

# Lao PDR National Forest Inventory

## Standard Operating Procedures (SOP) Manual for Terrestrial Carbon Measurement

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## INTRODUCTION AND HOW TO USE THIS DOCUMENT

Lao PDR plans to conduct the 3rd National Forest Inventory (NFI) during the 2018/19 dry season in order to update its emissions factors and assess potential emission reductions from reduced logging following the implementation of Prime Minister Order 15. These results will be integrated into Lao PDR's 2019 Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC) as well as results-based payments under the Forest Carbon Partnership Facility's (FCPF) Carbon Fund (CF).

Responsibility for the implementation of 3rd NFI also falls to the Forest Inventory and Planning Division (FIPD) under the Department of Forestry (DOF). FIPD most recently conducted the 2nd NFI during the two dry seasons; 2015/16 and 2016/17 with support from the JICA funded project, the Sustainable Forest Management and REDD+ Support Project (hereafter "F-REDD"). The experience and lessons learned from the 2nd Lao PDR NFI will be leveraged for the implementation of the 3rd NFI to ensure greater efficiency and effectiveness.

The JICA funded project above mentioned, F-REDD, currently supports DOF and FIPD with REDD+ capacity building and implementation. The F-REDD project has requested Forest Carbon, a South East Asia based REDD+ technical consulting and project developer, to assist with the design and revision of standard operation procedures required for the implementation of the 3rd NFI. Forest Carbon fulfilled a similar function during the implementation of the 2nd NFI. To support this process for the 3rd NFI, Forest Carbon proposes to collaborate with Winrock International, a U.S. based non-profit with extensive forestry inventory and REDD+ expertise, to support the Work. This document contains the recommended standard operating procedures for designing and implementing a NFI for Lao PDR. This document was designed to be used in conjunction with a number of companion products:

- National Forest Inventory for Forest Carbon Sampling – Guidance Document<sup>1</sup>
- A tablet based 'app' has been developed by Forest Carbon for field data collection
- The "NFI Calc" R-script developed by Forest Carbon to transform field data collected on tablets into analyzed data
- Winrock Sample Plot Calculator Excel Tool, provides estimate of number of plots based on variability of preliminary data
- "Module C-CS: Calculations for Estimating Carbon Stocks. Leaf technical guidance series for the development of a forest carbon monitoring system for REDD+<sup>2</sup>" which describes the calculations to conduct to estimate carbon stocks
- "Allometric Equation Evaluation Guidance Document<sup>3</sup>" which provides information on how to develop allometric equations for use in the NFI.

Using these products together will allow standing carbon stocks to be measured and estimated within sampled strata. This document shall be seen as a living document. As specific decisions are made in the NFI development, they need to be reflected in this document.

The purpose of this document is to provide standard field measurement approaches to assist in quantifying the amount of carbon stored within the various organic pools found within a landscape.

The SOPs are grouped by purpose. The first set of SOPs are general and can be used for many field measurement goals. A set of SOPs are also presented on the measurement of the carbon pools to be measured in the proposed Lao PDR NFI. These can be used to estimate the standing stock of a carbon pool within a stratum.

The SOPs should not be conducted without receiving extensive field training in the measurement methods performed by a qualified forester or ecologist.

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<sup>1</sup> Walker, SM, KM Goslee, G Eickhoff, Y Morikawa. 2015. National Forest Inventory for Forest Carbon Sampling – Guidance Document. Winrock International, Forest Carbon Partners, KKC on behalf of Lao PDR FIPD

<sup>2</sup> Goslee, K, SM Walker, A Grais, L Murray, F Casarim, S Brown. 2013. Module C-CS: Calculations for Estimating Carbon Stocks. Leaf technical guidance series for the development of a forest carbon monitoring system for REDD+. USAID LEAF.

<sup>3</sup> Walker, SM, T Tepe. 2015. Allometric Equation Evaluation Guidance. Winrock International on behalf of KKC

For the Lao PDR NFI, data collection can take place either using field datasheets or an Android-based tablet using Open Data Kit (ODK), synchronized with a secure on-line data aggregation server (such as [www.ona.io](http://www.ona.io)). An ODK form<sup>4</sup> was designed for this SOP by Forest Carbon.

For navigation purposes, it is recommended that tablets download OruxMaps, and be equipped with data to make use of satellite imagery (2015 Landsat 8, 2012/2013 RapidEye) and a variety of GIS data layers to make inventory points, backup points, roads, rivers, villages and other access points easily visible to the teams while in the field.

Following data collection, ODK data is exported into either tab delimited files (.xlsx or .csv). For paper datasheet collection, a tab delimited template for data entry has been developed (See Appendix II). These tab delimited files can then be used as input for a companion R script that has been developed.

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<sup>4</sup> Eickhoff, G., 2015. "NFI\_Inventory\_v9.xlsx" ODK Form for Lao NFI Piloting

## GENERAL SOPS:

The following Standard Operating Procedures are used for a variety of purposes and studies. They provide general guidance or provide guidance on the use of a specific measurement tool.

SOP Field Safety

SOP Quality Assurance/Quality Control

SOP Data Storage and Archiving

SOP Labeling of Plots

SOP Calibration of Haglöf DME 201 Cruiser

SOP Use of a Clinometer

SOP Measurement of Height

## SOP FIELD SAFETY

No matter what activities are engaged in or where they are carried out, *safety is the first priority* and all precautions must be well thought out in advance and then strictly adhered to. Planned field activities must remain flexible and allow for adjustments in response to on-the-ground assessments of hazards and safety conditions. Accordingly, field personnel must be vigilant and always avoid unnecessary risks.

Field crew members in particular must be well prepared. It is recommended that personnel engaging in field activities hold general first aid training and if possible training in CPR.

The following guidelines will apply to all field-based activities:

- Mandatory buddy system. Field crews will include no less than two people who must be directly accompanying each other for the entire duration of field work. Ideally field crews should include a minimum of three people; in case of an accident resulting in injury one person may leave to seek help while another person stays with the injured crew member.
- For each day in the field, specific location and scheduling information must be logged in advance with a point person who can be reached at any time during the anticipated duration of field work. While in the field, crews should check in with their designated point person once per day.
- Each independent crew must carry a radio, satellite phone or cell phone provided by the institution. Crews should make sure to check batteries each time before entering the field.
- Trip planning will include identification of the nearest medical facility and specific directions to reach that facility. When in areas with poisonous snakes, advance communication should be made to verify that appropriate antivenins are available. Where applicable, hunting regulations should be checked with local state agencies prior to field work.
- Personnel will carry personal and institutional insurance cards with them at all times. As well, personnel will carry identification and, if possible, institutional business cards at all times.
- Field crews will carry a first aid kit with them at all times. First aid kits should contain Epinephrin/Adrenalin or an antihistamine for allergic reactions (e.g. bee/wasp stings). Sun block and insect repellent should be carried in the field.
- Where poisonous snakes are common, snake chaps are recommended. In the event of snake bite, the victim should be taken immediately to a medical facility. Conventional “snake bite kits” (e.g. suction cups, razors) have been proven ineffective or even harmful and should not be used.
- Basic field clothing should be appropriate for the range of field conditions likely to be encountered. This will include: sturdy boots with good ankle support or rubber boots, long sleeves and pants, rain gear, and gloves. Blaze orange (vest or hat) is recommended when and where hunting may be taking place. Where necessary, to avoid extended contact with plant oils, ticks, and/or chiggers, a change of clothes should be made at the end of each day in the field and field clothes should not be reworn without first laundering.
- Ensure personnel stay sufficiently hydrated and carry enough clean water for the intended activity. Carry iodine tablets or other water purification tablets in case there is a need to use water from an unpurified source.
- Heightened caution should be given while operating any motor vehicle, particularly on backcountry roads where conditions are unreliable and rights-of-way are often not designated or adhered to. ATVs should always be operated at low speeds (<15 mph).
- Some plots may be too hazardous to sample. Situations include: plot center on a slope too steep to safely collect data (i.e., >100% slope or on a cliff); presence of bees; volcanic activity; illegal activities; etc. When hazardous situations arise, a discussion should be conducted among the team members to assess the situation.

## SOP LABELING SAMPLING POINTS

Proper labeling of sampling points is important because it provides a unique signature to sampled locations as well as information about the sampling conducted. Experience has shown that sample points should be named with multiple characters defining the type of sampling conducted, the area, the number of the sample point and any other relevant information.

All sample points must be numbered with a unique name and number. The labeling system must be finalized prior to data collection. The character denoting the number should include at least as many digits as total numbers of plots expected to be sampled. In other words, if the number of sample points is expected to be greater than 1000 but less than 10000, the number characters must be at least four integers e.g. 0001 to 9999.

The following is the labeling format

- Plot number (for e.g. 0891)
- Sub-plot letter (A, B, C, D up to J)
- Main or backup plot (1 or 2)
- Province code (number according to Lao nomenclature for provinces)
- District code (number according to Lao nomenclature for districts)
- Inventory Year (for e.g. 16 for 2016)
- Field season within the inventory year (for e.g. 2 for the second field season within the same year)

All sample points should be given a unique number. The reason for this is that if after the field phase a plot is found to be in the wrong stratum, the letter and stratum number can be changed but the plot will still have a unique number based on the last three digits.

As an example, a plot ID for the current NFI will look like the following:

0891A1\_0701\_16\_2

For ease of reading on maps and tablet, the six first digit can be displayed: 0891A1.

## SOP QUALITY ASSURANCE/QUALITY CONTROL

Those responsible for aspects of data collection and analysis should be fully trained in all aspects of the field data collection and data analyses. Standard operating procedures should be followed rigidly to ensure accurate measurement and re-measurement. It is highly recommended that a verification document be produced and filed with the field measurement and calculation documents that show that QA/QC steps have been followed.

### Quality Assurance

#### *Data collection in field:*

During all data collection in the field, the crew member responsible for recording must repeat all measurements called by the crew member conducting the measurement. This is to ensure the measurement call was acknowledged and that proper number is recorded on the data sheet. In addition, all data sheets should include a 'Data recorded by' field with the name of the crew member responsible for recording data. If any confusion exists, the transcribers will know which crew member to contact.

After data is collected at each plot and before the crew leaves the plot, the crew leader shall double check to make sure that all data are correctly and completely filled. The crew leader must ensure the data recorded matches with field conditions, for instance, by verifying the number of trees recorded.

#### *Data sheet checks:*

If using paper datasheets, at the end of each day all data sheets must be checked by team leaders to ensure that all the relevant information was collected. If for some reason there is some information that seems odd or is missing, mistakes can be corrected the following day. Once this is verified and potential mistakes checked, corrected data sheets shall be handed over to the person responsible for their safe keeping while the crew is still in the field. Data sheets shall be stored in a dry and safe place while in the field. After data sheets have been validated by crew leaders, the data entry process can commence.

When using tablet based data collection methods, a significant degree of data sheet checks is automatically integrated into the electronic forms. Data parameter limits are integrated into the electronic form to prevent erroneous entries being entered (for e.g. a DBH of 1000cm instead of 100.0cm) or data entries being missed (the electronic form will not allow you to progress unless certain data parameters have been entered into the form. Nevertheless, the team leader should re-check data entered into the forms before being submitted to the cloud server.

#### *Field data collection Hot Checks:*

After the training of field crews has been completed, observations of each field crew and each crew member should be made. A lead coordinator shall observe each field crew member during data collection of a field plot to verify measurement processes and correct any errors in techniques. It is recommended that the crew chiefs switch to a different crew to ensure data collection procedures are consistent across all field crews. Any errors or misunderstandings should be explained and corrected. These types of checks should be repeated throughout the field measurement campaign to make sure incorrect measurement techniques have not started to take place.

### Quality Control

#### *Field measurement error estimation*

A second type of field check is used to quantify the amount of error due to field measurement techniques. To implement this type of check, a complete re-measurement of a number of plots by people other than the original field crews is performed. This auditing crew should be experienced in forest measurement and highly attentive to detail. A total of 10% of sampling locations should be randomly or systematically chosen to be re-measured. Where clustered tree-plots are used, all tree-plots within a selected cluster shall be measured. All trees shall be re-measured in each plot. Field crews taking measurements should not be aware of which plots will be re-measured whenever possible.

After re-measurement, data analysis is conducted and biomass estimates are compared with estimates from the original data. Any errors discovered could be expressed as a percentage of all plots that have been rechecked to provide an estimate of the measurement error.



For all the verified plots:

$$\text{Measurement Error (\%)} = \left| \frac{(\text{t C/ha of measured plot} - \text{t C/ha of re-measured plot})}{\text{t C/ha of re-measured plot}} \times 100 \right|$$

This error level will be included in the carbon stock reporting.

#### *Data Entry quality control check:*

If using paper datasheets that need to be transcribed, then after all data has been entered into computer file(s), a random check shall be conducted. Sheets shall be selected randomly for re-checks and compared with data entered. Ten percent of all data sheets shall be checked for consistency and accuracy in data entry. Other techniques such as data sorting and verification of resulting estimates shall be employed to ensure data entered properly corresponds to field sites visited. Personnel experienced in data entry and analysis will be able to identify errors especially oddly large or small numbers. Errors can be reduced if the entered data is reviewed using expert judgment and, if necessary, through comparison with independent data.

This step is not necessary is making using of tablet based data collection methods as the data is automatically collected and collated into tab delimited files in the cloud server.

### **QA/QC of Laboratory Measurements**

Standard operating procedures (SOPs) should be created and rigorously followed for each part of all laboratory analyses. All instruments should be calibrated.

For example, all combustion instruments for measuring total C or C forms should be calibrated using commercially-available certified C standards. SOPs should include steps to calibrate and check analyses. Blanks can be analyzed, or analytical runs can include a check sample of known C concentration. One standard per batch/run should be included in the samples sent to a remote lab as an additional check of the quality of the instruments and lab procedures.

All balances for measuring dry weights should be calibrated against known weights. Where possible, 10-20 % of samples could be reanalyzed/reweighed to produce an error estimate.

# SOP TABLET-BASED DATA STORAGE AND ARCHIVING

## Field equipment:

Android Tablet  
Protective tablet casing

## Office equipment:

Computer  
Connection to network server

This SOP describes the methods for storing and archiving data in a simple yet safe and retractable way, so data can be accessed whenever necessary. Data storage and archiving is a very important and final component of the data collection process. The basic framework involving data storage and archiving follows.

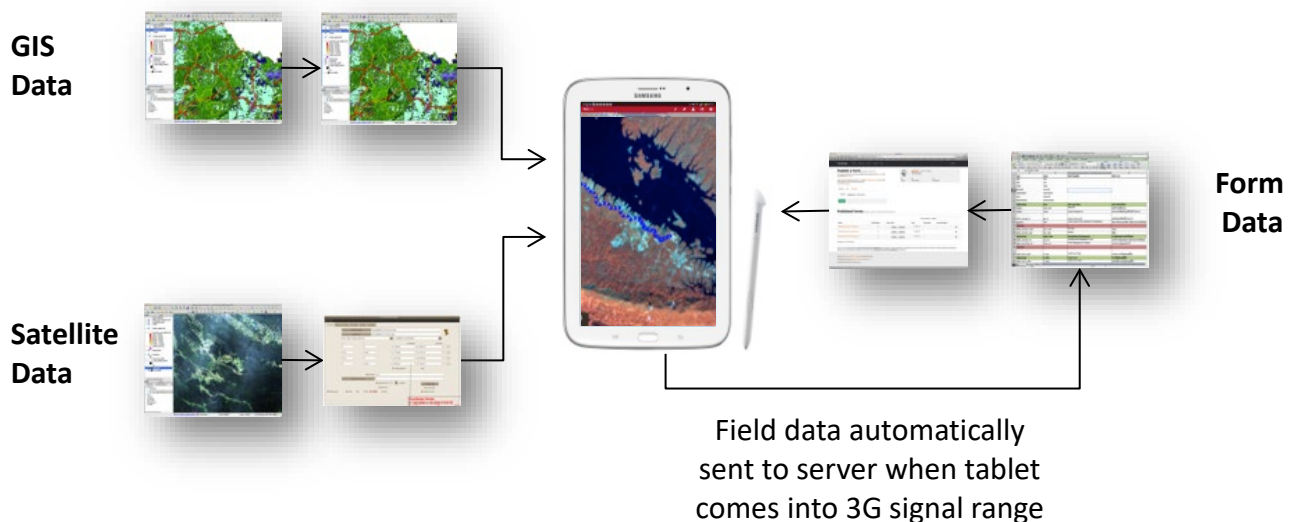


Figure 1: Data Storage Flow

## Data storage in the field

In the field one person (the Team Leader) is responsible for carrying, operating and recording field data into an Android-based tablet computer. The tablet and data collection form will automatically record many types of data, including data collection start/stop time, GPS position and other features of the data collection process. Once the field team has finished the plot, the tablet will automatically send data to the cloud-based data aggregation server or any other server designated by the inventory team.

Ona.io ([www.ona.io](http://www.ona.io)) is the recommended, freely available and secure cloud-based server.

If a 3G connection is not available at the location of the plot, the tablet will automatically send data to the server once the field team comes within a 3G signal later in the day. Where field teams will be outside of a 3G connection for multiple days, teams should take special care and synchronize field data with a computer whenever possible. Keeping the tablet in a waterproof case when traveling between plots or overnight is recommended.

## Data storage in the office

Once the field team has returned to the office or laboratory, data should be downloaded from the server in all available formats (.xlsx, .csv, .pdf) and stored electronically.

### Hard copy

Two copies of the the .xlsx and .csv versions of the data should be printed in hard copy and kept in separate locations in a special jacket folder in the filing cabinet with the location name and date written on the label.

Inside of these jackets there are folders with the different types of data collected. After all data has passed through a Quality Assurance / Quality Control process to detect errors, the final data set should be printed and stored in secure fireproof filing cabinets in two separate locations.

### **Soft Copy**

The exported data is stored on a computer in the office, along with all tools used for entering data. These data files are backed up on a server. All digital data collected and compiled (photos, proposal and report for exercise) are also stored in the archive file on both the desktop in the office and on the server. On the server there are a few folders in which all data are placed as follows:

1. '*Field Data*', in which sub folders are created and are named the same way (Location) as the hard copy folder so as to have a uniform filing system. In each sub folder there are two folders; pictures and scanned data sheets in which the respective information are placed;
2. '*Data Analysis*' in which all completed tools are placed after the data entry has been completed;
3. '*Template*' in which all tool templates and field data sheets used in the data analysis are placed;
4. '*Documents*' in which all documents related to the project are placed; and
5. '*Field Proposal & Report*' in which all field exercise proposals and report are placed.

### **Procedure for Compiling and Managing Field Log Book or Electronic Log Book**

This log book will be both of an electronic form and of the traditional book keeping format (a book). Both log forms will be updated simultaneously and twice for each field venture, before and after each trip. Log books will be used for recording the logistics of the field exercise, and providing explanation about field campaigns (e.g. date of departure to the field and date of returning, number of plots, location, field crew, challenges etc.). Each field inventory will be given a unique reference number and each report will also be given a reference number related to that of the inventory. This is to facilitate cross-referencing processes.

Upon returning to the office after field records are entered, the log books will be stored in a secure filing cabinet or placed on the network server via desktop computers respectively, after being updated. Upon the completion of field reports of which each report will be given a unique reference number, the log books will be revisited and the report number will be inserted for future references.

It is important to restrict access to log books and information only to users, as they alone are responsible for making changes.

## SOP CALIBRATION OF HAGLÖF DME 201 CRUISER

This equipment may be used to establish the boundaries of permanent or temporary circular plots. Please see the SOP Plot Design for more information. The Haglöf Distance Measuring Equipment (DME) 201 Cruiser<sup>5</sup> contains two components: the measuring unit and the transponder. The DME uses ultrasound waves to calculate distance between the measuring unit and the transponder. However, the speed that sound waves travel through air is slightly influenced by humidity and temperature. If the DME is being used in a desert the sound waves will travel slightly faster than in a tropical humid environment. Therefore, it is important to calibrate the device prior to data collection in each plot.

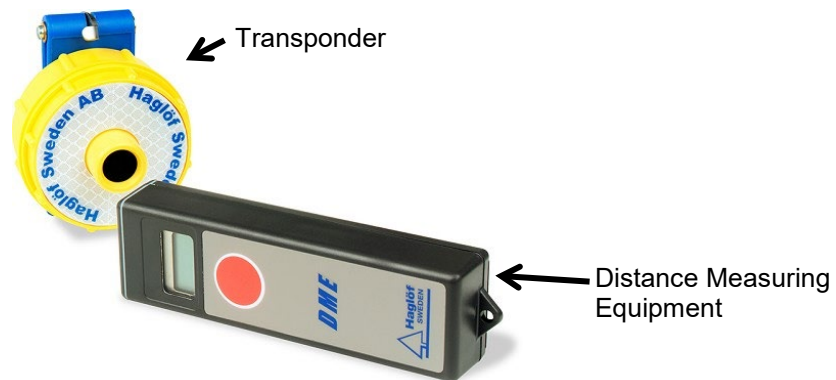


Figure 2: Haglöf DME 201 Cruiser<sup>6</sup>

1. Before the crew arrives in the field, the crew chief should have already taken the measuring instrument (grey rectangular box) out of the box. This instrument needs a minimum of 10 minutes to adjust to local temperature conditions. Therefore, it should not be in its box or in someone's pocket immediately prior to use. It needs to be in contact with the open air for at least 10 minutes before it is used, if not, it can cause inaccurate readings. It is allowable for this instrument to be carried using a neck strap.
2. After the DME has had a chance to adjust to local temperature and humidity conditions, it is ready to be calibrated. One person should hold the transponder in their hand while the crew chief takes the measuring instrument and a measuring tape and proceeds to a clear point 10 m away. The measuring tape should be pulled tight and should not be draped on the ground. The measuring tape and the transponder and measuring instrument must be parallel to each other and held at breast height (1.3m).
3. The crew chief should hold the measuring instrument in one hand and the end of the measuring tape in the other. The second person at the other end of the tape should do the same with the transponder. The crew chief should then point the measuring unit at the transponder and press the red button nine times. Hold the measuring unit very still until 10 m is displayed on the screen. If it does not, repeat.
4. The DME can display in metric or English units, i.e. feet or meters. *Make sure for field work that the DME is set to measure in meters.* To change the DME to display in meters or feet click the red button on the measuring unit five times. Meters display with two decimal places but only one decimal place when it is set for feet. If the wrong unit of measurement is displayed, quickly press the red button one additional time (after the five) and verify that the decimal units have changed to the correct unit of measurement.
5. Place the transponder on the tripod so that it is placed directly over the plot center.

<sup>5</sup> For example: [www.forestry-suppliers.com](http://www.forestry-suppliers.com)

<sup>6</sup> Photo source:

[http://www.forestry-suppliers.com/product\\_pages/View\\_Catalog\\_Page.asp?mi=1378&title=Hagl%F6f+DME+201+Cruiser](http://www.forestry-suppliers.com/product_pages/View_Catalog_Page.asp?mi=1378&title=Hagl%F6f+DME+201+Cruiser)

## SOP FIELD WORK WITH THE GPSMAP 60CSX

The following SOP describes how to use a specific GPS unit model, the Garmin GPSMAP 60CSX. However, many GPS units, especially Garmin models, work in similar ways and therefore this SOP can be used generally to assist with a variety of models.

### Basic requirements

- The same coordinate system and measurement units should be used for all fieldwork.
- An advanced user can pick a projected coordinate system appropriate for the study site location. A novice should use a geographic coordinate system based on WGS84 geodetic datum (usually the default datum on GPS units) and record the coordinate pairs in decimal degrees or longitude and latitude coordinates.
- The coordinate system and datum used must be recorded on the field notes.
- The data should be collected using metric units not English units.
- Remove batteries when the unit is not in use for more than a week.
- Calibrate the electronic compass every time you install new batteries (see below for directions).

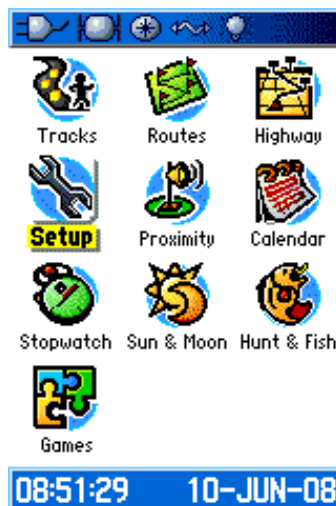


### GPSMAP 60CSx Main pages

This section describes the most important functions available from the main pages of the GPS unit. Field members are advised to consult with the GPSMAP 60CSx manual for more detailed information on all functions.

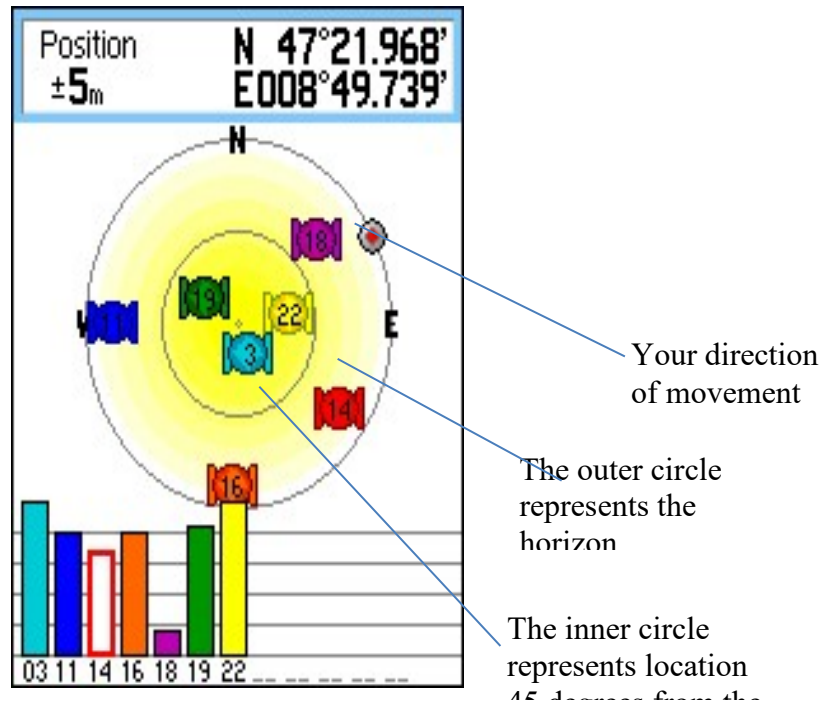
To navigate between pages press PAGE button.

#### Main menu



- The **MAIN menu** is accessible from any page by pressing the **MENU** twice
- To select an item from the **MAIN menu**, highlight the menu item and press **ENTER**

## Satellite page



Satellite page shows:

- Current position (coordinates)
- Accuracy of current position information.
- Constellation of the satellites.
- Strength of satellites' signals.

## Map page



A standard map with basic information comes with the GPS software. Additional GIS layers can be uploaded to the unit. The **Map page** contains field data and a map.

To show data field on the Map Page (or any other page):

- Press **MENU**, select **Data Fields** to see the Map page option menu. Select the number of data fields desired and press **ENTER**.

To change a data field display:

- Press **MENU**, select **Change Data Fields** and press **ENTER**.
- The field is selected; press **ENTER** to open the list of data field options.
- Use **ROCKER** key to select an option and press **ENTER**.

### Compass page



The **Compass page** guides the user to a selected destination with a graphic compass display and a bearing or course pointer.

The compass should be calibrated in following occasions:

- When you first use the GPS unit.
- After installing new battery.
- After moving more than 160 km from the previous location.
- When there is temperature change > 20°C from the last calibration.

#### How to calibrate GPSMAP 60CSx

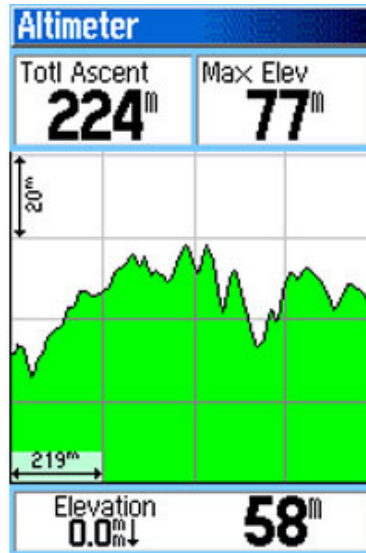
1. Press **MENU** while on the Compass page
2. Highlight **Calibrate Compass** to open the compass calibration page.
3. With the **START** button highlighted, press **ENTER** and follow on-screen directions for holding and turning the unit.

The unit must be held level and turned slowly clockwise.

Messages appear on the screen for guidance and indicate the success or failure of the calibration.

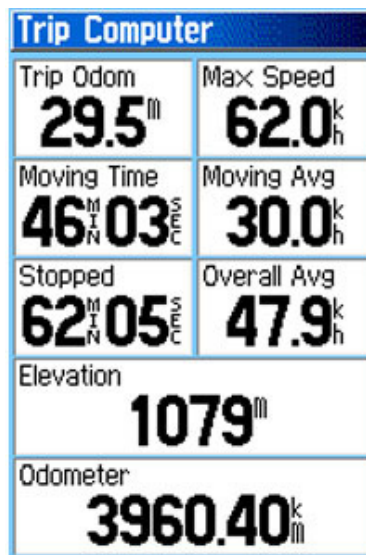
When the **on-screen button "STOP"** appears on the screen, press **ENTER** to return to the Compass page.

## Altimeter page



The **Altimeter page** shows the user a profile of elevation changes over distance or time, or a profile of pressure changes over time.

## Trip computer page



**Trip computer page** shows eight types of navigation data. Each field is selectable and can contain one of many data information options. The trip computer page can be reset before every new trip.

## Waypoints

Waypoints are sets of coordinates –longitude and latitude that identify a point in physical space. Waypoints can **be used to select the location of any point important to the user.**

### To mark a waypoint:

From the **Map page**:

1. Press and hold **MARK** until the Mark Waypoint page appears.
2. To accept the waypoint with default information, highlight **OK** and press **ENTER**.
3. To change any name of the waypoint, select the appropriate field and press **ENTER** to open on-screen keypad. After selecting each character of the name press **ENTER**; when finish typing the new name highlight the **OK on-screen button** and press **ENTER**. The new name will appear in the name field.



4. Navigate to the **AVG** on-screen button to average the location; press **ENTER**.
5. Once in the averaging page, wait until the accuracy error drops to ~5m and press **ENTER**.
6. Select **OK** and confirm your changes by pressing **ENTER**.

#### *To search for waypoint:*

If you want to navigate to a waypoint that is stored in the GPS unit, use the **FIND menu**:

1. Press **FIND** key to open the **FIND menu**.
2. Select the icon for the type of item you want (usually the **Waypoints** icon) to find and press **ENTER** to open the waypoint page.
3. Use the **ROCKER** to navigate to the name of the waypoint you want to find. The arrow symbol will point you to the direction of the point you want to find.

## Track

A track log records a line along a set of points, which the GPS unit records automatically at a set time or distance interval chosen by the user.

#### *To set up a track log:*

From any page:

1. Press **MENU** twice to open the **Main page**.
2. Select **Tracks** and press **ENTER** to open the **Tracks page**.
3. Highlight the **Setup** button and press **ENTER**.
4. Select **AUTO** as the collection method, **0.01** as the interval and select the desired **colour** of the track.
5. Make sure that **On** is highlighted for the **Track Log**.
6. Press the **Page** button and navigate to the **Map page**. On this page you will see the map and the progression of your track.

#### *To save a track log:*

1. Press **MENU** twice navigate to the **Tracks** icon and press **ENTER**.
2. A message will prompt "Do you want to select the entire track" Select **NO** if you want to save the last track you have collected as separate track.
3. The map screen will appear and at the bottom of the page a message will appear saying "Please select the beginning of the track"; navigate with the arrow to the beginning point of the last track you collected and press **ENTER**; a list of points for the last track will appear. Select the beginning point of the track. When selecting the beginning and ending point of the track the user should make sure that the scale on the map page is 1:20m or 1:30m.
4. Press **ENTER** to save the track.

#### *To calculate the area of a track:*

1. With the **Track Log page** open and the **Track Log** on, press **MENU** to open the Options Menu.
2. Select "Area Calculation", and press **ENTER**.
3. Press **ENTER** to start the area calculation. As you move and define the area's boundaries, a **STOP** button appears on the page.
4. When finished defining the area, press **ENTER** and select **SAVE**.

## Route

A route creates a sequence of waypoints that lead to a final destination.

#### *To create a route:*

1. Press **MENU** twice to open the main Menu.
2. Highlight the **Routes** icon and press **ENTER**.
3. Select **New** and press **ENTER**.
4. With **Select Next Point** highlighted, press **ENTER**.

5. Use **Find Menu** to select a route waypoint.
6. Select **USE** and press **ENTER** to add it to the route.
7. To add more points to the route, repeat steps 4 through 6.

#### *To navigate to a route:*

1. Press **MENU** twice and select **Route**.
2. Highlight a saved route, and press **ENTER** to open the Route page.
3. Highlight the **Navigate** button and press **ENTER**.
4. To stop navigating, press **MENU** -> **Stop Navigation** ->**ENTER**.

## Downloading and uploading data

Data can be viewed and transferred to and from the GPS unit using either the Garmin MapSource program (manufacturer software) or the DNR Garmin extension software.

**Garmin MapSource** provides the user with geographic data that can be viewed on your PC and added to the base map of your compatible Garmin GPS device. With MapSource, the user can:

1. Transfer saved waypoints, routes, and tracks from your GPS device and save them to your PC. (MapSource transfer data as an .gdb .mps, .txt, .gpx, or .dxf file)
2. Create, view, and edit waypoints, routes, and tracks.
3. Find items, addresses, and Points of Interest included in the map data.
4. Transfer map data, waypoints, routes, and tracks to your GPS device.

**DNR Garmin** integrates GIS Software (ESRI's ArcView 3.x and ArcMap, ArcExplorer, MN DNR's Landview, Google Earth) with all types of Garmin brand GPS units. It uses a Visual Basic program that interacts with Garmin GPS via a serial/USB port allowing GIS users to transfer Waypoints, Tracks, and Routes from a Garmin GPS to ArcView, ArcMap, Landview, ArcExplorer, or Google Earth and store them as points, lines or polygons. Information can also be uploaded from ArcView/ArcMap/Landview graphics or shapefiles to the GPS unit and used as tracks or waypoints.

DNR Garmin can also be used to perform real-time tracking with your GPS and GIS. Connected to a laptop computer with ArcView, ArcMap or Landview a Garmin GPS can be a valuable tool for locating oneself and for interactive data collection.

The extension can be downloaded from:

<http://www.dnr.state.mn.us/mis/gis/DNRGPS/DNRGPS.html>.

Please follow instructions for software installation. DNR Garmin tool will be added as a toolbar to ArcGIS if that is the GIS program installed.

#### *Downloading data from the GPS Unit into the PC*

There are two steps to downloading data from a GPS to the PC:

##### *Download data from the GPS*

1. Select the download option from one of the following menus: Waypoint, Track, or Route. The data will be downloaded from your GPS into the data table.
2. Once the data is downloaded you may edit it prior to saving. Edits include modifying cell values or converting between waypoints/tracks/routes.

#### *Save data to a file or GIS graphic from the DNRGarmin Data Table*

1. Go to **File => Save To** and choose a destination (File, ArcView, Landview, ArcMap, ArcExplorer).

**Note:** You can only save to Arcview/Landview/ArcMap/ArcExplorer if that software is running.

#### Notes:

Each waypoint, track point, and route point has one or more attributes associated with it depending on the type of GPS unit used. Extra columns can be turned off if not needed. Individual route points can also be deleted if desired.

Data is downloaded in Lat/Long WGS84 coordinates. When the download is complete this spatial information is projected to the user-specified projection. The projected Y and X coordinates are stored in the Y\_Proj and X\_Proj fields.

Once the GPS information is stored in the Data Table, it can be saved as a text file, DBF Table, Shapefile, GPX file, KML file, ArcView Graphic, ArcMap Graphic, or Geodatabase Feature Class.

When the GPS unit is connected to the computer it shows up as a mass storage device (a Drive in Windows Explorer). When you download data using DNRGarmin, the program is pulling data from a GPX file on the storage device called CURRENT.GPX (possibly located at GARMIN/GPX or GARMIN/GPX/CURRENT).

#### *Uploading data to a GPS Unit*

There are two steps to uploading data from a PC to a GPS unit:

1. Load data from a file or GIS software into the DNRGarmin Data Table.
2. Go to File => Load From and choose a source (File, ArcView, Landview, ArcMap, etc).

#### Notes:

ArcView/Landview/ArcMap must be running in order to load to those programs.

For track logs, each Garmin Unit has a different amount of memory to store coordinates. If you are loading lines or polygons from ArcView or ArcMap, the program will check to see how many vertices are in the selected shapes. If the number of vertices is greater than the number of points it will generalize the shapes.

Once the data is loaded you may edit it prior to upload. Edits include modifying cell values or converting between waypoints/tracks/routes.

## SOP USE OF A CLINOMETER AND MEASUREMENT OF SLOPE

A clinometer is a piece of equipment used to measure angles. This equipment is widely used in the field for multiple reasons, among them: measuring slope of the terrain and measuring tree height. Usually a clinometer has two sets of units for measuring angles:

**Right side:** percent (%)

**Left side:** degrees

The Clinometer will indicate the units. For example, if using a Suunto® Clinometer, look into the clinometer and tilt your head back to look all the way up. The right side will say %. On other models, the units might be marked on the side.

To measure an angle using a clinometer:

1. Holding the clinometer string, bring it up to your dominant eye (the string on the clinometer should be below the eye piece, stretching downward)
2. Keep both eyes open and simultaneously aim at the object you want to measure in the distance and look at the numbers through the clinometer
3. Record the % or degrees at the point that crosses what you are measuring.

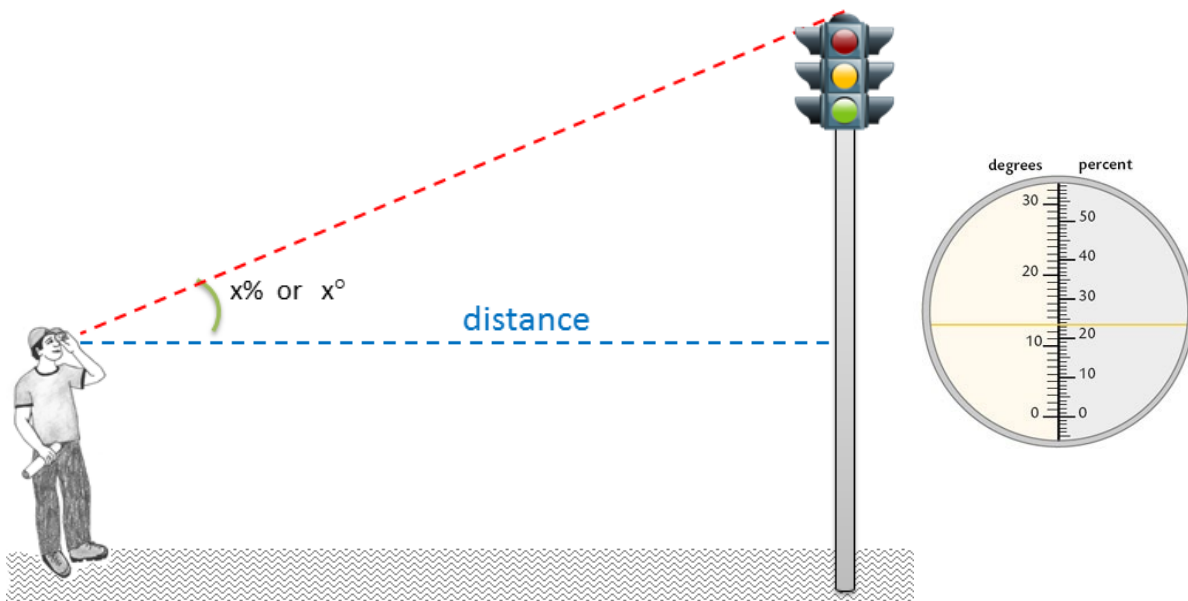


Figure 3: Measuring angle degrees or % using clinometer

### Measurement of slope

Slope is measured using a clinometer and two people.

To measure slope, both people will make use of a stick or other marker that is 1.3m in height. The person not holding the clinometer will ensure that the top of the 1.3m marker is clearly visible/identifiable (e.g. by painting the top of the marker with a bright color). The person holding the clinometer should stand 5m uphill from the plot center point, while the second person will walk 5m downslope from the plot center (this should be measured using a tape measure pulled tightly). The person with clinometer shall then aim at the 1.3m-level location of the partner and record the angle reading displayed in the clinometer. This angle is the slope angle and should be recorded as percent (in the cases of very steep slopes, it can be recorded as degrees, making sure to note the unit used in the data sheets).

## STOCKS OF CARBON POOLS SOPS:

The following set of SOPs can be used to establish plots to estimate the standing carbon stock of the various carbon pools. These SOPs will need to be altered based on the specific methods used by the field campaign.

SOP Sampling Design and Layout

SOP Establishment of Sampling Plots

SOP Measurement of Trees

SOP Measurement of Standing Dead Wood

## SOP SAMPLING DESIGN AND LAYOUT

This SOP describes the methods to determine the locations where sampling will take place along with the sampling layout and shape of sampling plots for all vegetation types and carbon pools. This SOP must be implemented prior to field data collection and requires operations in a GIS environment.

Prior to implementing this approach the strata must have been chosen, a separate GIS shapefile created for each stratum, and the target number of sampling points for each stratum must have been determined. In addition, the minimum mapping unit must also have been determined and all locations within all forest land cover layers must meet the definition of a forest (e.g. all forest polygons must meet the definition of a forest).

This SOP must be repeated for *each* stratum separately.

For each stratum, all sampling will take place in association with the plot anchor point. For live trees, dead trees, and stumps, sampling will use a 'floating' clustered design with four to ten nested tree-plots.

In the 'floating' cluster nested tree-plot design, all sampling at each sampling point takes place only in locations under the same stratum. The location of the plot anchor point and of each nested tree-plots is determined prior to field sampling and in a GIS environment, as delineated below. Due to the highly fragmented landscape and the terrain causing some locations to require significant time to access, a desk based 'pre-assessment' will take place using high resolution imagery to increase the probability that sampling locations contain the target land cover type. In GIS, for a given stratum an plot anchor point is placed using the two-staged sampling design described below. This also serves as the first tree-plot center (tree-plot A) and then up to nine additional points (B, C, D, E,..., J) are then randomly placed in GIS within the given stratum within a 300 m radius of the plot anchor point, but no closer than 75 m from each other or the plot anchor point. These serve as the tree-plots. One cluster must have at least six tree-plots to provide enough opportunity to the field team to measure four valid tree-plots in forested area.

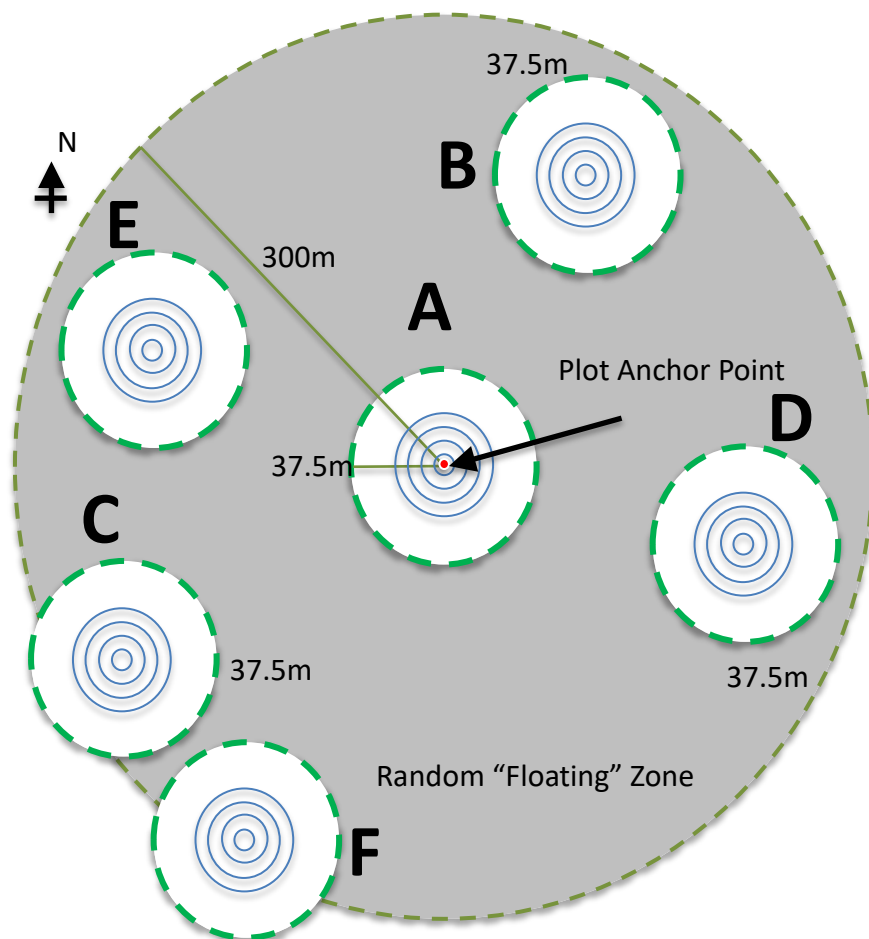


Figure 4: A “floating” cluster plot with a fixed center tree-plot.

### Determine Sampling Locations using stratified two-stage sampling.

For the estimation of carbon stocks in the tree, non-tree woody, non-woody vegetation, litter, and deadwood pools, sampling should take place across a stratum in an unbiased way. Sampling layout and the design for determining sampling locations can differ for each stratum, however, the below approach is recommended for all stratum included in the expected Lao PDR NFI. The following method should be implemented for one stratum at a time.

This sampling design consists of selecting **primary sampling units (PSUs)** at the first stage and then selecting **secondary sampling units (SSUs)** at the second stage of sampling. The approach described ensures that any location has an equal probability of being sampled. The initial sampling units are chosen by using a systematic sampling with a random start approach. A ‘grid’ is placed across the area to be sampled in a randomly selected orientation. The grid cells will then serve as the ‘primary sampling unit’ (PSUs). Once the PSUs are chosen, a particular location within the PSU is randomly chosen to initiate field sampling. This is referred here to as the SSU1.

Thus, the definition of these terms is:

- **PSU-grid** cell: an individual grid cell of a known and defined size (e.g. 3 km x 3 km square) within the grid that has been superimposed across the area to be sampled. PSU-grid cell is given a unique ID. This ID number will then be used within the identification of a PSU.
- **PSU<sub>i</sub>** – this is the spatial extent of the stratum *i* within a given PSU-grid cell. The label of the PSU shall correspond to the PSU-grid ID and include stratum notation (here denoted as *i*).
- **SSU1<sub>i</sub>** – this is a point, representing the starting point of the sampling at this location. The SSU1<sub>i</sub> is located within selected PSU<sub>i</sub>.

## Methods and Procedures

Except for Step 0, all the following steps to implement two-stage list sampling design shall be repeated for each stratum separately. The entire gridded area shall be used to determine selected PSUs for each stratum and thus each PSU-grid cell shall have an equal probability to be selected during the list sampling selection for all stratum. (If one PSU-grid happens to be selected for both strata A and B, this is allowable. There will then a  $PSU_A$  for stratum A and a  $PSU_B$  for stratum B, and thus two SSU points located within the boundary of this PSU, one for stratum A and one for stratum B.)

First, the size of the grids needs to be defined (Figure 1). The size of the grid cells takes into consideration other field surveys that may occur in Lao PDR; or align with the size of other REDD+ systematic sampling taking place elsewhere within Laos (i.e. PAREDD, CiPAD and others) to facilitate a future national forest monitoring system (NFMS) for the country. The PSU-grid cell size shall be small enough so that a sufficient quantity of PSU-grid cells will be available for sampling yet large enough to ensure both that the field cluster plot design can fit within a PSU selected and that sample plots are well distributed across the landscape.

### STEP 0: Create inaccessible area

To create inaccessible area as a mask for hiding features by using following definition:

- Areas with slope >35 degrees
- Forest areas that fell within the 'barren land and rock' land class in the FIPD 2002 land cover classification

### STEP 1: Create PSU-grid (3 x 3 km)

To create a PSU-grid across the area to be sampled, a 3km x 3km grid polygon shape file needs to be created in ArcGIS through function of "Create Fishnet". The grid layout does not need to be aligned with other sampling grids taking place in Laos so can be chosen randomly. Each square of the grid should be considered a "PSU". The shape file has a unique identification number (ID) for each PSU-grid (PSU\_ID).

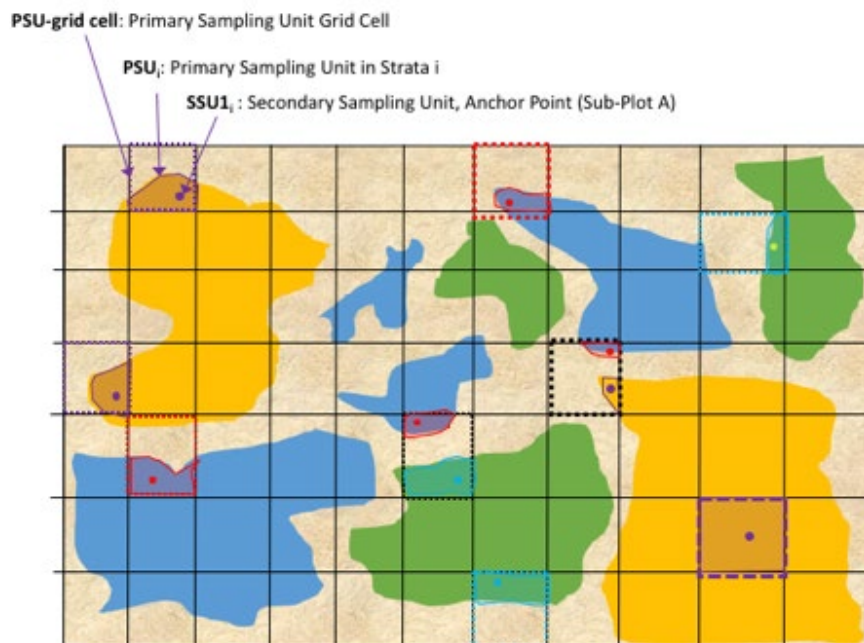


Figure 5: Example of selected PSU-grids in dashed lines and selected PSUs (polygons) with SSUs (dots) assigned within. Note, some PSU-grids may randomly be selected for two different stratum.

### STEP 2: Create a list of PSUs for the stratum of interest

To create  $PSU_i$ s for each stratum, use Intersect function in ArcGIS to combine the PSU-grid shapefile with the stratum shapefile. Next calculate the area of each  $PSU_i$  for each stratum in ArcGIS. If the area of the  $PSU_i$  is less than the minimum area in the Lao forest definition, exclude that  $PSU_i$  in the two stage list sampling procedure (The reason for this is that we are respecting the minimum threshold area for defining forest in Lao PDR, thus only PSUs with area greater than such threshold should be included in the PSUs grid list.). A list of all PSUs should be created and the attribute table exported as DBF table, maintaining record of  $PSU_i\_ID$  and area in hectares.

### STEP 3: Select PSUs with probability proportional to size

To ensure all locations within a stratum have an equal probability of being measured, the probability that a given PSU<sub>i</sub> will be selected must be made proportional to its area. To select PSU<sub>i</sub>s with probability proportional to their size, use the list of PSUs from Step 2 and calculate the cumulative area of each stratum associated with each PSU. Cumulative area is defined as sum of all PSUs in the list up to and including the PSU itself. Once the cumulative areas are calculated, a random number between the smallest and the largest cumulative area should be generated. To select a PSU for forest sampling, the random number should be less than PSU's cumulative area and larger than the cumulative area for the previous PSU in the list.

The sampling design will determine the total number of PSUs that are targeted for measurement. At this stage, the number of PSUs selected should be at least 10%, rounded up, more than the targeted number of sampling points. This is to account for PSUs that must be rejected either before fieldwork or during, as described in the following steps.

All of the operations conducted in Excel are explained below:

1. After opening the DBF file in Excel, calculate the cumulative area for each PSU in a new column.
2. In the next column, create a list of random numbers between the minimum and maximum cumulative area of the PSUs grid list shall be generated created using following formula:  
$$=RAND ()*(B - A) + A$$

#### Where:

B is the maximum cumulative area, and

A is the minimum cumulative area for the list of PSUs

Once the random numbers have been created, convert the formula in each cell into a number to prevent new random numbers from being generated.

To select a PSU<sub>i</sub> for sampling, the random number should be compared to the cumulative PSU area. The PSU<sub>i</sub> shall be selected when the random number is smaller than the PSU cumulative area and greater than the previous PSU in the list cumulative area.

For example, if the random number is 26,446.42 and the cumulative area for PSU<sub>i</sub> with ID=1151 is 32,689.23 ha and the cumulative area for the previous PSU is equal to 22,758.71 ha, the PSU ID=1151 will be selected, because 26,446.42 (random number) < 32,689.23 (PSU<sub>i</sub> cumulative area) and 26,446.42 > 22,758.71 (cumulative area of the previous PSU in the list)

A table of selected PSU<sub>i</sub>s following the order of random number generated shall be created containing information on PSU ID, PSU<sub>i</sub> area, PSU<sub>i</sub> cumulative area, the order of the generated random number and random number itself.

Each selected PSU should be assigned a random rank from 1-n where n is the number of PSUs selected (including the 10% oversample), and assigned to a column named PSU\_RANK. Ranks should increase in increment of 1, and no rank should be repeated. This ranking should be made completely independently of any spatial or non-spatial attribute of the PSUs, and should not be rated to the random number generated for PSU selection.

This random ranking should be done separately each time this PSU is selected, such as in the case where the same PSU grid cell is selected more than once for sampling of different strata.

### STEP 4: Create three potential plot anchor points within the stratum and PSU

The table of selected PSUs in Excel shall be imported to ArcGIS and joined to the stratum PSUs shapefile to identify the selected PSUs. Generate **three** random plot anchor points that will potentially serve as SSU<sub>n,i</sub>. These plot anchor points must meet the following criteria:

- No plot anchor point shall be closer than 600m to another plot anchor point
- No plot anchor point shall be closer than 100m to the boundary of the strata it is located in within the PSU

If the size of the PSU does not permit generating 3 plot anchor points that satisfy these criteria, assign the maximum that can be accommodated, but no less than 2.



Each of 3 plot anchor points must be assigned a randomized ranking from 1-3. If less than 3 plot anchor points were generated, assign a randomized rank from 1-n where n is the number of plots generate. Assign this rank to a column named PLOT\_RANK.

**STEP 5: Generate ten potential tree-plot points for each of three plot anchor points within the PSU**

Generate in a GIS software nine randomly placed points within a 300m radius of each plot anchor point. These nine points are potential "tree-plot points," that can serve as the center point of tree-plots.

Tree-plot points must meet the following criteria:

- Be within a 300m radius of the plot anchor point
- No closer than 75m to either the plot anchor point or to any other tree-plot point.

Generate a single tree-plot point coinciding with the plot anchor point (at the exact same location), bringing the total number of tree-plot points to ten.

If the size or shape of the PSU does not allow for generation of enough tree-plot points to satisfy the above criteria, you can reduce the number of tree-plots points generated, but it must be no less than 6.

If 6 cannot be generated, no tree-plot points should be generated for this plot anchor point, and the PLOT\_RANK or the associated plot anchor point should be recoded to -2.

Assign the tree-plot coinciding with the plot anchor point a TREE-PLOT\_RANK of 1. For the remaining 9 tree-plot points, assign a randomized ranking from 2-10. If less than 10 tree-plot points were generated, assign a randomized rank from 2-n where n is the number of tree-plot points generated. Assign this random rank to a column named TREE-PLOT\_RANK. **Important:** the tree-plot coinciding with the plot anchor point shall *always* be assigned the TREE-PLOT\_RANK = 1.

**STEP 6: Create a vector layer of the boundaries of each tree-plot within the cluster**

Each of the 10 tree-plots (or as few as 6 if 10 were not possible) should be converted to a circle vector shape with the tree-plot point serving as the circle center. The radius of the circle shall equal that of the largest nested tree-plot.

**STEP 7: compile a GIS shapefile of all plots and tree-plots generated for the stratum.**

Depending on the software used, the approach here will differ. Overall the objective is to produce a single spatial vector layer of tree-plots generated in the previous steps for a single stratum. The vector layer should show actual bounds of the largest nested tree-plot, not just point or centroids. The vector layer or shapefile should have a table associated structured in the following way:

**Table 1. Illustrative example of a subset of the table associated with tree-plot layer generated in Sample Design and Layout. Column IS\_forest\_RS is populated with values through the subsequent steps**

Stratum	PSU_RANK	PLOT_RANK	TREE-PLOT_RANK	Is_forest_RS
EG	1	1	1	Yes
EG	1	1	2	Yes
EG	1	1	3	Yes
EG	1	1	4	No
EG	1	2	1	Yes
EG	1	2	2	Yes
EG	1	2	3	Yes

A sample design with 40 PSUs selected for sampling within a single stratum could have up to 40 PSUs x 3 plots x 10 tree-plots, or 1200 rows.

## Remote sensing based review of plot suitability

Sampling locations can be evaluated for suitability in some ways before entering the field, to reduce the amount of wasted effort spent on rejected clusters. Specifically, the location of plots in forest or non-forest can typically be assessed using visual interpretation of medium-high resolution imagery (1-10m).

Compile a dataset of imagery representing a recent view of the landscape with sufficient resolution, either spatial or spectral, to allow visual identification of forest vs. non forest areas. Sentinel 10m multiband imagery is a good option and is freely available. Google earth can also be used to supplement areas where Sentinel has missing coverage.

Instructions for visual interpretation of remote sensing requires training that is outside the scope of this SOP. The analyst must already be familiar with the principles of multiband image interpretation as it relates to forest monitoring in Lao PDR.

The overall objectives are to navigate to each plot and tree-plot and assess whether it is forest or non-forest. You should complete this exercise with at least enough valid PSUs to meet the objective of the sampling strategy, and for each selected PSU to have at least 2 valid plots, and for each valid plot, to have at least 6 valid tree-plots.

Steps:

1. Overlay the polygon vector layer representation of the sampling strategy, showing all tree-plot locations for one stratum
2. Navigate to each sampling location, and subsequently to each tree-plot for evaluation in a sequential order always moving from the lowest rank to the next highest:
  - a. Navigate to the PSU that has PSU\_RANK = 1
  - b. Navigate to the sampling location (plot) that has PLOT\_RANK = 1
  - c. Navigate to the tree-plot that has PLOT\_RANK = 1
3. Visually inspect each tree-plot in the sampling location, beginning at PLOT\_RANK = 1 and always moving up to the next rank.
4. Record, either in the spatial dataset itself (i.e. shapefile table) or a separate table, whether the tree-plot area appears to be forest in the imagery. In the column IS\_FOREST\_RS record either 'yes' or 'no.'
5. If at least 6 of the 10 tree-plots are found to be in forest, the plot is considered valid and will be retained in the sampling design. If the plot is NOT valid, change the PLOT\_RANK to -1.
6. Once you have completed assessment of all the tree-plots for this plot, move to the next ranked plot (PLOT\_RANK = 2) in the same PSU and repeat steps 3-5 above.
7. If at least 2 Sampling Locations (Plots) are found to be valid within the PSU, then the PSU is considered valid, and will be retained in the sampling design. If there are NOT sufficient (2) valid sampling locations (plots) in the PSU, recode PSU\_RANK to -1 and move to the next PSU
8. Once you have identified a minimum of 2 plots within the PSU that are valid, you can cease evaluating additional plots in that PSU and move to the next-ranked PSU.
9. Once you have found enough PSUs to be valid to satisfy the sampling design, you can cease evaluating new PSUs.
10. Recode all PLOT\_RANK to convert from a numeric series to alphabetical using the following lookups:  
1:A; 2:B; 3:C; 4:D; 5:E; 6:F; 7:G 8:H 9:I 10:J

After you have completed the entire assessment, determine if, after discounting rejected PSUs, you still retain enough plots to satisfy the sampling design. If not, you must generate new random PSU selection only considering PSU's not already selected in the first round.

Be **conservative** in your rejection of tree-plots. Only reject tree-plots where you are highly confident they are in non-forest

Do not delete any PSU, plot, or tree-plot data. If a plot is not evaluated because the target number of plots was already achieved, the field 'IS\_FOREST\_RS' will be left blank.

**Important:** You will produce in a final dataset of valid PSUs for the stratum, each PSU having 2 valid plots, and each plot 6-10 valid tree-plots. All PSUs, Plots, and Tree-plots will have their own randomly assigned rank. **PSU's and Plots must ALWAYS be collected in order of rank.**

## SOP ESTABLISHMENT OF SAMPLING PLOTS

### Required equipment:

GPS  
Flagging tape  
Rope  
Clinometer (to measure slope)  
>10 m measuring tape (to calibrate DME)  
Distance Measuring Equipment (DME)  
Additional Items for Permanent Plots  
Metal (usually iron) bar about 1-2 cm in diameter and 30 cm long  
Hammer  
Fluorescent paint  
Duct tape  
Permanent marker

### Coordination

Coordination regarding access to sampling plots should be conducted by the survey team in advance of trying to access a plot. This includes conferring with district forestry officials and local villagers to determine the best way to navigate to a sampling plot. In fact, district forestry officials and local villagers compose a key part of each survey team. It may be necessary to spend a day's time coordinating access and securing the participation of local villagers to several plots in a certain area. As such, the expected time per survey plot is expected to be 1.5 days (0.5 days for coordination and 1 day for surveying).

### Establish Clustered Nested Tree-plots

A cluster of 4 circular nested tree-plots will be sampled at each plot. The GPS location of a plot anchor point along with a set of 6-10 potential tree-plots will already have been already randomly pre-determined with an assigned rank (A to J) prior to field work. Each PSU will have at least 2 plots in a ranked order. The lowest ranked plot should be visited first. If it is found invalid, the second plot is visited. Field crews will be given these GPS tree-plot points for these plots and tree-plots head of time.

Navigate to predetermined latitude and longitude of the 1<sup>st</sup> plot within the PSU using a GPS. Once the field crew has arrived near to the plot's perimeter, it should stop to determine the most efficient route to collect tree-plots A-B-C-D in any order. Tree-plot A does not necessarily need to be visited first. If one of these four tree-plots is outside of forest and no nearby forest can be found within 40m, then the 5<sup>th</sup> ranked tree-plot (E) shall be measured as stated below. This process shall be repeated until 4 forested tree-plots of, three of which must be from the same stratum, have been measured or all 10 potential tree-plots have been visited. Once field measurements have taken place within 4 tree-plots, three of which are from the same stratum, field measurements may cease for this plot and PSU. All other tree-plot locations for that plot, and any remaining plots within the PSU, can be ignored and left unmeasured.

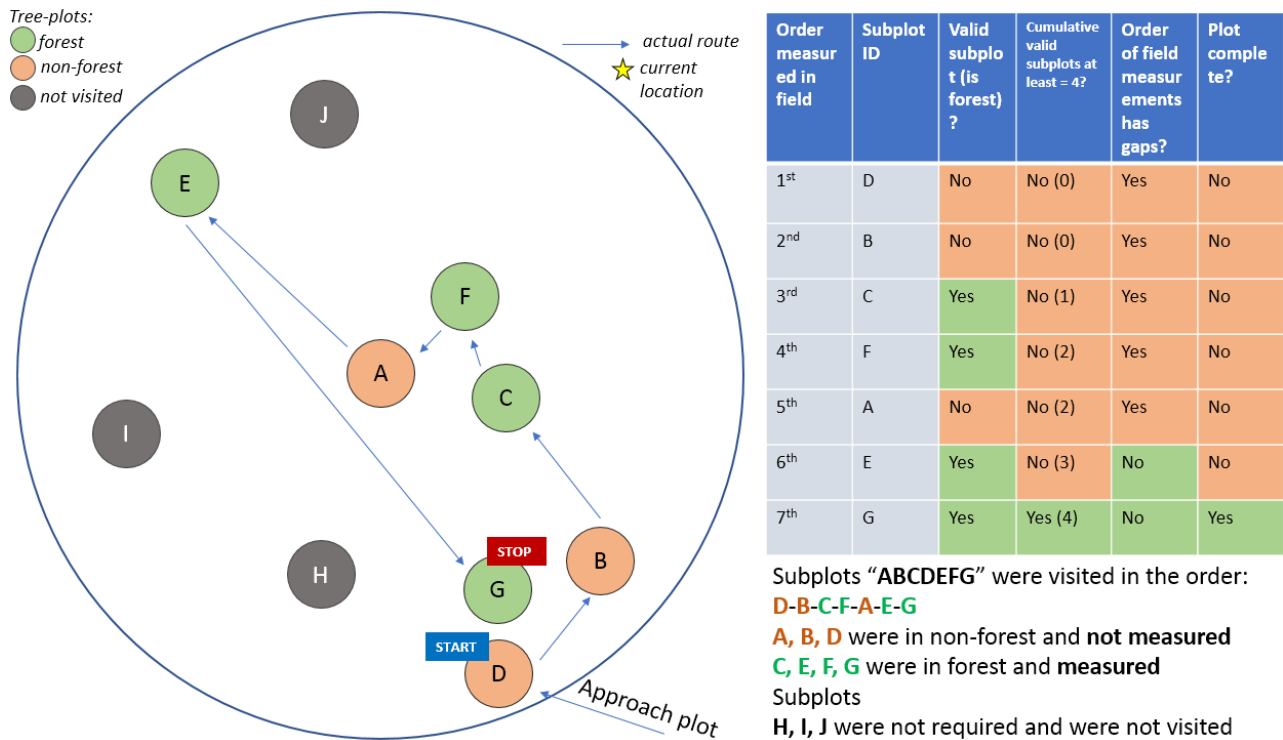
**IMPORTANT:** For all following fieldwork, Plots and Tree-plots MUST be collected such that an uninterrupted series of records is produced, beginning at the lowest rank and continuing until the target number of observations is recorded (4 in the case of tree-plots per plot). In practical terms, it may be more convenient to visit certain tree-plots before others to minimize walking distances. The following is permitted:

- For tree-plots, any of rank A,B,C,D can always be measured in any order.
- If any one tree-plot in A-D is found to be invalid (non-forest), then A-E can be recorded in any order
- If any two tree-plots in A-E are found to be invalid (non-forest), then A-F can be recorded in any order
- If any three tree-plots in A-E are found to be invalid (non-forest), then A-G can be recorded in any order
- And so on until at least 4 valid tree-plots are identified within a unbroken series of tree-plot ranks

### Example of field navigation within one plot:

**Figure 6** highlights a possible scenario for visiting tree-plots located within a single plot.

1. Approaching from the south-east of the plot, the field team determines that the best route to visit tree-plots ABCD is D-B-C-A.
2. Tree-plot D is found to be non-forest and not measured. 4 more valid tree-plots are still required, so field team must now consider tree-plots BCDE. The route is modified to go B-C-A-E.
3. Tree-plot B is found to be non-forest and not measured. 4 more valid tree-plots are still required, so field team must now consider tree-plots CDEF. The route is modified to go C-F-A-D.
4. Tree-plots C and F are both forest, and are recorded, but A is found to be non-forest and is not measured. 2 more valid tree-plots are still required, so the field team must now consider tree-plots EG. The route is modified to go E-G.
5. Tree-plots E and G are both found to be valid and are measured. 4 valid plots have been collected, and the plot is considered complete. No additional tree plots are visited.



**Figure 6.** example of field navigation of tree-plots by rank

For EACH tree-plot visited:

1. Navigate to predetermined latitude and longitude of the primary sampling location using a GPS (this is tree-plot A of plot 1). Walk an additional 5 steps in the direction of travel. These additional steps reduce bias in choosing the plot anchor point.
2. Evaluate the forest cover. If an entire tree-plot would fall under one **forest** class at this location, then establish the tree plot.. A plot should be established even where the forest class observed on the ground does not agree with what it was predicted to be by a land cover map.
3. If any tree-plot is found to be partially or entirely in **non-forest**, but in which forested areas are nearby, the sampling location shall be moved in the direction of the closest forested area so that the tree-plot point is at least 40 m from a forest edge across the entire tree-plot
4. If no close forest area is within 40 m , then no sampling shall take place at this tree plot.. The team leader should make an entry for "**tree-plot A**" on the datasheet or tablet, indicating the reason why the sub-plot was not installed. The team should move on to "**tree-plot B**".
5. At the tree-plot point, mark a 'waypoint' on GPS and record GPS coordinates, accuracy, elevation, and waypoint number on data sheet or tablet. To record a GPS location, place the GPS at the tree-plot center/corner and let it record for > 5 minutes prior to marking a 'waypoint'. The minimum precision

level should be  $\pm 5$  m. Leaving the GPS at one location for several minutes allows the GPS to get a more accurate location by averaging many location acquisitions. The longer the GPS acquires locations the more accurate the final location. The accuracy of the location is estimated and is displayed by the GPS. If there is heavy vegetation cover, it may take a longer time to acquire an accurate location. In some cases, it may be necessary to move slightly or devise a way of getting the GPS higher in the air to acquire satellite signals. For more information, see SOPs on the use of GPS and the manual of the GPS being used<sup>7</sup>.

6. Label the tree-plot point based on SOP Labeling Plots.

These same procedures listed above shall be repeated until ALL of the following criteria are met:

- 1) Four tree-plots are in the land-use class Natural Forest.
- 2) At least 3 of the 4 forested tree-plots have the same land use class (e.g. one of the 5 forest classes, EF, MDF, MDB, CF, or DD).
- 3) Field-visited plots (either measured or rejected as invalid) must form an uninterrupted series beginning with A.

As soon as these criteria are met, the PSU is considered successfully sampled and the field team can cease all measurement within the PSU.

If these criteria cannot be met within the plot after visiting all available tree-plots, the entire plot is rejected as invalid, and the field team should move to the next-ranked plot located within the current PSU.

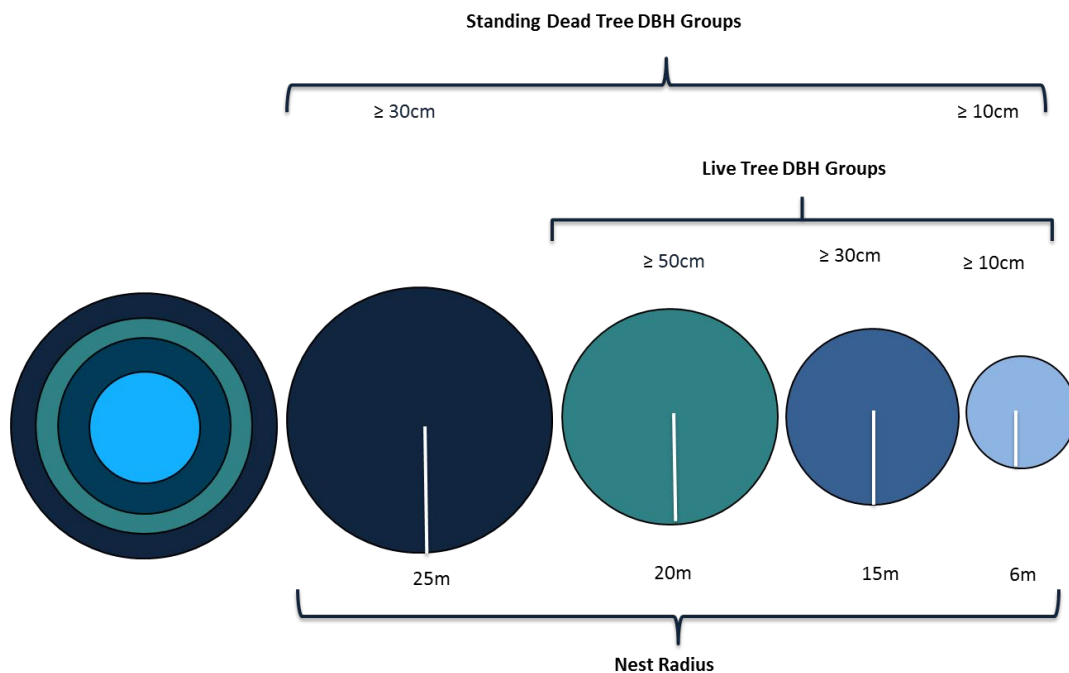
In summary, a few simple rules will help field teams understand and make field-based decisions during collection, these include:

1. The plot anchor point does **not** necessarily need to be visited first (tree-plot A). Any of A,B,C,D can be visited first.
2. If any tree-plot observed in the field is non-forest, but is near the edge of forest area, the tree-plot should be shifted in the direction of the closes forest such that the tree-plot point is at least 40 m from the forest edge.
3. If a tree-plot cannot be shifted to reach forest, it is invalid and another tree-plot must be visited to achieve.
4. The measured tree-plots must be from an uninterrupted series from A-*n* where, where each tree-plot within A-*n* has either been measured or visited and determined to be invalid, and where *n* is the highest rank tree-plot needed to collect 4 valid tree-plots. (see Figure 6). Within this series of tree-plots, they can be collected in any order.
5. At least 3 tree-plots must be in the stratum they are predicted to be based on the cluster's stratum designation
6. Data entries must be made for all sub-plots, even if:
  - o no data was collected,
  - o a team did not go to the location,
  - o access was impossible,
  - o stratum was non-forest.

The following circular nest sizes for standing dead trees and live trees are recommended for each stratum as below.

	Live trees	Standing deadwood
6 m	10 cm - 30 cm	10-30 cm
15 m	30-50 cm	>30cm
20 m	>50 cm	>30 cm
25 m		>30cm

<sup>7</sup> If a Garmin GPS Map60 is being used, the following steps can be used: a) prior to saving new waypoint, press MENU. b) Highlight 'Average Location' and press ENTER. c) Let GPS sit for many minutes until 'Estimated Accuracy' stabilizes. d) press ENTER to save location. (see manuals at [www.garmin.com](http://www.garmin.com) for more information)



**Figure 7 Nest radii (when slope <10% and size classes for each nest).**

In the nested tree-plots, the following vegetation types will be sampled: Trees; Standing Dead Trees. The methods for sampling each of these vegetation types in the tree-plots are described in the respective SOP.

The dimensions and vegetation types sampled in each nest is presented in SOP Sampling Design and Layout. Based on the Sampling Layout determined in SOP Sampling Design and Layout, walk to the tree-plot center point.

1. Label the tree-plot based on SOP Labeling Plots
2. Measure the slope using a clinometer following the 'SOP Use of a Clinometer and Measurement of Slope'. If the slope is greater than 10% record the exact slope.
3. Correct for the size of the tree-plot area to account for the slope. (see below 'Tree-plot Area correction'), record the sizes of each of the nests for that tree-plot on the data sheet and inform all crew members.
4. Describe land and vegetation conditions of plot 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.
5. Mark center of the plot with an iron stake. This plot center mark will be used to identify the plot center during any third-party verification or quality checks.

When using Distance Measuring Equipment (DME) the only requirement is to 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.

## Slope Corrections - Conducted in the field

If the sampling location area falls on a slope that is greater than 10%, then slope angle should be measured using a clinometer so that an adjustment can be made to the location sampled. If slope is less than 10%, correction is not required.

### Tree-plot area correction

Where tree-plots are on sloped ground, tree-plot size has to be adjusted to reflect the true horizontal projection. When a tree-plot is to be established on sloped terrain, the radius for each of the nests within the tree-plot may need to be adjusted. That means the radii for the various nests will be slightly longer in the field to ensure the vertical projection of each of the nested tree-plots will yield the same area as if the tree-plot were established on flat terrain.

The slope must be measured for each of the clustered tree-plots.

To determine the corrected radius, the radius on the slope is first calculated, using the following equation:

$$\text{Sloped\_Radius} = \frac{\text{Nest\_Radius}}{\cos \theta}$$

### Where:

Sloped\_Radius = Length of radius (m) on slope that corresponds to horizontal radius

Nest\_Radius = Length of radius agreed upon in flat terrain (m)

Cos $\theta$  = Cosine of the slope angle

The true horizontal projection of a circular plot on a slope is an ellipse, but because it is not possible to establish an ellipse in the field with accuracy, the plot is adjusted to be a circle having the same area as the ellipse. Therefore, after determining the corrected radius on the slope, the area is calculated as follows:

$$\text{Corrected\_Area} = \pi * \text{Nest\_Radius} * \text{Sloped\_Radius}$$

The corrected radius, to be used in the field, is then calculated as follows:

$$\text{Corrected\_Radius} = \sqrt{\frac{\text{Corrected\_Area}}{\pi}}$$

The correction of the tree-plot nests should be conducted in the field by the crew leader, based on the corrected radius for the appropriate slope as shown in the table in Appendix 1. Measured slope gradient should be approximated to the nearest slope gradient. This should be printed and used by the crew leader. A simplified version is also provided in the Team Leader's tablet.

## Extrapolation to Hectare – Conducted during data analysis

Following field data collection, during data analyses, any measurements taken at the plot level are extrapolated to the area of a full hectare to produce carbon stock estimates on a 'per hectare' basis. Extrapolation is done by the use of scaling factors that are calculated as the proportion of a hectare (10,000 m<sup>2</sup>) that is occupied by a given nested plot or clip plot:

$$\text{Scaling\_factor} = \frac{10,000\text{m}^2}{\text{Horizontal\_Area\_of\_nest\_ (m}^2)}$$



## SOP MEASUREMENT OF TREES

### Field equipment:

Tree name list

Diameter tapes

Flagging tape

Tree poles: Small-diameter PVC piping or wooden sticks cut the exact length of diameter measurements (eg 1.3 m if DBH will be measured)

Distance Measuring Equipment (DME)

Spray Paint

### For measuring height (see SOP Measurement of Height):

Clinometer

>20m measuring tape

The design and establishment of plots shall be determined following SOP Plot Design and SOP Establishment of Plots. In the NFI, temporary tree-plots will be used.

1. Assign one person (Team Leader) to record the data and all others should be measuring and marking trees. The recorder should stand in the center of the nested tree-plot being measured. He or she should track those measuring the trees and should try and ensure that no trees are missed.
2. 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 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.
3. **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 important to carefully decide if a tree is in or out of a plot. To definitively determine whether the tree is in or out of the plot, use a DME 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 more than 50% of the base of the trunk is within the boundary of the nest, the tree is considered within the nest. If more than 50% of the base of the trunk is outside of the boundary, it is out and should not be measured. If it is exactly on the border of the plot, flip a coin to determine if it is in or out.
4. Record the name of the tree, based on tree naming system developed prior to field data collection.
5. **Tree Pole placement:** For each tree, place the Tree Pole (e.g. 1.3 m plastic pole) against the tree to indicate the location of measurement (e.g. DBH). Placement of the Tree Pole depends on the slope of the ground, leaning angle of the tree, and shape of the tree bole (see Figure below for correct placement of diameter tape).
  - a. **Slope:** Always place tree pole and measure diameter on the *upslope* side of the tree
  - b. **Leaning tree:** Always measure the height of a measurement (e.g. 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 location of measurement (e.g. DBH).
  - c. **Dead tree:** If a tree is in dead class 1 (see SOP Measurement of Standing Dead Wood), mark as dead on data sheet. Trees are considered alive if there are green leaves present. Even if there are only one or two green leaves present the tree is considered alive. However, in deciduous forests during a season when trees drop their leaves (i.e. dry season) a branch or the stem must be cut to verify that the cambium is alive in order to determine if the tree is alive or dead.
  - d. **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 and tag the stems that exceed the minimum diameter for the nest. 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.
  - e. **Buttressed tree**
    - i. If the buttress is shorter than the allometric equation's dictated measurement point (e.g. 1.3 m, measure the diameter at the standard (e.g. 1.3 m) height.
    - ii. If the buttress is taller than 1.3 m, measure the diameter at 30 cm above top of buttress as shown in example D in the figure above, and above the top of the mangrove roots in

the figure below. In cases where the buttress or mangrove roots are too tall and out of reach, the following procedure shall be followed:

1. Taking into consideration the safety of field crew, climb the tree to take measurement 30 cm above the top of the buttress. In fluted buttress, it is possible to carve steps on the buttress itself to allow climbing to top of buttress. Extreme caution should be employed and climbing should only be performed when conditions are deemed safe by field crew leader.
2. If climbing is considered unsafe, poles can be use. Mark 30 cm from the top of the pole. Attach DBH tape to the top of the pole and place this along the bole so that the 30 cm mark lines up with the top of the buttress. Use a series of other poles to move the DBH tape into position around the tree until it reaches the zero point on the DBH tape, ensuring the tape measure is perpendicular to the bole and does not flip upside down. Poles can be made from tall saplings found outside the sampling plot in the forest or by linking Tree Poles together (e.g. with pvc connectors)
3. If no alternatives exist, poles shall be placed against the tree, at the edge of its circumference, projecting the diameter at exactly 30 cm above top of buttress down to the ground. An observer is required to ensure poles are properly placed at the very edge of tree's circumference in a way that linear distance between poles represents the diameter of tree at 30 cm above end of buttress. The **linear distance** (e.g. use regular tape measure NOT DBH tape measure) between the two poles shall be measured. At least two measurements shall be taken on opposite sides of tree using this method, and then averaged to estimate tree DBH. Poles can be made from tall saplings found outside the sampling plot in the forest or by linking Tree Poles together (e.g. with pvc connectors).

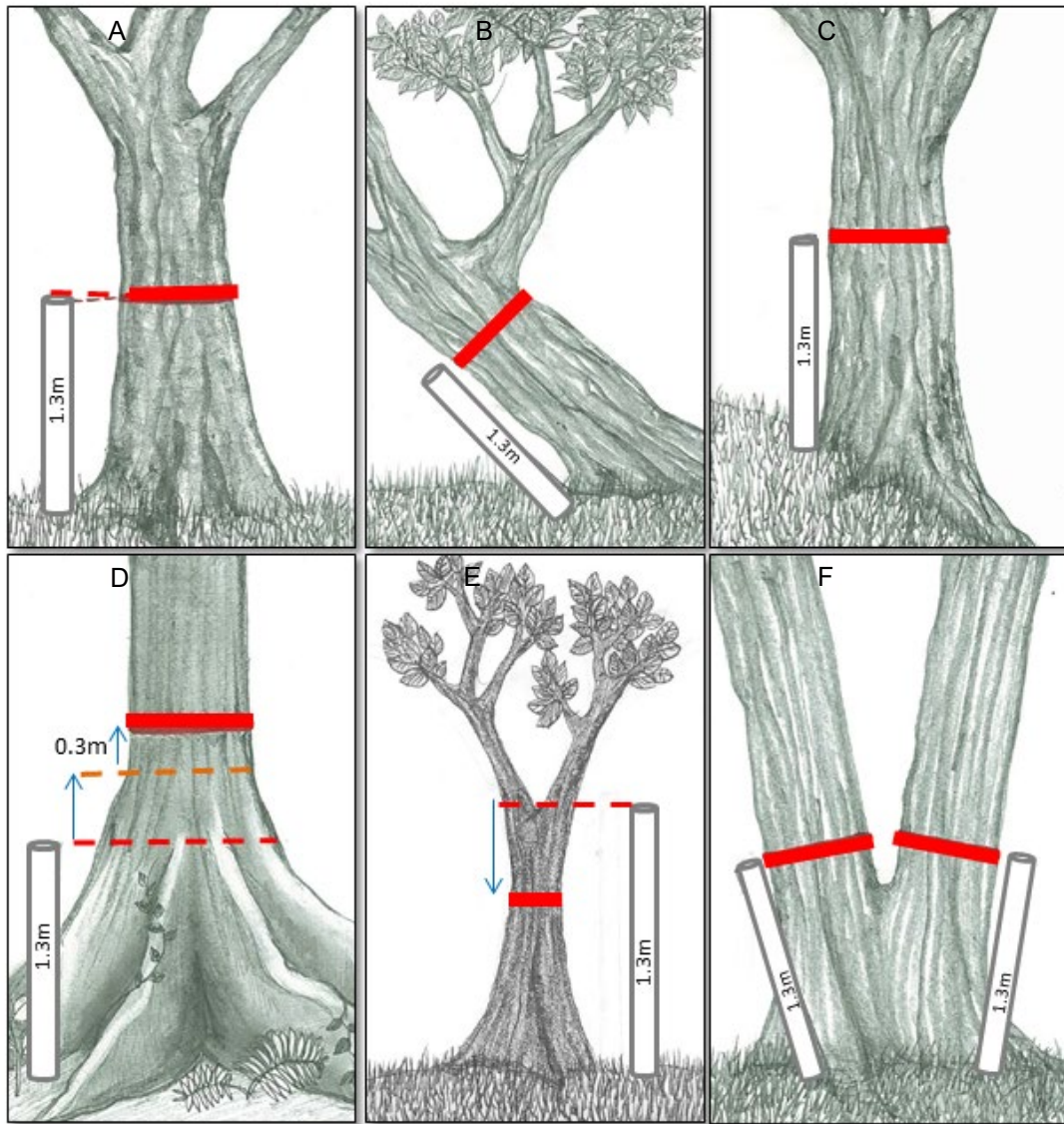


Figure 8: Proper placement of diameter tape when allometric equation used requires measurement at DBH (1.3 m)

- f. **Diameter measurement:** Tree diameter should be measured to the nearest 0.1 cm (e.g. diameter of 10.2 cm *not* 10 cm).
  - i. 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. (see Figure below)
  - ii. If a liana or vine is growing on a tree that is going to be measured, do not cut the liana to clear a spot to measure the tree's diameter. If possible, pull the liana away from the trunk and run the diameter tape underneath. If the liana is too big to pull away from the trunk, estimate the diameter of the liana and subtract from total tree diameter. Cutting a liana from a tree should only be done if there are no other options. The same standard should be followed for any other type of natural organisms (mushrooms, epiphytes, fungal growths, termite nests, etc.) that are found on the tree.
  - iii. Place mark on the tree to indicate to crew members that the tree has been measured.



**Figure 9: Measurement of diameter using a diameter tape and tree pole**

When all of the trees in the tree-plot have been measured, there should be a double-check by the team leader to see that all of the appropriate trees have been measured.

# SOP MEASUREMENT OF STANDING DEAD WOOD

## Field Equipment:

DBH tape  
Clinometer  
Distance Measuring Equipment (DME)  
Laser range finder (OPTIONAL)  
Measuring tape

## Other:

'Sound dead wood' density estimate (see SOP 6 Measurement of dead wood density)

Standing dead wood refers to trees that have died but are still upright. Usually the minimum size class of dead trees measured is the same as the minimum live tree measured (for example trees greater than 10 cm DBH and taller than 1.3 m). However, standing dead wood generally also includes dead wood stumps from trees that were greater than 10 cm DBH when alive but have a current height of less than 1.3 m, thus all standing dead wood with a diameter greater than 10 DBH or at stump height shall be measured.

This SOP must be done in conjunction with the SOP Measurement and Estimation of Dead Wood Density.

Generally, measurements of standing dead wood take place concurrently with live tree measurements. Each standing dead trees should be classified into three 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: Dead trees containing large branches or no branches at all but taller than 1.3 m,.
- Class 3: Dead trees containing only large branches or no branches at all, but less than 1.3 m

By classifying trees into these three simplified classes, a conservative estimate of biomass will be taken.

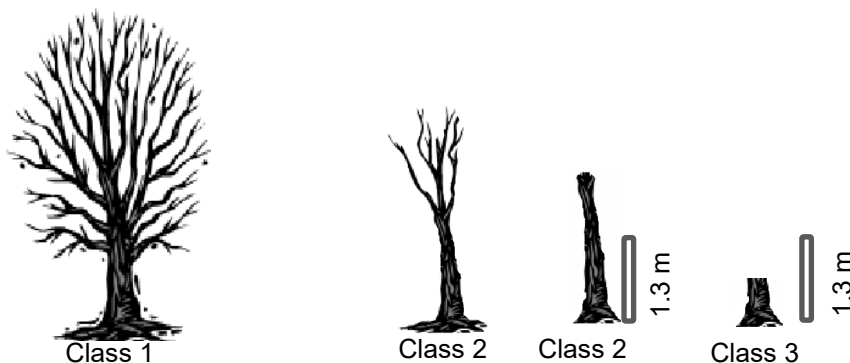


Figure: Example of trees in Class 1, Class 2 and Class 3

## Field Measurements

The design and establishment of plots shall be determined following SOP Plot Design and SOP Establishment of Plots. The instructions here assume these SOPs have already been followed. Please see SOP Establishment of Sampling Plots for the size classes of trees to be measured

### Class 1 trees:

1. Follow the same measurement protocols as for the measurement of live trees, including the measurement of tree variables (e.g. DBH) (see SOP Measurement of Trees). Mark tree as 'Dead' on datasheet.

### Class 2 trees (see Figure below):

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 ( $H$ ) either using a clinometer and measuring tape or laser range finder (see SOP Measurement of tree height) or through direct measurement using tape measure (e.g. when dead wood is less than 2 m high)
5. Measure diameter at top of stump ( $D_{top}$ ) either through direct measurement (e.g. when diameter at top can be reached directly) or through the use of a relascope. Alternatively, do not take a measurement at the top of the stump and write 'None' or 'NA' on datasheet.

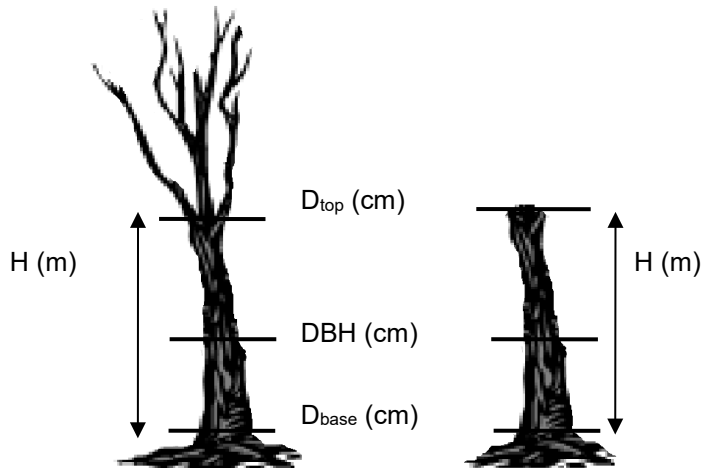
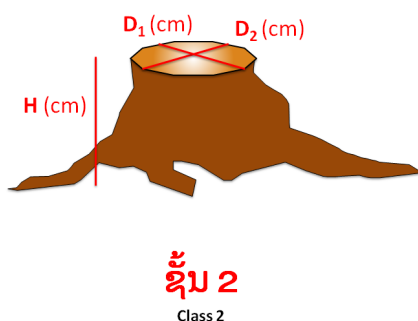


Figure2 Standing dead tree measurement locations

### Class 3 trees (stumps)

Stumps are a special type of class 2 standing deadwood. These are standing deadwood trees that fall below 1.3m; they are typically the result of logging. Stumps are measured in all nests according to the diameter requirements of each nest.



For stumps, three measurements are taken:

1. Height ( $H$ ) - this will be below 1.3m
2. Smallest Diameter ( $D_1$ ) – this is the smallest diameter across the top of the stump
3.  $D_2$  – the diameter at a  $90^\circ$  angle to  $D_1$ .
4. Likely cause: Natural, Unknown, Machine, Saw Axe, Unknown

The stump is considered as falling within a nest if either  $D_1$  or  $D_2$  meet the minimum diameter requirement for the nest.

## Volume Equations

A full description of the steps required to estimate standing dead wood biomass per hectare are not included here. However, equations are provided to estimate the volume of an individual standing dead tree. Different approaches can be used for different trees, depending on whether it is possible to measure the diameter at the top of a given dead tree.

To estimate the biomass of an individual standing dead tree, the estimated volume is multiplied by the average density calculated for 'sound wood' (see SOP Measurement of Deadwood Density).

**Option 1:** Diameter at top ( $D_{top}$ ) was measured directly:

Volume estimated assuming tree is a truncated cone:

$$Volume = \left( \frac{\pi * Height}{12} \right) \cdot (D_{base}^2 + (D_{base} \cdot D_{top}) + D_{top}^2)$$

**Option 2:** Diameter at top ( $D_{top}$ ) was measured using a Relascope:

Volume estimated assuming tree is a truncated cone:

$$Volume = \left( \frac{\pi * Height}{12} \right) \cdot (D_{base}^2 + (D_{base} \cdot D_{top}) + D_{top}^2)$$

**Option 3:** Diameter at top ( $D_{top}$ ) estimated using taper equation:

$$D_{top} = D_{base} - \left[ H \cdot \left( \frac{D_{base} - DBH}{130 \cdot 100} \right) \right]$$

Volume estimated assuming tree is a truncated cone:

$$Volume = \left( \frac{\pi * Height}{12} \right) \cdot (D_{base}^2 + (D_{base} \cdot D_{top}) + D_{top}^2)$$

**Option 4:** Diameter at top ( $D_{top}$ ) is assumed to be zero.

Volume estimated assuming tree is a cone.

$$Volume = \frac{1}{3} \cdot \pi \cdot \left( \frac{D_{base}}{2} \right)^2 \cdot H$$

# SOP MEASUREMENT OF STANDING DEAD TREE HEIGHT

## Field Equipment

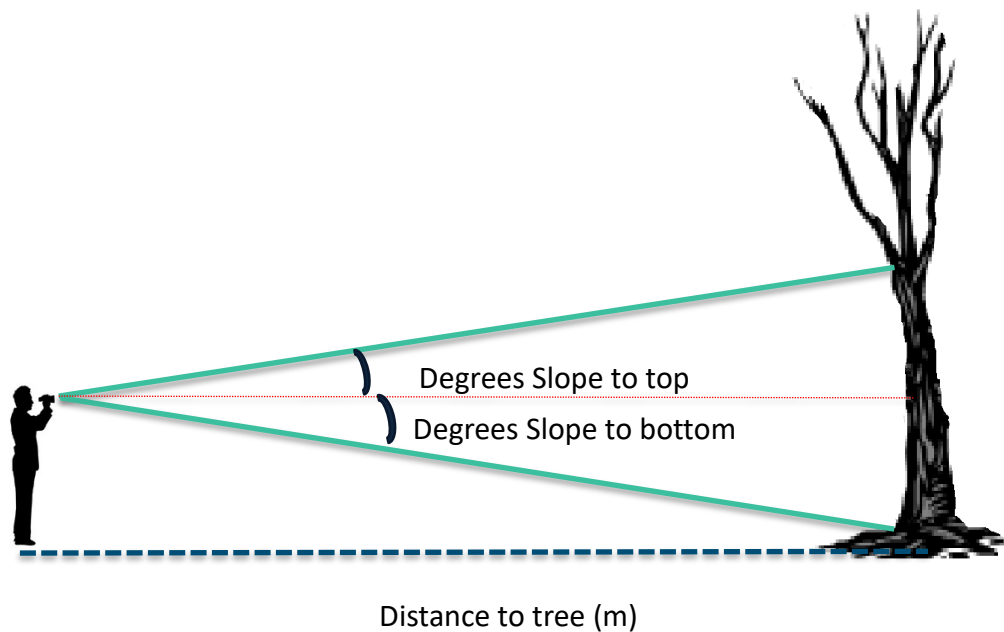
Measuring tape  
Clinometer

When measuring the height of deadwood trees taller than 2m, it is necessary to follow the guidance provided below. This SOP is to be used in conjunction with the SOP Measurement of Standing Deadwood.

## Field Measurements

When determining the height (H) of class 2 standing deadwood trees that are taller than 2m, the following should be done:

1. Measure 10m from the base of the deadwood tree using the measuring tape. This should be in a direction that will allow the top of the bole to be visible. In case the tree is on a slope, follow the same contour slope as the tree. The measurement away from the tree needs to be as flat as possible.
2. Use the clinometer to measure the angle (in Degrees) to the top of the bole and to the base of the tree. In the case that the tree is too tall and the clinometer reading to the top of the bole is beyond the clinometers range, move further away. Re-record the distance to the tree and re-measure the slope to both the top of the bole and the base of the tree.







## APPENDIX I: EXAMPLE DATASHEETS

### 1. Nested Tree-plot Radius Correction Table

## Nested Tree-plot Radius Correction Table – to correct area of plot based on slope

Slope (%)	Corrected Radii (m)																													
0	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
10	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.1	22.1	23.1	24.1	25.1	26.1	27.1	28.1	29.1	30.1	
15	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.1	10.1	11.1	12.1	13.1	14.1	15.1	16.1	17.1	18.1	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.1	27.2	28.2	29.2	30.2	
20	2.0	3.0	4.0	5.0	6.1	7.1	8.1	9.1	10.1	11.1	12.1	13.1	14.1	15.1	16.2	17.2	18.2	19.2	20.2	21.2	22.2	23.2	24.2	25.2	26.3	27.3	28.3	29.3	30.3	
25	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.1	10.2	11.2	12.2	13.2	14.2	15.2	16.2	17.3	18.3	19.3	20.3	21.3	22.3	23.4	24.4	25.4	26.4	27.4	28.4	29.4	30.5	
30	2.0	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.2	11.2	12.3	13.3	14.3	15.3	16.3	17.4	18.4	19.4	20.4	21.5	22.5	23.5	24.5	25.5	26.6	27.6	28.6	29.6	30.7	
35	2.1	3.1	4.1	5.1	6.2	7.2	8.2	9.3	10.3	11.3	12.4	13.4	14.4	15.4	16.5	17.5	18.5	19.6	20.6	21.6	22.6	23.7	24.7	25.7	26.8	27.8	28.8	29.9	30.9	
40	2.1	3.1	4.2	5.2	6.2	7.3	8.3	9.3	10.4	11.4	12.5	13.5	14.5	15.6	16.6	17.6	18.7	19.7	20.8	21.8	22.8	23.9	24.9	25.9	27.0	28.0	29.1	30.1	31.1	
45	2.1	3.1	4.2	5.2	6.3	7.3	8.4	9.4	10.5	11.5	12.6	13.6	14.7	15.7	16.8	17.8	18.8	19.9	20.9	22.0	23.0	24.1	25.1	26.2	27.2	28.3	29.3	30.4	31.4	
50	2.1	3.2	4.2	5.3	6.3	7.4	8.5	9.5	10.6	11.6	12.7	13.7	14.8	15.9	16.9	18.0	19.0	20.1	21.1	22.2	23.3	24.3	25.4	26.4	27.5	28.5	29.6	30.7	31.7	
55	2.1	3.2	4.3	5.3	6.4	7.5	8.5	9.6	10.7	11.8	12.8	13.9	15.0	16.0	17.1	18.2	19.2	20.3	21.4	22.4	23.5	24.6	25.6	26.7	27.8	28.8	29.9	31.0	32.0	
60	2.2	3.2	4.3	5.4	6.5	7.6	8.6	9.7	10.8	11.9	13.0	14.0	15.1	16.2	17.3	18.4	19.4	20.5	21.6	22.7	23.8	24.8	25.9	27.0	28.1	29.2	30.2	31.3	32.4	
65	2.2	3.3	4.4	5.5	6.6	7.6	8.7	9.8	10.9	12.0	13.1	14.2	15.3	16.4	17.5	18.6	19.7	20.7	21.8	22.9	24.0	25.1	26.2	27.3	28.4	29.5	30.6	31.7	32.8	
70	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.0	12.2	13.3	14.4	15.5	16.6	17.7	18.8	19.9	21.0	22.1	23.2	24.3	25.4	26.5	27.6	28.7	29.8	30.9	32.0	33.1	
75	2.2	3.4	4.5	5.6	6.7	7.8	8.9	10.1	11.2	12.3	13.4	14.5	15.7	16.8	17.9	19.0	20.1	21.2	22.4	23.5	24.6	25.7	26.8	28.0	29.1	30.2	31.3	32.4	33.5	
80	2.3	3.4	4.5	5.7	6.8	7.9	9.1	10.2	11.3	12.4	13.6	14.7	15.8	17.0	18.1	19.2	20.4	21.5	22.6	23.8	24.9	26.0	27.2	28.3	29.4	30.6	31.7	32.8	33.9	
85	2.3	3.4	4.6	5.7	6.9	8.0	9.2	10.3	11.5	12.6	13.7	14.9	16.0	17.2	18.3	19.5	20.6	21.8	22.9	24.1	25.2	26.3	27.5	28.6	29.8	30.9	32.1	33.2	34.4	
90	2.3	3.5	4.6	5.8	7.0	8.1	9.3	10.4	11.6	12.8	13.9	15.1	16.2	17.4	18.6	19.7	20.9	22.0	23.2	24.4	25.5	26.7	27.8	29.0	30.2	31.3	32.5	33.6	34.8	
95	2.3	3.5	4.7	5.9	7.0	8.2	9.4	10.6	11.7	12.9	14.1	15.3	16.4	17.6	18.8	20.0	21.1	22.3	23.5	24.7	25.8	27.0	28.2	29.4	30.5	31.7	32.9	34.1	35.2	
100	2.4	3.6	4.8	5.9	7.1	8.3	9.5	10.7	11.9	13.1	14.3	15.5	16.6	17.8	19.0	20.2	21.4	22.6	23.8	25.0	26.2	27.4	28.5	29.7	30.9	32.1	33.3	34.5	35.7	
105	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4	15.7	16.9	18.1	19.3	20.5	21.7	22.9	24.1	25.3	26.5	27.7	28.9	30.1	31.3	32.5	33.7	34.9	36.1	
110	2.4	3.7	4.9	6.1	7.3	8.5	9.8	11.0	12.2	13.4	14.6	15.9	17.1	18.3	19.5	20.7	21.9	23.2	24.4	25.6	26.8	28.0	29.3	30.5	31.7	32.9	34.1	35.4	36.6	
115	2.5	3.7	4.9	6.2	7.4	8.6	9.9	11.1	12.3	13.6	14.8	16.0	17.3	18.5	19.8	21.0	22.2	23.5	24.7	25.9	27.2	28.4	29.6	30.9	32.1	33.3	34.6	35.8	37.0	
120	2.5	3.7	5.0	6.2	7.5	8.7	10.0	11.2	12.5	13.7	15.0	16.2	17.5	18.7	20.0	21.2	22.5	23.7	25.0	26.2	27.5	28.7	30.0	31.2	32.5	33.7	35.0	36.2	37.5	
125	2.5	3.8	5.1	6.3	7.6	8.9	10.1	11.4	12.7	13.9	15.2	16.4	17.7	19.0	20.2	21.5	22.8	24.0	25.3	26.6	27.8	29.1	30.4	31.6	32.9	34.2	35.4	36.7	38.0	
130	2.6	3.8	5.1	6.4	7.7	9.0	10.2	11.5	12.8	14.1	15.4	16.6	17.9	19.2	20.5	21.8	23.1	24.3	25.6	26.9	28.2	29.5	30.7	32.0	33.3	34.6	35.9	37.1	38.4	
135	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13.0	14.3	15.6	16.9	18.1	19.4	20.7	22.0	23.3	24.6	25.9	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6	38.9	
140	2.6	3.9	5.2	6.6	7.9	9.2	10.5	11.8	13.1	14.4	15.7	17.1	18.4	19.7	21.0	22.3	23.6	24.9	26.2	27.5	28.9	30.2	31.5	32.8	34.1	35.4	36.7	38.0	39.3	
145	2.7	4.0	5.3	6.6	8.0	9.3	10.6	11.9	13.3	14.6	15.9	17.3	18.6	19.9	21.2	22.6	23.9	25.2	26.5	27.9	29.2	30.5	31.9	33.2	34.5	35.8	37.2	38.5	39.8	
150	2.7	4.0	5.4	6.7	8.1	9.4	10.7	12.1	13.4	14.8	16.1	17.5	18.8	20.1	21.5	22.8	24.2	25.5	26.9	28.2	29.5	30.9	32.2	33.6	34.9	36.3	37.6	38.9	40.3	

## APPENDIX II: FIELD EQUIPMENT REQUIREMENTS PER FIELD TEAM

Equipment	Quantity	Crew Member	SOP	Use/Info
<b>NFI Sampling Coordinator</b>				
Tablet	1/team			
Tablet charging cable/cord	2/team			
Tablet backup battery	1/team			
GPS	2/team			
GPS memory card	1/team			
AA batteries for GPS				
<b>Field Sampling Crew</b>				
Machete	2/team	Village guides	All	
Whistles	1/person		All	one per team member
First Aid Kit	1/team		All	
Chalk sticks	many		Tree plots	to mark measured trees
1.3 m poles	2/team	DME Person1 and 2	Tree plots	make from PVC piping or sturdy sticks
Durable plastic tarp ~2 m x 2 m	1/team		All	to put equipment on while measuring plot
Two-way radios	1/team	Crew Chief	All	
Tablet		Crew Chief	All	
Tablet cord		Crew Chief	All	
Camera (or use Tablet)	1/team	Crew Chief	All	
GPS	2/team	Crew Chief & assistant	All	
GPS Waterproof case	1/GPS	Crew Chief	All	
GPS memory		Crew Chief	All	
AA batteries for GPS	many	Crew Chief	All	
clip board	1/team	Crew Chief	All	
Compass	1/team	Crew Chief	Navigation, safety	
Bright colored spray paint	many	Crew Chief	temporary mark tree-plot center	
DME			Tree plots	Haglof DME 201 Cruiser
DME pole	1/team	DME Person1	Tree plots	
DME transponder (yellow piece)	1/team	DME Person1	Tree plots	
DME distance measuring unit (grey small box)	2/team	DME Person1 and 2	Tree plots	
AA batteries for transponder	many	DME Person1	Tree plots	

9V batter for DME grey box	many	DME Person1 and 2	Tree plots	
Clinometer (slope)	1/team	DME Person 2	Slope, tree heights, standing dead trees, palms	*Note: must have clinometer that measures slope. If have height specific clinometer, then MUST also purchase slope clinometer*
Clinometer case		DME Person 2	Slope, tree heights, standing dead trees, palms	
Measuring Tape - 50 m	2/team	LDW Person 1	LDW	
Biodegradable Flagging tape	2/team		All	
diameter tape measure	2/team	DME Person1 and 2	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"
Work gloves	1 set/person		All	for people doing clip plots, and weighing vegetation
Equipment backpacks	2/team		All	to carry equipment, lunch, and water into field
Small backpack or hipsack	1/person		All	to carry small equipment while in field
Water bottles	1/person		All	
Lunch containers	1/person		All	reusable containers to carry lunch into field
Permanent Marker	5/team		All	
Pens	many		All	
Pencils	many		All	
Pencil sharpeners	many		All	
Erasers	many		All	
Stapler	1/team		All	staple datasheets together
Staples			All	staple datasheets together
small notebooks	1/person		LDW	
<b>NTV, bamboo sampling:</b>				
calipers (see Bamboo SOP for size)	2/team	LDW Person 1	Bamboo	
hanging scale - 500 g	1/team		Subsamples - non-tree veg, shrubs, litter, dead wood density, saplings	weigh subsamples
hanging scale - 5 kg	1/team		non-tree veg, shrubs, litter, dead wood density, saplings	weigh saplings, shrubs, non-tree vegetation. Size needed depends on how large understory vegetation is
hook - for hanging scale	1/scale			accessories for scales
case - for hanging scale	1/scale			accessories for scales
clip - for hanging scale	1/scale			accessories for scales

Cloth bags. Can buy professional ones OR make locally		subsamples: non-tree veg, shrubs, litter, dead wood density, saplings	for subsamples. Need to be around 20 cm x 30 cm. have cloth bags made at market. must be closable - If cloth, can make with draw string or maybe able to staple
Clip Plot (pvc)	1/team	non-tree veg, shrubs, litter	For clip plots: non-tree veg., shrubs, litter. get PVC piping and cut into 50 cm long sets, and 25 cm long sets. Also get elbows to put together. Piping can be very narrow. DO NOT GLUE together! Using four pipes and four elbow connectors, we will make a square frame that can be assembled and disassembled in the field.
Clippers	2/team	non-tree veg, shrubs, litter	to cut understory vegetation for clip plots, litter
Lightweight plastic sheeting		non-tree veg, shrubs, litter, dead wood density, saplings	to weigh vegetation on