivalent) is the recommended method for determining total soil carbon (Nelson and Sommers 1996) but the Walkley-Black method is also commonly used.

Figure 13: In this picture the soil cores are being scraped into a bucket where they will be thoroughly mixed and then a subsample will be placed in a bag to be sent to the laboratory.

*Bulk Density*

Four small pits, one at each of the four Clip plots, will be dug and aggregated into one sample.

Dig a soil pit 30 cm deep; making sure that one of the walls is perpendicular to the soil surface.

For each sampling plot, two estimate of bulk density shall be taken using a bulk density ring one at 7.5cm depth and a second at 22cm depth. These depths should be measured as the center of the bulk density ring. When taking samples of bulk density, care should be taken to avoid any loss of soil from the ring and any compaction of soil. *This is very important*. The goal of the bulk density sample is to get an accurate quantity and density of soil from each layer. If the soil is compacted by hammering the bulk density ring in too hard, or soil is lost from the sample it can significantly alter the final estimation of soil organic carbon.

Cover the bulk density ring with a piece of wood and hammer the ring into the side of the soil pit (avoid compacting the soil).

When the ring is flush with the side of the soil pit dig around the ring until the soil ring can be removed along with all the soil inside. If soil falls out of the ring, the process must be repeated.

Carefully place the soil contained in the bulk density ring into a sample bag and label BD1 and BD2 along with Plot ID#.

Therefore, each sampling plot (e.g. tree plot) will have three soil samples: 1 bag for soil carbon estimation and two bags for bulk density estimation.

Promptly send soil samples to a professional lab for analysis.

Figure 14: Bulk density ring with soil samples; and the pit from where soil profile is taken.

### 5.5.9. Measurement of Bamboos

Allometric equation will be based in bamboo size class and stem count. The size class will be divided into small, medium, and large. Small is based on an average stem size ≤4cm, medium is based on average stem sized >4cm and ≤8cm, and large ≥8cm.Dependeing on the intensity of occurrence, measure the DBH and Height of average bamboo culm for each class from 2m or 4 m or 10 m radius and record in Form-5. In the 2m plot count the bamboo stems. If the bamboo is a clump the number of stems should be estimated to the best of the ability of the field team.

Classify the average size of the bamboo stems in the 2, 4, 10 or 17.84m plot into small, medium and large.

Count the number of stems in each clump and number of clumps in each DBH class.

After field data collection, a number of each bamboo size class will be weighed to estimate the average biomass of each size class (see ‘SOP Destructive sampling of trees, saplings, palms, and bamboo’).

## 5.5.10. Measurement of Litter and Herbaceous

The small areas where litter and herbaceous (non-woody)is measured are here referred to as ‘clip plots’. A square clip plot frame made of PVC pipe 50 cm x 50 cm will be made for sampling. It will remain in pieces so that it can be constructed around existing vegetation. The ‘elbows’ used to connect two pieces of piping together may be glued to one piece of piping.

As five individual teams will be engaged for data collection, a fixed bearing of 45, 135, 225, 315 degrees and at a distance of 10 m from the center will be followed.

Clip plots will be used to sample litter and the same clip plots will be used for herbaceous vegetation measurement.

*Litter*

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

- Record the sample ID# as “Litter, Plot ID#” on the plot sheet (Form 3E) and on the subsample bag that the littler subsample will be collected in(e.g. Litter, LNP001 for Litter Subsample, Lawachara National Park plot 001).
- Record the weight of the empty sheeting or tarp where litter will be placed.
- Place clip plot at location. The clip plot frame may need to be placed around existing vegetation and then constructed (Figure 18).
- Collect all litter inside the frame. A knife can be used to cut pieces that fall on the border of the sampling frame. Place the litter on the plastic sheeting or tarp.
- Weigh litter. Record the total weight of litter within the clip plot.
- If there is no litter within the clip plot area, the clip plots should *not* be moved. Instead the litter shall be recorded on the data sheet as ‘zero’.
- Take a sub-sample of litter. This should be a subset of the total sample and shall be made up of a mix of litter types found within the total sample. Place subsample temporarily in a sample bag.
- Repeat steps 1-4 for the remaining three locations.
- Combine all four subsamples into one subsample bag.
- Weigh the subsample bag empty. Record weight (Form 6).
- Combine the subsamples from all 4 subplots into one subsample bag.
- Weigh the subsample bag with the subsample inside. The weight should be between 100- 300 g. Record the actual weight (Form 3E).
- Label the subsample bag with the plot identification number (e.g. LNP001), subsample identification number (i.e. Litter), and weight of subsample.
- Take the subsample bag and subsample from field. Bring to the laboratory and dry the subsample. Reweigh the subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the total dry weight of litter found within the clip plot.

Figure 15: Example of litter clip plots

*Measurement of Herbaceous Vegetation*

Record the sample ID# as "Veg, Plot ID#" on the plot sheet (Form 6) and on the subsample bag that the non-tree vegetation subsample will be collected in (e.g. Veg, LNP001 for Non-tree Vegetation Subsample, Lawachara National Park plot 001).

Record the weight of the empty sheeting or tarp where litter will be placed.

1. Identify all herbaceous and non-timber woody vegetation that has stalk base originating from inside the area of the clip plot. This vegetation shall be cut at ground level. Any vegetation which have stems and leaves hanging into the plot but whose base is located outside the area of the plot shall *not* be clipped and measured.
2. Weigh clipped vegetation.
3. If there is no herbaceous vegetation within the clip plot area, the clip plots should *not* be moved. Instead the herbaceous biomass shall be recorded on the data sheet as 'zero'.
4. Take a sub-sample of vegetation. This should be a subset of the total sample and shall be made up of a mix of species and vegetation found within the total sample. Place vegetation temporarily in a sample bag.
5. Repeat steps 1-4 for the remaining three locations.
6. Combine sub-samples into one sub-sample bag.
    - Weigh the subsample bag empty. Record weight (Form 6)
    - Combine the subsamples from all 4 subplots into one subsample bag.
    - Weigh the subsample bag with the subsample inside. The weight should be between 100- 300 g. Record the actual weight.
    - Label the subsample bag with the plot identification number, subsample identification number, and weight of subsample.
    - Take the subsample bag and the subsample from field. Bring it to laboratory and dry the subsample. Reweigh the subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the total dry weight of non-woody vegetation found within the clip plot.

Figure 16: Example of measuring herbaceous biomass within a clip plot

## 5.6. Destructive Samples of Trees, Saplings, Palms, Bamboos, Shrubs &Herbs

We have volume table and densities of all important tree species in Bangladesh. We will use these for estimation of biomasses of trees. But, we do not have equations/models to estimate the biomasses of bamboos, canes, shrubs. We will collect destructive samples for estimation of biomass for these.

### 5.6.1. Measuring the Weight of an Average Seedling &Sapling

The small trees will be divided into two groups: Seedlings and Saplings (DBH<5.0 cm). The seedling is a tree that has not yet attained a height of 1.3 m. The sapling is a tree that has attained a height more than 1.3 m with a DBH< 5.0 cm..

At each of selected locations:

1. Select2 (two)seedling and 2 (two)sapling that representthe full range of sizes (from small to large samples)
2. Cut sapling at base
3. Weigh empty piece of plastic sheeting. Record weight of plastic sheeting in Form 6.
4. Place all of harvested sapling on plastic sheeting and weigh. Record weight of sapling.
5. Select a representative subsample of sapling.
6. Weigh the subsample bag empty. Record weight.
7. Weigh the subsample bag with the subsample inside. Record weight.
8. Label the subsample bag with the sapling name (Seedling01, 02, 03,… and sapling01, 02, 03,…), Plot ID#number (e.g. LNP001), weight of sapling/seedling , and weight of subsample
9. Until samples are taken to the laboratory, place samples in location that allows air drying to occur.

   Repeat steps 2-9 for seedlings.

Later, the subsample will be oven dried to constant weight at 70C, weighed, and the ratio of dry weight to fresh weight will be calculated.

### 5.6.2. Destructive Sampling of Bamboo

Measure the DBH and height of the bamboo(culm)

Calibrate hanging scales at start of each day with ‘calibration weights’.

Cut down a selection of stems that are representative of the plot.

Mark of the bamboo is small, medium or large size class

If there are multiple size classes cut a selection of each size class.

Weigh each stem and mark if it is small, medium or large. Record weights and height of each stem.

Take total of 5 sub-samples of stems from sample:

Each subsample should weigh about 200g. Each subsample should be made up of a mix of the sizes of stems.

Weigh the empty subsample bag. Record weight of just the bag.

Weigh the subsample bag with the subsample inside. Record weight.

Label the subsample bag with the bamboo identification number (Bamboo-small01, 02, 03…, Bamboo-med01, 02,03…), Plot ID# number (e.g. LNP001), weight of bamboo shoot, and weight of subsample

Take subsample bag and subsample from the field. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the bamboo.

### 5.6.3. Destructive Sampling of shrubs and herbaceous vegetation

1. At a random selection of plots with shrubs destructively harvest a variety of shrubs that are of different sizes.

2. The entire shrub will need to be weighed.Ifpossible cut the shrub into small pieces and place on a plastic tarp.
3. Record the weight of the empty plastic tarp on Form 6
4. Record the weight of the tarp with the entire shrub on it.
    - Take a sub-samples from each shrub:
    - Each subsample should weigh about 200g. Each subsample should be made up of a mix of the sizes of stems.
    - Weigh the empty subsample bag. Record weight of just the bag.
    - Weigh the subsample bag with the subsample inside. Record weight.
    - Label the subsample bag with the shrub identification number (Shrub01, 02, 03…, Plot ID# number (e.g. LNP001), weight of total shrub, and weight of subsample
5. Take subsample bag and subsample from the field. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the bamboo.

# Appendix 1: Field Forms

## Form 1 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 | Encroach ment | 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%) |
|---|---|---|---|
| | | | |

Notes:

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

## Form 2 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<br>Tree diameter: small, ≥5.0cm | | | | Plot radius: medium, 10.0m<br>Tree diameter: medium, ≥20.0cm | | | | Plot radius: medium, 17.84m<br>Tree diameter: medium, ≥50.0cm | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tree # | Species | DBH (cm) | | Tree # | Species | DBH (cm) | | Tree # | Species | DBH (cm) |
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| Co-dominant Trees and Palms where height is measured | | | | | | |
|---|---|---|---|---|---|---|
| Tree # | Species | Height (m) | Clinometer angle | | Eye to tree (m) | Equipment Used |
| | | | + | - | | |
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Data review (name, date, notes) Data Entry (name, date, notes) Entry Review (name, date, notes)

## Form 3: 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) |
| | | | | | | |
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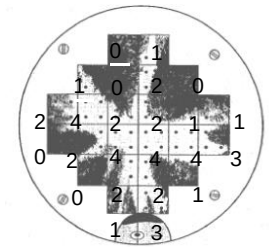
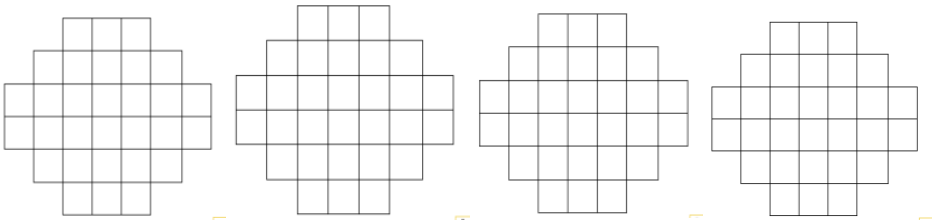
### Form 3B Canopy cover

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 the dots)



North reading
Sum of dots
_____

East reading
Sum of dots
_____

South reading
Sum of dots
_____

West reading
Sum of dots
_____

Data review (name, date, notes)

Data Entry (name, date, notes)

Entry Review (name, date, notes)

## Form 4: 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) |
| | | | | + | - | | |
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### 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) |
|---|---|---|
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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 review (name, date, notes) Data Entry (name, date, notes) Entry Review (name, date, notes)

## Form 5: 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) | | |
| | | | | + | - | | | | |
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Bamboo: Small (diameter< 4cm), Med. (diameter 4-8cm) and Large (diameter>8cm)

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

## Form 6: 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 (dbh< 4cm) | | | | | | | | |
| | Bamboo: Med. (dbh4-8cm) | | | | | | | | |
| | Bamboo: Large (dbh>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) | - | | | | | | | |
| | Palms | | | | | | | | |
| | | | | | | | | | |

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

## Field data collection using Nexus tab:

For field data collection from sample plots, the field enumerator will use Nexus 7 tablets. Under the "grant for nonprofit" program of Google.com, CREL stuffs had the opportunity to use Google's state-of-an-art technology to collect and monitor field movement for Carbon Inventory 2014. We developed and initiated data collection, distribution and monitoring with Nexus 7 tablet. Google's android based application development environment (ADE) called Open Data Kit (ODK) will be used to develop the data collection kit which will gather field information in one place. The *ODK Collect* will be used to enter the data directly in the tab, while *ODK Aggregate* is the web based central server will gather and distribute those data. The field teams are oriented with using tabs during hands-on training. The front page of ODK interface is shown below:

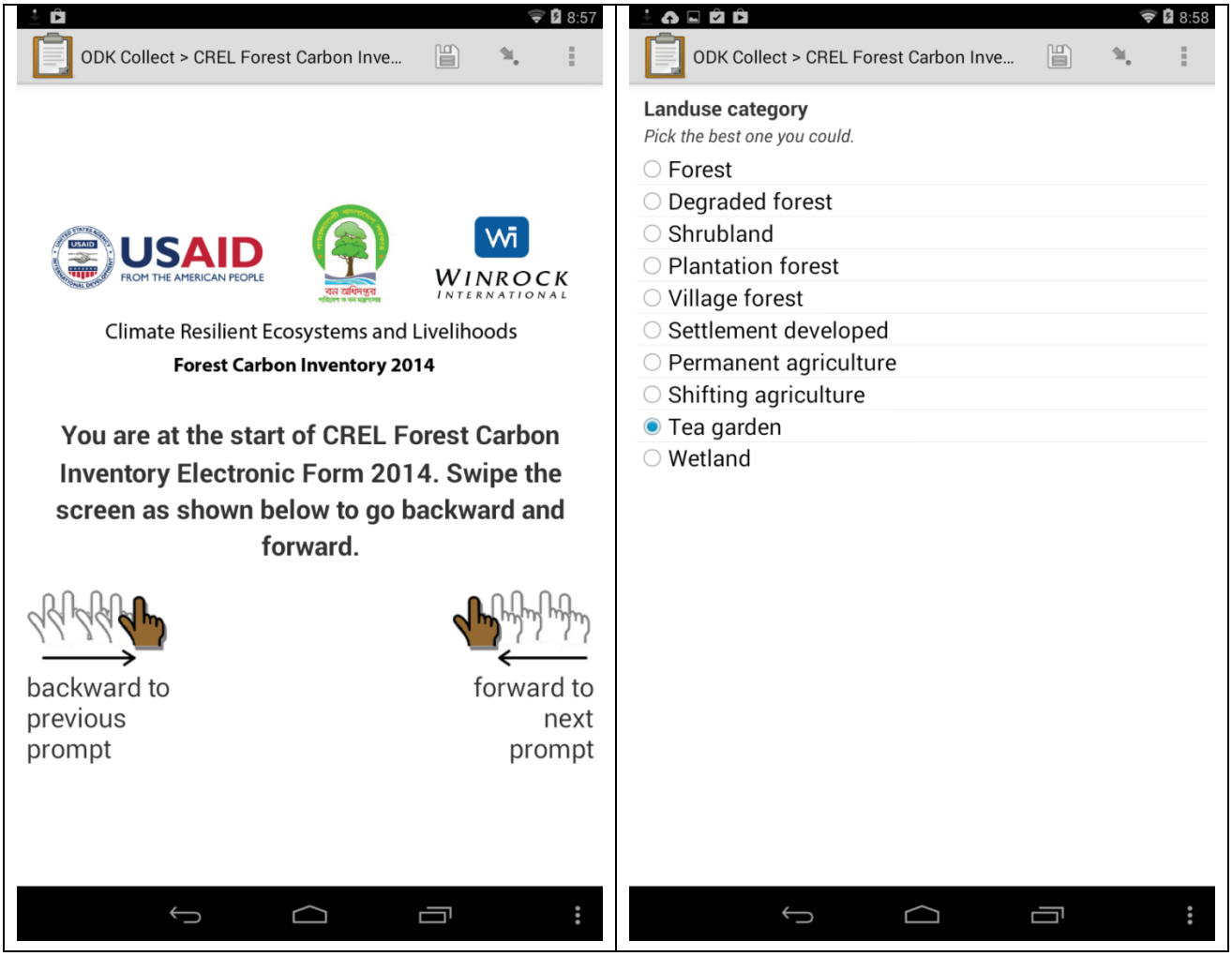


Figure 17: ODK interface used in Forest Carbon Inventory 2014.