Standard Operating Procedures for Terrestrial Carbon Measurement

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INTRODUCTION AND HOW TO USE THIS DOCUMENT

The active and important role vegetation and soil play in the global carbon cycle and global climate change is now internationally recognized. Vegetation and soil can act as both a net source and a net sink of greenhouse gas (GHG), depending on how the land is managed. Alterations in land use management techniques that result in changes to net GHG emissions are now a significant component to the regulatory and voluntary actions taking place globally to combat climate change.

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 methods presented in each Standard Operating Procedure (SOP) have been developed over time by foresters and ecologists to accurately and efficiently estimate carbon stocks.

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 all the carbon pools. These can be used to estimate the standing stock of a carbon pool within a stratum. Another set of SOPs are presented to estimate the emissions resulting from selective logging. Various SOPs are also presented on estimating canopy cover. These SOPs should only be used when the purpose of data collection is known.

This manual *does not* specify guidance on stratification, sampling design, sampling intensity, the spatial distribution of sampling points, pool measurement selection, or the methods needed to transform field measurement data into carbon stock estimates. Therefore, additional guidance is required prior to any field data collection.

The SOPs present a *generic* approach that will be appropriate for most land cover types, ecosystems, and locations. However, all the field measurement methods presented in this document may require adaptation for the specific ecosystem, land cover, and vegetation type in the location where sampling will take place.

The SOP manual is also *not specific* to any regulatory or voluntary market standard such as the Clean Development Mechanism (CDM), Climate Action Reserve (CAR), American Carbon Registry (ACR), Verified Carbon Standard (VCS), CarbonFix, or PlanVivo.

Therefore, it is imperative that methods presented here are adapted into a specific SOP manual, developed for a specific field measurement campaign. The particular adaptations required should be conducted by a forester or ecologist with detailed knowledge in field carbon stock measurement and in the particular carbon market regulatory requirements.

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

It is expected that this manual will be updated overtime as the carbon market changes and as terrestrial carbon science evolves. Therefore, it is recommended that prior to use, users visit Winrock International's website to determine if a more recent version is available at www.winrock.org/ecosystems.

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 Plots

The following provides recommendations on how plots should be labeled. However, this SOP must be altered and provide explicit instructions on how each plot will be labeled for a given field measurement campaign.

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

All plots must be numbered with a unique name and number. The labeling system must be finalized prior to data collection. The character denoting the number of the plot should include at least as many digits as total numbers of plots expected to be sampled. In other words, if the number of plots is expected to be greater than 100 but less than 1000, the number characters must be at least three integers eg 001 to 999.

The following is an example of a recommended plot labeling format: number/letter/number/three numbers.

- The first number indicates the parcel or location number.
- The letter is one letter that describes the strata. It is recommended that all strata be given a unique letter before the field phase starts, and that the letter best describes the strata. For example, use Y for young secondary, V for very young secondary, M for mid-secondary, P for pasture, R for regenerating, T for tall evergreen etc.
- The next number is a unique number to correspond to the same stratum– 1, 2, 3, 4 etc.
- The last three numbers identify the specific plot within the strata and project area.

All plots must be numbered uniquely after the first number for the stratum. For example, if all plots in stratum 1 are numbered 1001 through 1020, then plots in stratum 2 are numbered 2021 onwards; if all plots in stratum 2 are numbered through 2104, then plots in stratum 3 are numbered starting with 3105, etc. 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.

An example of plot numbers are:

7-Y1-001 (location 7, Young secondary, strata number 1, plot 001)

7-D4-125 (location 7, Degraded mature, strata number 4, plot 125).

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 remeasurement. 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:

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.

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.

Data Entry checks:

To ensure that data is entered correctly, the person entering data (whether during fieldwork or after a return to the office) will recheck all of the data entered and compare it with the original hard copy data sheet before entering another sheet. It is advised that field crew leaders either enter the data, or participate in the data entry process. Crew leaders have a good understanding of the field sites visited, and can provide insightful assistance regarding potential unusual situations identified in data sheets. Communication between all personnel involved in measuring and analyzing data should be used to resolve any apparent anomalies before final analysis of the monitoring data can be completed. If there are any problems with the plot data (that cannot be resolved), the plot should not be used in the analysis.

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 remeasurement 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 plots (or clusters if clustered plots are used) should be randomly or systematically chosen to be remeasured. Where clustered plots are used, all plots within a selected cluster shall be measured. All trees shall be remeasured in each plot. Field crews taking measurements should not be aware of which plots will be remeasured whenever possible.

After remeasurement, 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:

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

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

Data Entry quality control check:

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.

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 Data Storage and Archiving

Field equipment
Field log book/electronic field log book
Laptop computer
Desktop computer
External data storage (harddrive, cloud, usb)
Connection to network server
Scanner

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.

Data storage in the field

In the field one person is responsible for storing and keeping the field data sheets; this person can also be the person who also validates the data on the sheets and is one of the team leaders.

If the data entry process is being done or started in the field, these sheets will be used after which they must be returned to the person responsible for their safe keeping. These sheets are stored in a dry and safe place where they cannot be tampered with until they are transported to the office.

Data storage in the Office

In the office, all original field data sheets shall be scanned and compiled into a document to be stored electronically. This avoids any changes to be made to the original sheets.

Hard copy

The original data sheets are photocopied and are kept in separate location. The data sheets are placed 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 (Biomass, Logging, Skid trails,Roads and

Decks, Regrowth, Wood Density etc.). After all data has been entered into a digital format and SOP QA/QC completed, the two sets of data sheets are then stored in secure fireproof filing cabinets in two separate locations.

Soft Copy

The scanned data sheets are stored on a computer in the office, along with all tools with the entered data, including data entered in the field laptop. These data files are backed up on a server. Folders containing data and folders containing tools should be properly named and adequately organized. 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 Data File Backup

Any file(s) that is updated during the data analysis will be backed up to a network server. This back up will be done daily on the office computer(s), and at the end of every week they **must** be saved on an external hard drive and the folder on the server which is specifically designated for this data storage.

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 campaign will be given a unique reference number and each report will also be given a reference number related to that of the campaign. 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[1] 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.

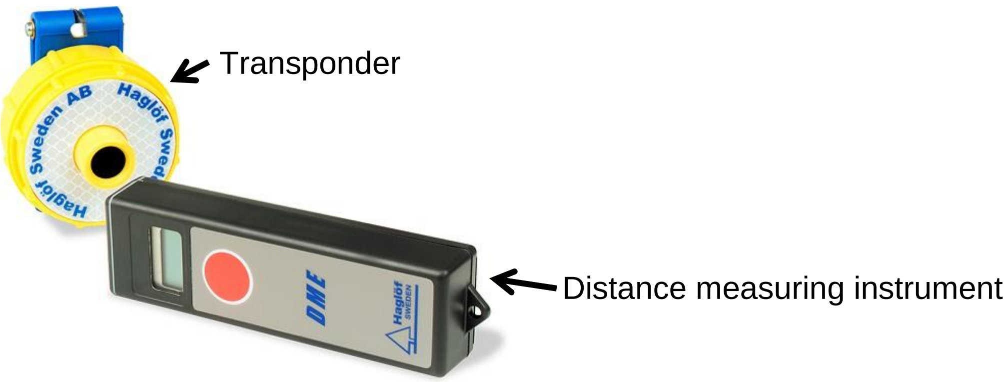


Figure: Haglöf DME 201 Cruiser

(photo source: http://www.forestry-suppliers.com/product_pages/View_Catalog_Page.asp?mi=1378&title=Hagl%F6f+DME+201+Cruiser)

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.
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.
5) Place the transponder on the tripod so that it is placed directly over the plot center.

[1] For example: www.forestry-suppliers.com

SOP Use of a clinometer:

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 %.

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.

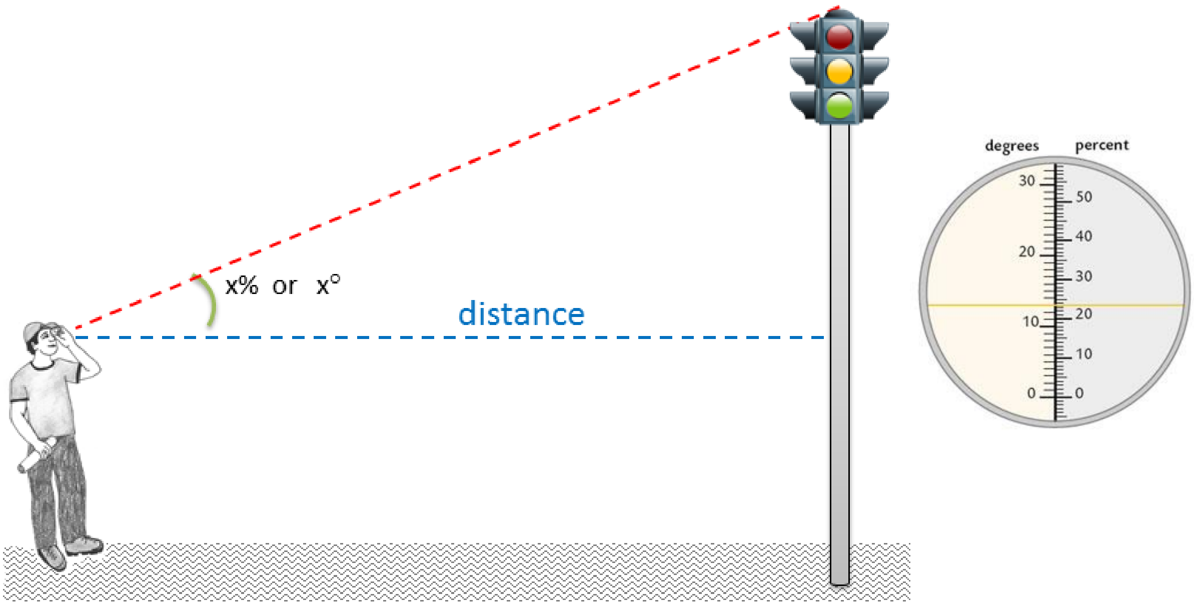


Figure: Measuring angle degrees or % using clinometer

SOP Measurement of Height

Field equipment:

Clinometer
Laser Range Finder or >50m measuring tape
Relascope (optional)

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

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

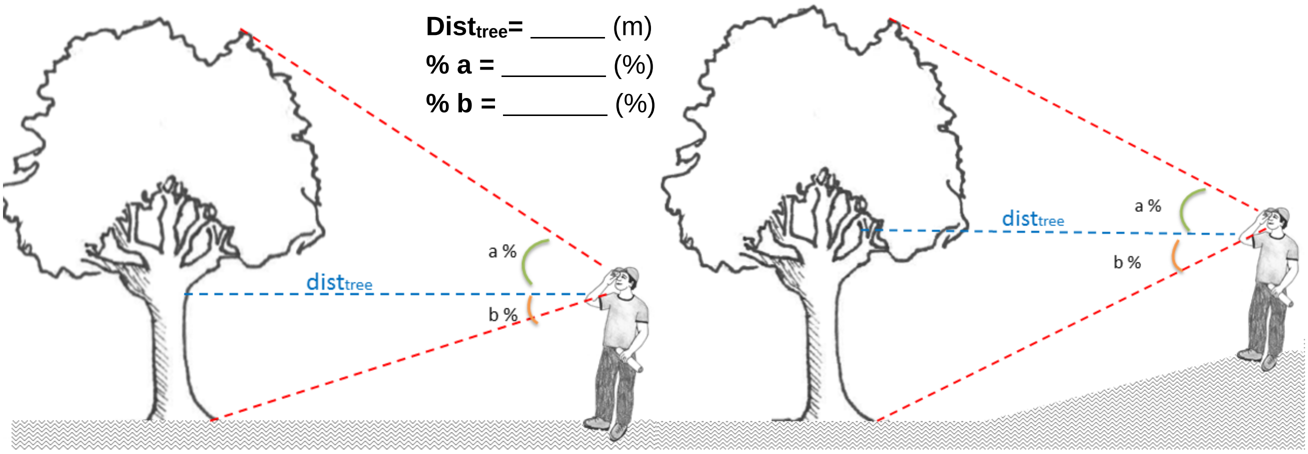


Figure Tree height field measurements

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 Stratification, Sampling Design and Layout
SOP Establishment of Plots
SOP Measurement of Trees
SOP Measurement of Palms, Lianas, and Bamboo
SOP Measurement of Non-tree Woody Vegetation
SOP Measurement of Non-woody Vegetation (herbaceous)
SOP Measurement of Litter Layer
SOP Sampling Soil Carbon
SOP Measurement of Standing Dead Wood
SOP Measurement of Lying Dead Wood

SOP Measurement and Estimation of Dead Wood Density Classes
SOP Destructive Sampling of trees, saplings, palms, bamboo, and Non-tree woody vegetation

SOP STRATIFICATION, 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.

The sampling design must address where sampling will be conducted, how it will be carried out, and what elements will be sampled. These items are addressed below, with initial recommendations for how best to address each item.

Stratification

Due to the spatial variability of land-use change drivers as well as the spatial variability of forest carbon stocks, **a stratified sampling design** is often useful in a forest carbon sampling design. Stratification of forest land can reduce sampling effort while maintaining accuracy and precision in estimates of carbon stocks.

The goal of stratification is to reduce within stratum variance and improve the precision of each stratum, thereby minimizing the number of samples required to achieve an overall level of certainty. A stratified sampling design also allows flexibility in designing a sampling protocol within each stratum that is tailored to the desired level of precision (targeted at a 90% confidence interval with a half width equivalent to ±10% of the mean) as well as the time and resources available to collect the data. For instance, if there are certain areas that are unlikely to experience change in the next ten years, it may be appropriate to reduce sampling in those areas relative to sampling conducted in areas more likely to experience change.

Potential criteria to be used in determining strata include:

- Forest type/species composition
- Land use and past management practices
- Age of vegetation
- Slope
- Precipitation and drainage
- Elevation
- Proximity to urbanization

Existing data can be used to identify and divide sampling units into relatively homogenous strata with regard to the factor of interest. Land within each stratum should be similar with respect to carbon stocks, with different strata having different carbon stocking. Each stratum may be comprised of one large block of land or several small blocks of land, provided that all of the blocks are similar with respect to carbon stocks.

Prior to implementing this approach, the strata must have been chosen and a separate GIS shapefile created for each stratum. 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.

Determine Sampling Locations using stratified two-stage sampling.

For the estimation of carbon stocks in the tree, non-tree woody, non-woody vegetation, 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 most forest stratum. 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. 5 x 5 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_i** – 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*).
- **$SSU1_i$** – this is a point, representing the starting point of the sampling at this location. The $SSU1_i$ is located within selected PSU_i.

Methods and Procedures

The following steps 2 to 4 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 the population of interest. 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 conditions.

• Areas with slope >65%

• Scrub / Forest areas under 2 ha completely surrounded by the land class 'barren land and rock'

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". 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).

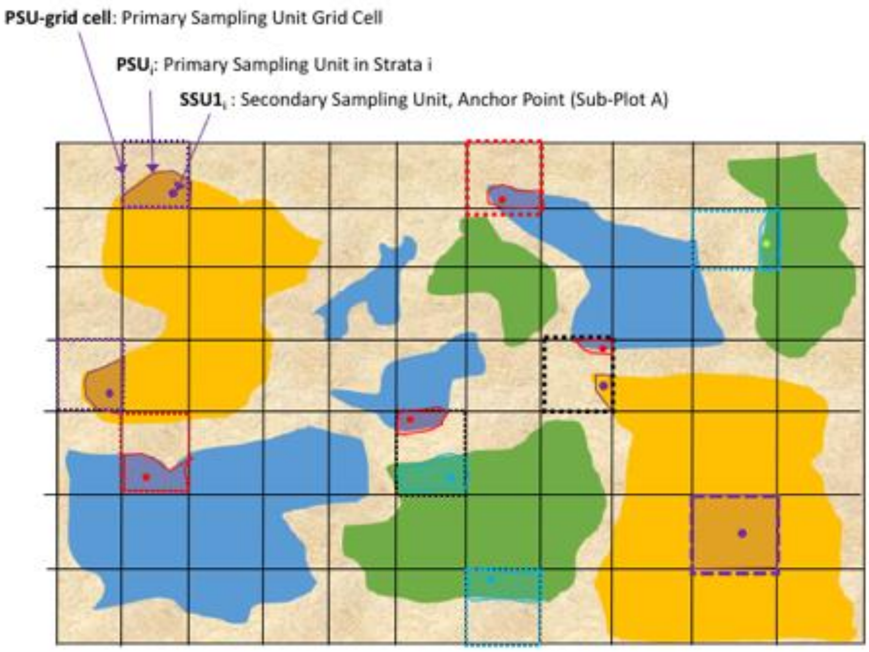


Figure 1: Example of selected PSU-grids in dashed lines and selected PSUs (polygons) with SSUs (dots) assigned within. Note, some PSU-grids may randomly be selected for two different stratum.

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

To create PSU_is 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 of the 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, 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_i will be selected must be made proportional to its area. To select PSU_is 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.

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_i for sampling, the random number should be compared to the cumulative PSU area. The PSU_i 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_i 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_i cumulative area) and 26,446.42>22758.71 (cumulative area of the previous PSU in the list)

A table of selected PSU_is following the order of random number generated shall be created containing information on PSU ID, PSU_i area, PSU_i cumulative area, the order of the generated random number and random number itself.

STEP 4: Assign secondary sampling unit ($SSU_{n,i}$)

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 a random point which will serve as the $SSU_{n,i}$.

STEP 5: Create two potential sampling location points

In the remaining area, use GIS software to generate 1 point in association with the SSU $_{n,i}$. One additional point shall be randomly placed within 1000 m of the SSU $_{n,i}$ and must be within the same stratum. They shall be allocated as 'primary' and 'backup' options for field sampling locations. Field crews will first navigate to the 'primary' option. If this point is not suitable for sampling because it does not fulfill the criteria described in SOP Establishment of Sampling Plots, then the 'backup' option will be used as the sampling location. For the point chosen for sampling, this will serve as the 'Anchor Point' for that sampling point.

Sampling Layout

Sampling Point Layout

Once the location of each sampling unit is chosen, the layout of sampling for each of the pools will need to be determined. Sampling can take place within one area per sampling point or sampling can take place at within multiple areas associated with each other per sampling point. This is often referred to as clustered sampling. The clustering multiple subplots together at one sampling unit allows field crews to sample a larger area per sampling point. Clustering of subplots at each sampling unit is recommended for natural forest areas and especially areas that have been selectively logged. Single-plots will be sufficient for stratum where the distribution of trees and the size classes of trees is expected to be relatively uniform and the whole area of interest is relatively accessible. For example, single plots are often used for measurements in areas where afforestation/reforestation is taking place.

Please note: this standard operating guidance is designed to be applicable to sampling approaches using both single plots and a cluster of subplots, therefore, in the following text, the term 'plot' is often used. However, where sampling is conducted using a clustered design, the sampling unit is the 'cluster-plot' and therefore each of the smaller areas sampled are actually subplots.

Single Plot Distribution

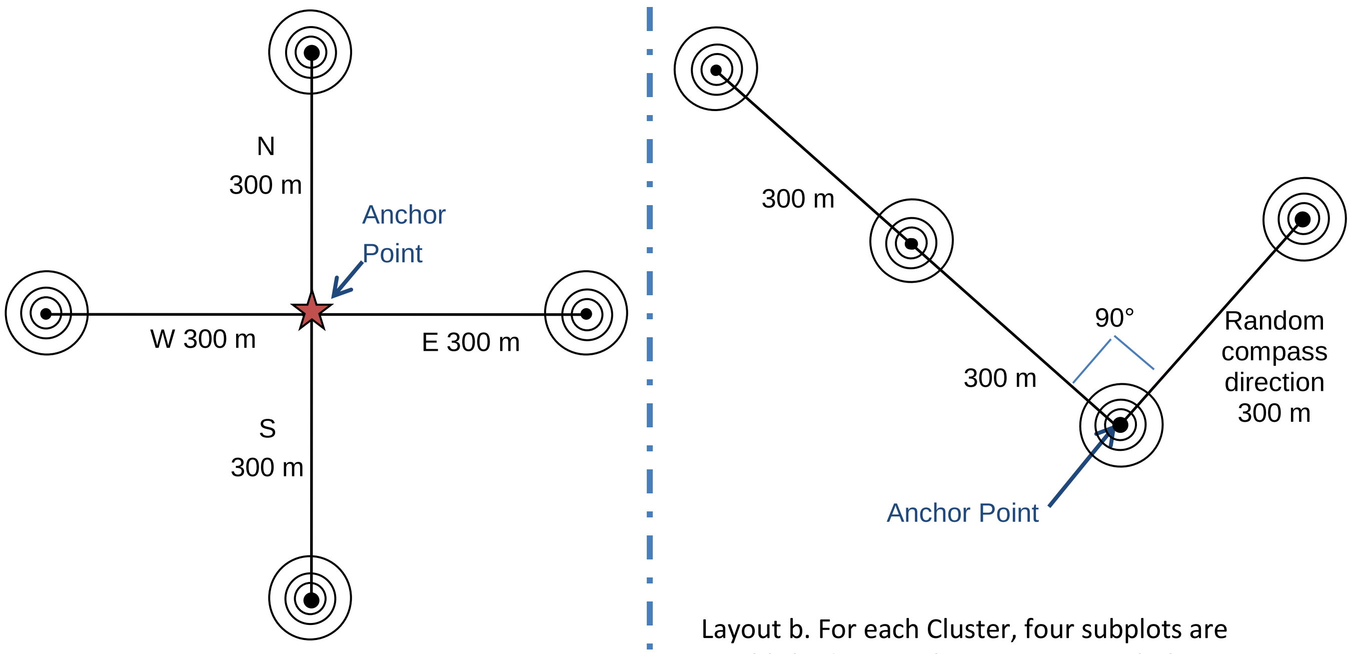
At each latitude/longitude sampling location determined prior to field data collection, one tree plot may be established. Once at the initial coordinates, to establish the plot center, walk an additional 10 steps in the direction of travel. This point shall be the plot center. These additional steps reduce bias in choosing the plot center.

Cluster-plot Distribution

If a cluster of subplots will be sampled for each sampling location, then all subplots within a cluster-plot must be within the same land cover stratum. Subplot labels must include cluster number and subplot number. Carbon stock calculation methods specific for clustered plots must be used.

To establish the Cluster center – referred to here as the Anchor Point, navigate to the initial latitude/longitude coordinates determined prior to field data collection, then walk an additional 10 steps in the direction of travel. This point will be the Anchor Point.. These additional steps reduce bias in choosing the Anchor Point.

Different cluster designs may be used. Two static options for tree biomass are presented in the Figure below. These are recommended for areas with large contiguous forest areas where it is very likely that all subplots will fall within the same stratum. Recommendations on the sampling layout for other vegetation types and carbon pools (bamboo, lianas, palms, non-tree woody, herbaceous, deadwood, litter, soil) are presented within the SOP for that vegetation/soil type.



Layout a. For each Cluster, four subplots are established at each of the cardinal points. The plot center is established 300 m away from the Cluster center

Layout b. For each Cluster, four subplots are established. At anchor point, one subplot is established. A random compass point is chosen to determine the direction of the plot on the short arm of the L. The other plots are located on the long arm of the L set at 90⁰ to the short arm.

Figure: Examples of layouts of one Cluster-lot of four tree subplots

For extremely fragmented stratum, a 'floating cluster nested tree plot design' is recommended. This is described below. For each stratum, all sampling will take place in association with the Anchor Point. For live trees, dead trees, and bamboo, sampling will use a 'floating' clustered design with four nested tree-plots. Where sampling for non-tree pools will be included, lying dead wood and clip-plot measurements (square boxes) shall be conducted for each plot. Sampling locations for these pools is described below. 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 'anchor point' and of each nested tree-plots is determined prior to field sampling and in a GIS environment. Due to the highly fragmented landscape and the terrain causing some locations to require significant time to access, a set of four potential subplot locations are chosen in GIS. In GIS, for a given stratum an Anchor Point is placed using the two-staged sampling design described above. The first tree-plot center (tree-plot A) is then placed on this Anchor Point. Three additional points (B, C, D) are then randomly placed within the given stratum within a 300 m radius of the Anchor Point, but no closer than 50 m from each other, the Anchor point, or the edge of the stratum to avoid overlap between tree-plots and tree-plots spanning more than one stratum. These serve as the center of four potential tree-plots.

When crews are in the field and have reached the anchor point, based on the accessibility of the tree-plots, the field teams will select which three additional points will serve as the tree-plots. See SOP establishment of Sampling Plots for more details.

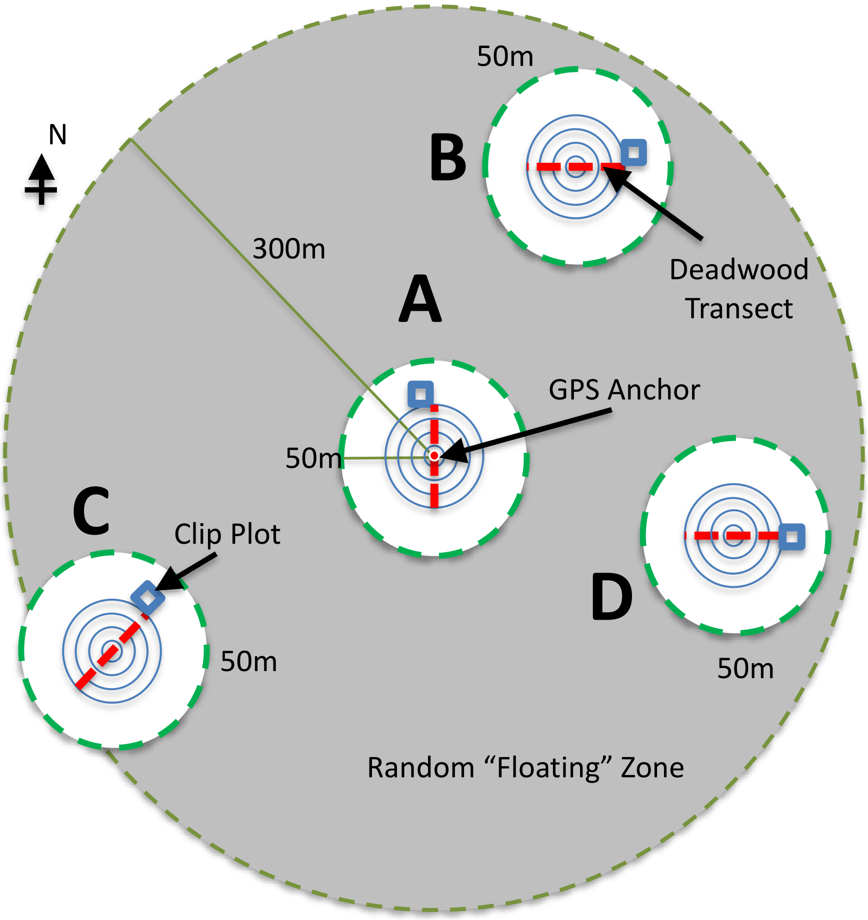


Figure 2: A "floating" cluster plot with a fixed center subplot. Red lines represent 40 m lying deadwood transects while blue boxes represent clip plots

Determining the size and shape of tree plots and subplots

The size and shape of the area to be sampled to estimate tree biomass is a trade-off between accuracy, precision, time, and cost for measurement. The most appropriate size and shape may also be dependent on the vegetation type found in the sampling area.

Tree Plot Shape

Plots can be circles, squares, or rectangles. Experience has shown that circular plots are more efficient because the actual boundary around the plot does not need not to be marked. The use of distance measuring equipment (e.g. the DME, Haglöf, Sweden) is the most recommended method for the establishment of circular plots. Although the initial investment may seem high, experience has shown that this method is time efficient and results in low levels of field measurement errors.

Alternatively, the plot boundaries of a circular plot can also be delineated using rope/cord of length(s) equal to the radius of the plot (this method can only be used where area corrections for slope are performed during data analysis. See SOP Establishment of Tree Plots). Square or rectangular-shaped plots can also be efficiently laid out with tape measures and stakes.

Where rope or other materials are used to measure plot boundaries, extreme care must be taken to ensure the rope length is equal to the measurement required. Such rope should be measured repeatedly as many types of rope will lengthen or contract over time and under various field conditions, such as when wet.

Nested Tree Plots

Experience has shown that sample tree plots containing smaller sub-units varying in size (nested tree plots) are cost efficient and scientifically robust for most vegetation types with trees. Nested plots are composed of several plots (typically 2 to 4, depending upon forest structure) plots and each plot in the nest should be viewed as being a separate plot. The tree plots could take the form of nested circles or nested squares/rectangles. In systems with low structural variation, such as single species, even-aged plantations, or in areas where trees do not exist, a single plot can be effectively used.

In each tree plot within a nest of plots, trees representing different diameter classes are measured. When trees attain the minimum size for one of the nested plots they are measured and included, and when they exceed the maximum size, measurement of that tree in that nest stops and begins in the next larger plot of the nest. See Table 1 for an example.

Tree Plot and Nest Size

It is possible to calculate the appropriate tree plot size specifically for each project; however, this adds an additional complication and an additional effort to the process. See Pearson, TRH, Brown, S, and Ravindranath, NH. 2005. *Integrating carbon benefit estimates into GEF projects*.

For simplicity, tree plot size rules are presented below that can be applied to forest types that include mature trees and where dbh will be measured (Figures below). Experience has shown that these plot sizes represent a reasonable balance of effort and precision. However, prior to initiation of plot measurement, it is recommended that limited sampling take place to determine the size of the largest trees. In a land cover stratum with few trees greater than 50 cm dbh, the minimum stem diameter measured within the largest nest may need to be adapted. For non-forest, savanna, and woodland strata, nest plot sizes and stem diameter sizes will need to be delineated.

If instead of nested plots, a single plot size is used then the plot size should be large enough that at least 8-10 trees per plot will be measured within the plot boundaries at the end of the project activity. Therefore, where afforestation is taking place substantially more than 8-10 trees will be measured per plot at the start of the project activity.

The actual plot sizes and tree diameter sizes used for each nest must be determined prior to the initiation of field measurements. This SOP must be altered to state the plot sizes and tree sizes that will be measured.

Table:Example tree stem diameter classes and nested plot sizes

Stem diameter	Circular plot radius	Square plot side lengths	Square plot diagonal length
†Saplings	2 m	3 m x 3 m	4.2 m
5 – 20 cm dbh	6 m	7 m x 7 m	9.9 m
20 – 50 cm dbh	14 m	25 m x 25 m	35.3 m
> 50 cm dbh	20 m	35 m x 35 m	49.5 m

† Saplings are defined as: stems <5 cm dbh, height >1.3 m

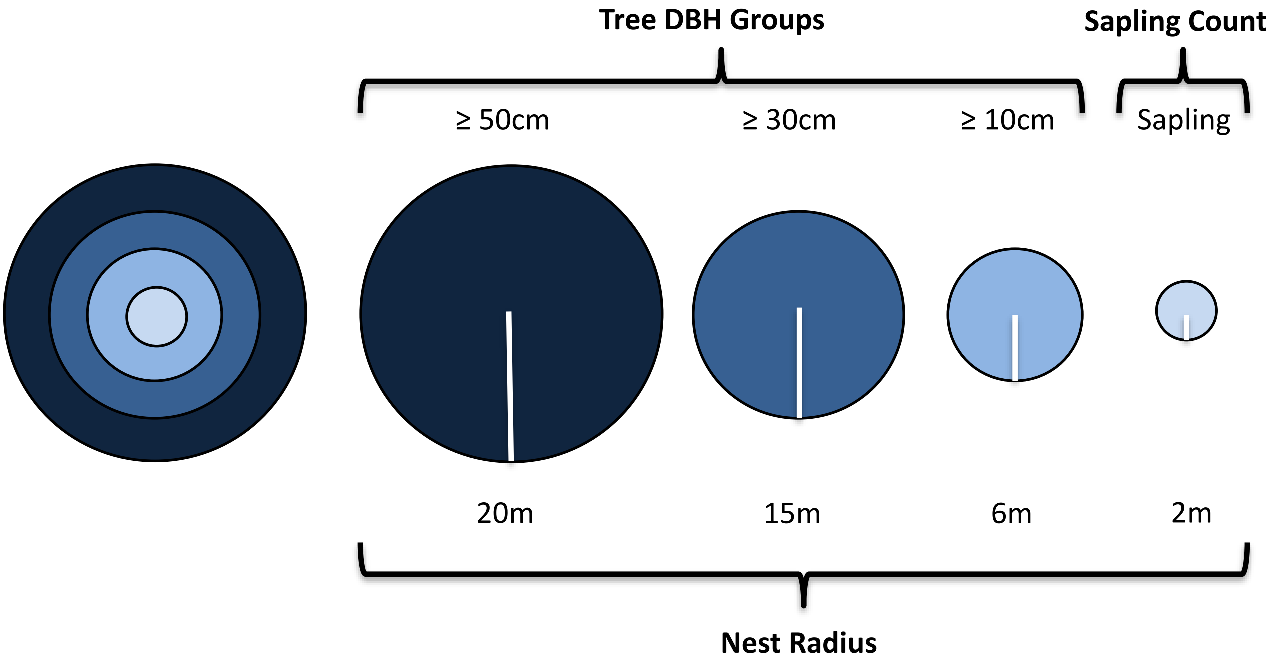


Figure: Schematic diagram of three-nest circular sampling plots (when slope <10% and size classes for each nest. Sapling defined as tree with height >1.3 m and DBH of <10 cm

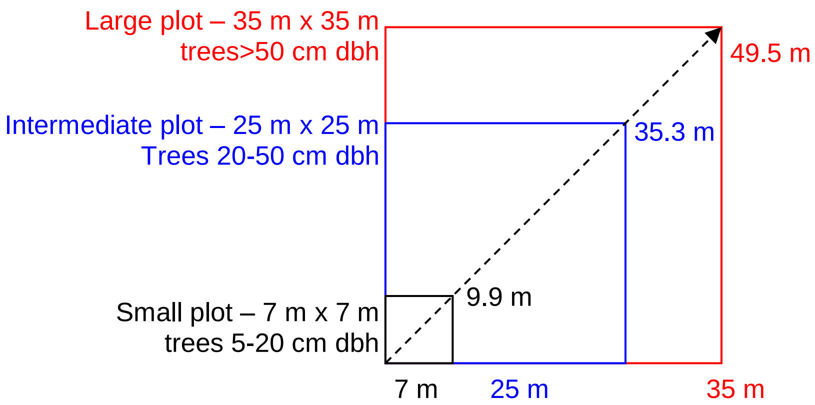


Figure: Schematic diagram of three-nest square sampling plots

Other vegetation and carbon pools

Each team will also measure standing and lying deadwood, non-tree vegetation in clip plots, and in clip plots. The location of sampling should follow the above sampling point layouts. Field measurement procedures should follow the relevant SOP.

SOP ESTABLISHMENT OF TREE PLOTS/SUBPLOTS

Required equipment:

All Tree Plots
GPS
Flagging tape
Rope
Clinometer (to measure slope)
>10 m measuring tape (to calibrate DME)

Circular Plots
Distance Measuring Equipment (DME)

Square/Rectangular Plots
Right Angle
Measuring tape
Rope
Stakes

Additional Items for Permanent Plots
Aluminum tags
Metal (usually iron) bar about 1-2 cm in diameter and 30 cm long
PVC tubing (1 m) and caps
Hammer
Fluorescent paint
Duct tape
Permanent marker

Prior to Field Sampling:

Based on SOP Sampling Layout, the location, size, and shape of the tree plots should be determined. In addition, the lat/long sampling unit locations that each team will navigate to should be uploaded to each team's GPS. Using a combination of spatial data such as land cover, elevation, roads, rivers, slope and local knowledge a plan shall be created on how plots will be located and the order in which plots measurements will take place.

Where a clustered-plot design will be used, each tree plot is actually a subplot within the cluster. However, since this guidance has been written to apply to both single and clustered designs, the term 'tree plot' will be used to refer to either a single tree plot OR a tree subplot within a cluster.

Establishing Anchor Point

When clustered sampling designs are used, the first step is to establish the anchor point. Each of the clusters are then established. If a single plot design is used, this step can be skipped.

Navigate to predetermined latitude and longitude of the primary sampling location using a GPS. Walk an additional 10 steps in the direction of travel. These additional steps reduce bias in choosing the anchor point. At the anchor 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 plot center/corner and let it record for > 5 minutes prior to marking a 'waypoint'. The minimum precision level should be ±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[2] .

Label the Anchor Point plot based on SOP Labeling Plots.

Establish Clustered Nested Tree-plots

As stated above, cluster plots can contain various numbers of nested tree-plots. The following assumes each cluster includes 4 circular nested tree-plots are sampled at each Sampling Location.

If an entire tree-plot would fall within the GIS allocated stratum at this location, then establish 'tree-plot A'. At the anchor point, evaluate the stratum at "**tree-plot A**". If an entire tree-plot would fall within the GIS allocated stratum at this location, then establish 'tree-plot A'.

If the GIS determined stratum is not the same as the stratum found on the ground at the Anchor Point, the sampling location shall be moved to 100m east from original Anchor point. If moved point is not still the same with GIS determined stratum, move to 100m south from original Anchor point. If the stratum is still incorrect after moving south, return to the Anchor and shift 100m west. Lastly, if the western point is still not in the correct stratum, make a final sift of 100m north.

If all 4 options (East, South, West and North) fall in an incorrect stratum than determined by the original GIS classification, then no sampling shall take place at "**tree-plot A**". The team leader should make an entry for "**sub-plot A**" on the datasheet or tablet, indicating the reason why the sub-plot was not installed. The team should move on to a different sub-plot sampling location.

For 'tree-plot B', and 'tree-plot C' this same procedure shall be repeated. If tree-plot A, B and C would fall in a different stratum than determined in GIS, then no sampling shall take place at this sampling location and it is not necessary to conduct 'tree-plot D'. At least two sub-plots must be the correct strata in order to justfy keeping the cluster plot for biomass calculation.

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

1. If any sub plot observed in the field does not match with the correct strata of interest, the sub plot should be shifted 100m from the Anchor point until the correct strata is found.
2. Sub-plot shifting progression should be first East, then South, West and then North.
3. At least 2 sub-plots must be in the correct strata in order to keep the cluster plot. If sub-plots A, B and C are all incorrect strata, then the cluster plot can be abandoned.
4. Data entries must be made for all sub-plots, even if:
    - no data was collected,
    - a team did not go to the location,
    - access was impossible,
    - stratum was incorrect,

In the nested tree-plots, the following vegetation types will be sampled: Trees; Saplings; Standing Dead Trees and Bamboo. The methods for sampling each of these vegetation types in the subplots 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 subplot center point.

[2] 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 for more information)

At the subplot center point, mark a 'waypoint' on GPS and record GPS coordinates, accuracy, elevation, and waypoint number on data sheet. To record a GPS location, place the GPS at the plot center/corner and let it record for > 5 minutes prior to marking a 'waypoint'. The minimum precision level should be ±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[3] .

1. Label the subplot 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 wooden stake wrapped with flagging tape. This plot center mark will be used to identify the plot center during any third-party verification or quality checks.

A long lasting material stake shall be placed at the plot center in circular plots This will be used to facilitate verification of plot measurements where required.

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.

Temporary Plots

Where plots are temporary in nature, a long lasting material stake shall be placed at the plot center in circular plots and at each corner in square/rectangular plots. This will be used to facilitate verification of plot measurements where required.

Circular plots

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.

Square/Rectangular plots

a. With a stake, mark the GPS waypoint as the first corner.
b. Determine a random compass direction (Select random number using second hand on watch and multiply this number by six.). Using this compass direction, measure to second corner. Mark the corner for each nest with a stake. Return to first corner, using a right angle and a compass, measure to the opposite corner. Mark the corner for each nest with a stake. Returning to the first corner, use compass to measure out the length of the diagonal. Mark the final corner with a stake. Mark the corner for each

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[3] 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 for more information)

nest with a stake. (See figure below as example). If desired, rope marked with nest plot lengths can be repeatedly used for each plot. However, the length of the rope and markings should be checked daily to make sure the rope has not stretched.

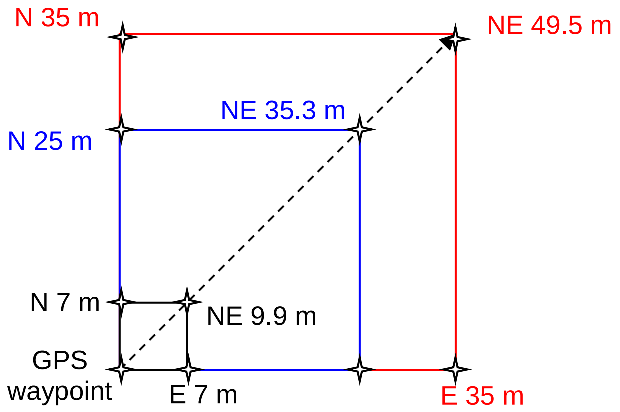

Figure: Schematic diagram of location of stakes in a nested square sampling plot

Permanent Plots

Permanent plots shall be marked using materials that will last longer than the project lifetime.

Circular plots

Recommended steps for marking the center of permanent plots with metal rebar (iron bar) and PVC pipe are described below. These materials are convenient, inexpensive, and readily available in most parts of the world. However, the risk of theft of these materials from permanent plots must be considered. Appropriate alternatives to these materials may need to be identified. The goal is to mark the center / corners in a manner that will allow the plot to be located in the future and therefore other strategies can be used. However: the GPS location alone *cannot* be used to locate the plot center in the future as the error in GPS measurements is too large.

a. At the plot center / corners, hammer a ~30 cm section of metal pipe/bar into the ground. The metal pipe/bar should be hammered until it is completely in the ground. If there are rocks or other obstructions in the soil, move the metal pipe/bar to another spot (within 2 m of the original location).
b. Hammer a 1 m section of PVC pipe over the metal bar. It is important that the PVC pipe is hammered straight into the ground. It should not lean. Use a block of strong wood to cover the top of the PVC pipe when hammering it into the ground, to prevent the PVC from splitting. At least 50 cm of the PVC should go into the ground.
c. Paint the PVC pipe with bright orange or bright blue spray paint (black, yellow and red will not be visible enough in a forest).
d. It is important that the plot be identified permanently for future monitoring. The best way is to place a plot-numbered tag inside the top of the pipe with a piece of wire, and a cap placed on top of the pipe to hold the tag in place. In addition, wrap duct tape around the top of the pipe and use a permanent black marker to write the plot number on the duct taped portion of the pipe.
e. At the plot center, mark tree branches with flagging tape to increase visibility.

Square/rectangular plots

For square or rectangular plots mark *each* of the corners with rebar and PVC tubing (as for circular plots), including the corners for each nest size.

Invisible plots

If there is a concern that the metal pipe and PVC pipe may be removed by someone or if the marking of the plot may lead to preferential treatment of the trees within those plots, then the invisible marking of plots should be considered. For this method a piece of iron (e.g. a piece of rebar) should be sunk below the soil surface at the plot center or at the corners of a square/rectangular plot. A metal detector would subsequently be used at each subsequent sampling to find the plot following initial navigation using the GPS.

Slope Corrections

Area correction due to slope – Conducted in the field

If the subplot 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 subplot area. If slope is less than 10%, correction is not required.

Slope Measurement

Slope is measured with the person using the clinometer identifying the eye-level of a partner of approximately the same height. One person should stand in the center of the subplot and the partner should go to the edge of the larger nested subplot. The person with clinometer, standing in center of subplot, shall then aim at the eye-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.

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 subplots will yield the same area as if the tree plot were established on flat terrain.

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

$$Sloped\_Radius = \frac{Nest\_Radius}{Cos\theta}$$

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)

Cosθ = 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:

$$Corrected\_Area = \pi * Nest\_Radius * Sloped\_Radius$$

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

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

The correction of the subplot 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 below. Measured slope gradient should be approximated to the nearest slope gradient. A correction table is presented in the appendix. This should be printed and used by the crew leader.

Area correction due to slope – Conducted during data analysis

Carbon measurements are reported on a horizontal-projection basis, thus, plots established on sloping lands must use a correction factor. This correction factor accounts for the fact that when distances measured along a slope are projected to the horizontal plane, they will be smaller. If the plot 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 plot area at the time of analysis. If the slope is less than 10%, correction is not required. The calculation of area correction is done during data analysis. In the field, only the average slope measurement is taken.

Following data collection, the slope will be used to estimate the projected horizontal area of the plot (see Figure below). It is recommended this be done as part of data analysis within computer spreadsheet.

$$L_{horixaontla} = L_{field} * \cos(slope)$$

Where:

$L_{horizontal}$	True horizontal length; m (for circular plots, this will be the radius. For square/rectangular plots, this will be the side parallel to the slope)
L_{field}	Length measured in the field, parallel with the slope; m (for circular plots, this will be the radius. For square/rectangular plots, this will be the side parallel to the slope)
Slope	Slope, measured in degrees
Cos	the cosine of the angle

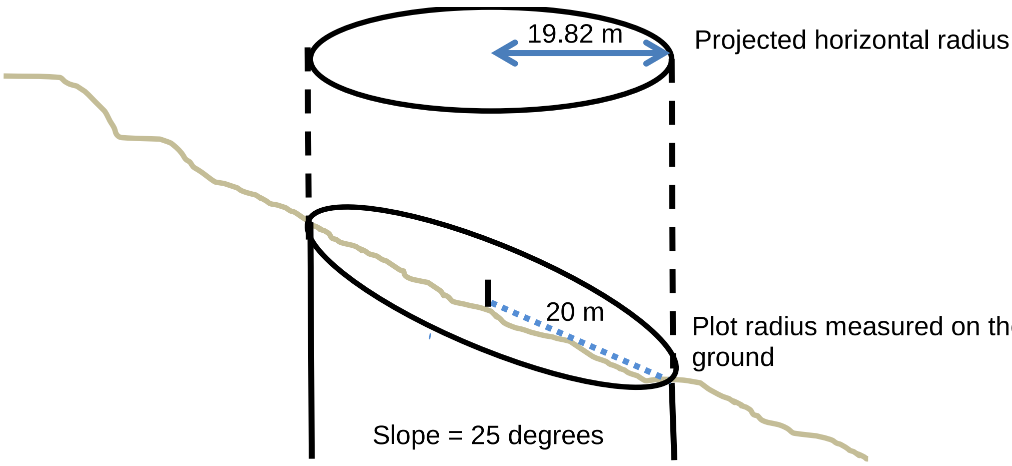

Figure Plot measurement on ground and projected horizontal size of plot. In this example, with a slope of 25 degrees, although the plot radius on the ground is measured as 20 m radius, the projected horizontal size of the plot has a radius of 19.82 m (20 m * cos(25 degrees) = 19.82 m).

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^2) that is occupied by a given nested plot or clip plot:

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

SOP MEASUREMENT OF TREES

Field equipment:

Tree name list

For measuring DBH:
Diameter tapes
Flagging tape
Tree poles: Small-diameter PVC piping cut the exact length of diameter measurements (eg 1.3 m if DBH will be measured)
Chalk sticks
Portable retractable ladder (3 m)
Portable retractable poles (at least 5 m)

For measuring height (see SOP Measurement of Height):
Clinometer
Laser Range Finder or >20m measuring tape

For permanently marking trees:
Aluminum nails and/or fishing line or aluminum wire (determine most appropriate material given local conditions eg. aluminum nails are not recommended for young trees <5cm)
Tree tags with unique sequential numbers
Hammers and/or wire cutters

Prior to Field Sampling

Allometric Equation(s) Selection

The biomass of live trees is usually estimated using an allometric equation that relates tree biomass with one or more specific tree variables such as tree species, diameter at breast height (DBH) diameter at stump height (DSH), total tree height, and/or wood density. The tree variable(s) measured in the field are then used to calculate biomass during data analysis.

Prior to field data collection, the allometric equation(s) that will be applied to trees must be determined. There are many existing allometric regression equations that have been previously developed and published. Documentation on the equation should list the minimum size tree applicable to the equation (e.g. Trees with a DBH ≥5 cm). It is recommended to use an existing equation where possible, however, prior to using a chosen equation, the applicability of the equation to the forest type / species must be assessed. Alternatively, an equation can be developed for the forest type and/or species of interest. See 'SOP Destructive sampling of trees, saplings, palms, and bamboo' for more information on how such equations are created and/or the applicability of existing equations verified.

Prior to field data collection, a standard list of tree names shall be developed. Depending on the biomass regression equation(s) used, the tree names may relate to actual tree species, tree genus, or tree family. A standard tree name list and tree name abbreviation list shall be created and brought to the field for reference and for filling out data sheets.

The minimum sized tree to be measured as a "tree" must be defined, usually this is based on the allometric equation applicability criteria (e.g. trees with a DBH of ≥5 cm and a height of ≥1.3 m). All trees of appropriate size will be measured in plots. Where nested plots are used, measurement will only occur for trees that meet the size class requirements for a given nest. For permanent plots, only trees measured shall be tagged with an aluminum numbered tag and nail.

Seedlings and Saplings

The biomass of trees smaller than the minimum size tree applicable to the allometric equation can be estimated using alternative approaches. One recommended approach is to divide small trees into two groups: seedlings and Saplings. Seedling biomass is included in non-tree biomass measurements (see SOP Measurement of Non-woody Vegetation). The size range of Saplings must be defined in this SOP (a common definition is trees ≤5 cm DBH and ≥1.3 m tall) and can be estimated by counting the number of saplings within a certain area and multiplying that by the average weight of a sapling. To estimate the average weight of a sapling, the sapling portion of 'SOP Destructive sampling of trees, saplings, palms, and bamboo' must be implemented prior to field data collection. In the field, saplings should be counted in a 2-m radius plot but should not be tagged. Another recommended approach is to measure the biomass of all trees below a minimum size in the non-tree biomass measurements (see SOP Measurement of Non-woody Vegetation). Where non-woody vegetation biomass will not be measured in the field, it is recommended saplings be accounted for using the Sapling Count method.

This SOP must be altered to describe the approach used for the measurement of trees and saplings. This will aid in field data collection initially and allow future measurements to be completed efficiently and accurately. Because DBH and height are common inputs for allometric equations used to estimate the biomass of trees, this SOP focuses on the measurement of DBH and height. If other parameters are to be measured, this information must be included in the SOP used for field data collection.

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. As stipulated by such SOPs, tree measurements can be taken in either temporary or permanent sample plots.

1. Assign one person to record the data and all others should be measuring and marking trees. The recorder should stand in the center of the nested 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 chalk mark facing the center of the plot should be placed on tree to allow the person recording the data to track measured and unmeasured trees.
3. Count the number of saplings (defined as trees <5 cm DBH and >1.3 m tall) in the smallest plot (e.g. 2 meter radius plot) and record on data sheet. (After field data collection, the number of saplings will be combined with the average sapling weight to estimate total sapling biomass (see 'SOP Destructive sampling of trees, saplings, palms, and bamboo')).
4. For temporary plots, trees should not be tagged. Move to step 6.
5. In **permanent** measurement plots, all trees of appropriate sizes for each nested plot should be tagged with the placement of an *aluminum* numbered tag and nail or alternatively fishing line or wire (see Figure below). The risk of theft of these materials must be considered. Appropriate locally available alternatives may need to be considered. The steps are as follows:
    a. To avoid any errors in the measurements due to the development over time of a bump at the site of the nail, it is recommended that the nail and tag be placed 10 cm below DBH. See detail instructions on where to measure the DBH below.
    b. In future inventories DBH will be measured 10 cm up from the nail.
    c. If the trees in the project area will be subjected to some kind of harvest in the future, the nail and tag may be placed at the base of the tree to avoid any chainsaw or other equipment accidents. Be sure the nail is placed *well below* the height of future cutting, as it is very dangerous for a chainsaw to hit a nail. Chainsaws *can* cut through aluminum, but contact between the nail and chainsaw or other equipment should be avoided to prevent the

possibility of accidents. Alternatively, tags may be attached to trees with fishing line or metal wire as shown below.

d. Each plot should contain a description of what approach was used so that future measurements can be completed efficiently and accurately.

e. Do not insert the nail fully so that there is room for the tree to grow, however, insert it deep enough to hold the tag firmly.

f. *Only* aluminum nails should be used.

Figure. Examples of tagged tree using fishing line (left) and a nail (right).

6. Measure the tree parameters required for the allometric equation to be used (eg diameter at breast height (DBH), diameter at stump height (DSH) and total tree height (H)) for all trees of appropriate sizes for each nested plot. Steps for measuring DBH of all trees of appropriate sizes for each nested plot are described below. If other tree parameters are required for the allometric equation to be used, this SOP should be altered to explicitly describe the procedures to be followed. It is important that the diameter tape is used properly using the following steps to ensure consistency of measurements:

   a. Record the name of the tree, based on tree naming system developed prior to field data collection.

   b. **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 (eg 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).

      i. **Slope:** Always place tree pole and measure diameter on the *upslope* side of the tree

      ii. **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).

      iii. **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 (ie 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.

      iv. **Multi-stem tree**: If the tree is multi-stemmed with forking below the point of measurement (eg 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.

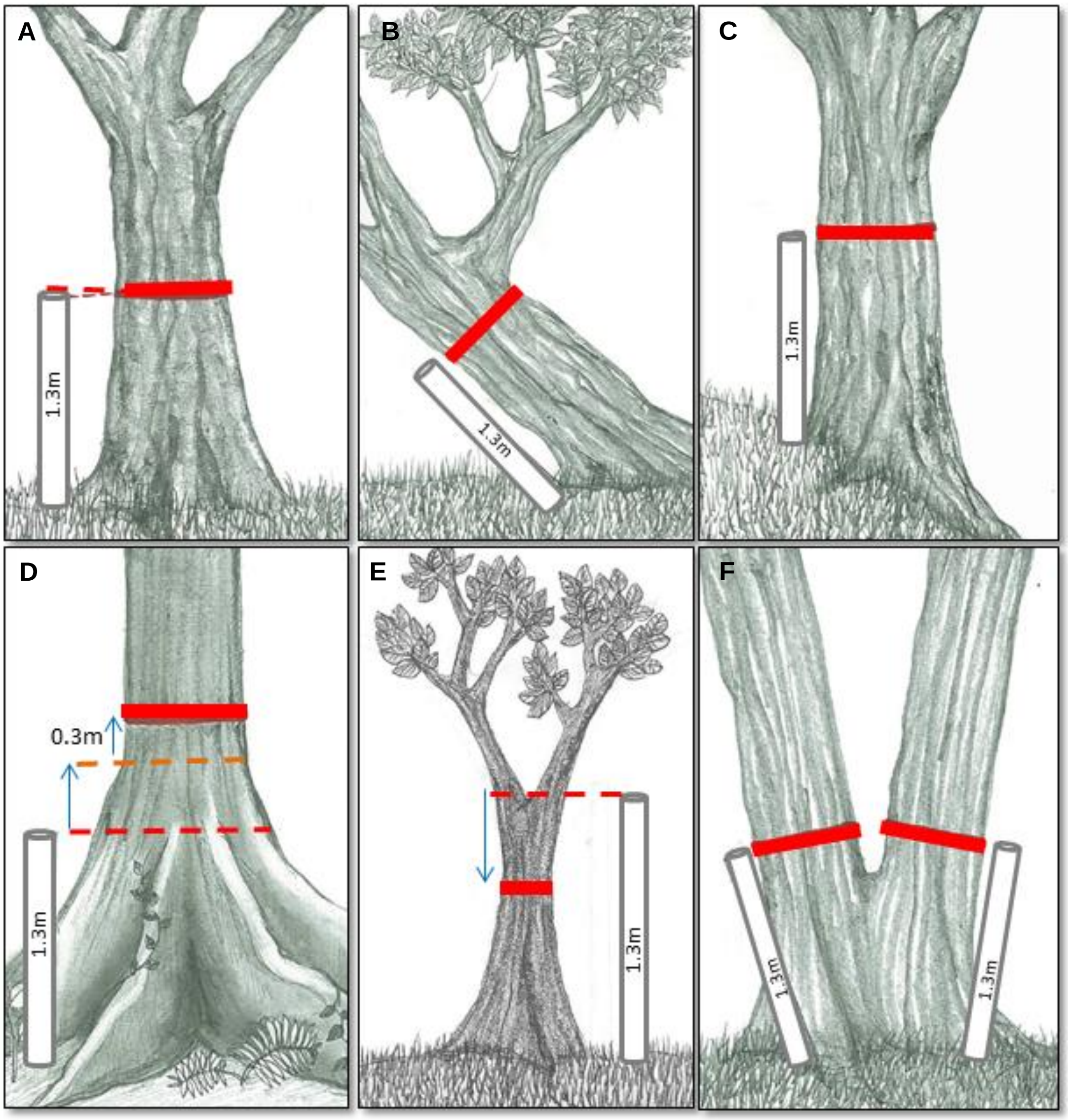

Figure: Proper placement of diameter tape when allometric equation used requires measurement at DBH (1.3 m)

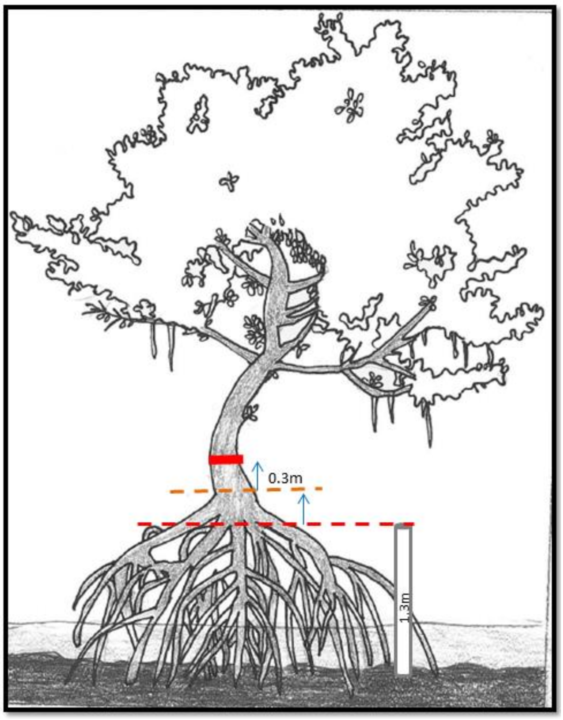

Figure Proper placement of diameter tape for a mangrove tree

v. **Buttressed tree or mangroves**

1. If the buttress or mangrove roots are 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.
2. If the buttress or mangrove roots are 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:
   i) Use portable retractable ladder and lean ladder against tree to allow for measurement of DBH 30 cm above from the top of the buttress.
   ii) If ladder is unavailable, and 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.
   iii) If ladder is unavailable, and climbing is considered unsafe, retractable poles should be use. 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** 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.

   Note: The distance between poles shall be measured linearly, and thus proper measuring tape shall be used. 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).

c. **Diameter measurement:** Tree diameter should be measured to the nearest 0.1 cm (eg 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 chalk mark on the tree to indicate to crew members that the tree has been measured.

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

d. **Other tree parameters:** Measure all other tree parameters included in the biomass regression equation to be used. If the allometric equation to be used requires height as an input for each tree/palm measured, two measurements of height should be taken to improve the precision of measurements, especially if it is difficult to identify the top of the tree/palm measured. See SOP Measurement of Height on how to measure tree height.

e. **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 tape measure to measure out from the plot center (or plot corner) 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 in. 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.

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

SOP MEASUREMENT OF PALMS, LIANAS, AND BAMBOO

Field equipment:

Tree name list

For measuring DBH:
Diameter tapes
Flagging tape
Tree poles: Small-diameter PVC piping cut the exact length of diameter measurements (eg 1.3 m if DBH will be measured)
Chalk sticks

For measuring height (see SOP Measurement of Height):
Clinometer
Laser Range Finder or >20m measuring tape

For permanently marking trees:
Aluminum nails and/or fishing line or aluminum wire (determine most appropriate material given local conditions)
Tree tags with unique sequential numbers
Hammers

Prior to Field Sampling

The biomass of palms, lianas, and bamboo varies significantly between land cover types. Prior to data collection initial field research should be undertaken to determine the distribution and dominance of these vegetation types within a land cover type. If such a vegetation type is common and dominant, field measurements methods are described below. If the vegetation type (palm, liana, bamboo) is not common and it is conservative to underestimate forest biomass, it is recommended that the vegetation type not be measured. This SOP must be altered to describe the approach that must be used for the measurement of palms, lianas, and bamboo.

The biomass of palms, lianas, and some types of bamboo is usually estimated using a previously created regression equation that relates biomass with one or more specific vegetation parameters such as species, diameter, height, and/or number of stems. Prior to plot establishments and measuring, the regression equations to be used to estimate the palm, liana, and bamboo biomass must be selected from existing equations and field verified for applicability or newly developed for the land use type of interest. See 'SOP Destructive sampling of trees, saplings, palms, and bamboo' for more information on how such equations are created and/or verified.

Prior to field data collection, a standard list of palm, liana, and bamboo names shall be developed. Depending on the biomass regression equations used, the names may relate to actual tree species, tree genus, or tree family. A standard name list and name abbreviation list shall be created and brought to the field for reference and for filling out data sheets.

The size classes to be measured in each nest will need to be determined prior to initiation of fieldwork. Measurement will only occur for individuals that meet the size class requirements for a given nest. For permanent plots, only individuals measured shall be tagged with an aluminum numbered tag and nail.

The biomass of individuals below a certain size threshold can be estimated by counting the number of individuals within a certain area and multiplying that by the average weight of an individual sapling. This 'sapling count' method is often used for trees (see SOP Measurement of Trees). To estimate the average weight of an individual, the sapling portion of 'SOP Destructive sampling of trees, saplings, palms, and bamboo' must be implemented prior to field data collection. In the field, such individuals should be counted in a 2-m radius plot but should not be tagged. Alternatively, the biomass of individuals below a size threshold can be included in the non-tree biomass measurements ('SOP Measuring non-tree vegetation'). However, only one approach can be taken for each stratum.

This SOP must be altered to describe the approach used for the measurement of palms, lianas, and bamboo. This will aid in field data collection initially allow future measurements to be completed efficiently and accurately.

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.

The following are the steps to be used in collecting measurements in the field. Often, these field measurements are taken at the same time as the measurement of trees.

Measuring Palms

The specific field measurements taken will be dependent on the allometric equation used, therefore, the below description offers only general guidance. A size threshold of 1.3 m height is usually used. All smaller palms should be measured either using the 'sapling count' method or with non-woody vegetation. Only one method can be used.

In tree plots, only palms with a stem taller than 1.3 m should be measured. Smaller palms will be measured either as non-tree woody vegetation or herbaceous vegetation.

a. Measure palms at the same time as trees.
b. Measure all palms taller than 1.3 m within the medium nested plot.
c. Measure the required palm variable (often this is Height of the palm from the base to the top of the stem).
d. For permanent sample plots, tag the palm in the same location as for trees.

Measuring Lianas

a. Lianas can be measured at the same time as trees. It is recommended that lianas be measured within the smallest nest.
b. The only lianas that should be measured are those originating from the nest (e.g. liana emerges from ground within nested plot where measurements taking place). Measure the liana variables (eg DBH) required by the allometric equation that will be applied.
c. Take care that the same liana is not measured more than one time.
d. If using permanent plots lianas should also be tagged in the same location as for other trees.

Measuring Bamboo

Allometric equations can be used to estimate the biomass of a bamboo patch. Usually the equations relate basal diameter and height to biomass. If no appropriate allometric equations exist, one must be created. See 'SOP Destructive sampling of trees, saplings, palms, and bamboo'. The specific field measurements taken will be dependent on the allometric equation used, therefore, the below description offers only general guidance.

a. The nest size within which bamboo will be measured will be dependent on the prevalence of bamboo. If highly prevalent, then the smaller nest size can be used. Otherwise, all bamboo patches should be measured in the medium nested plot.

b. Measure the bamboo parameters required in the biomass regression equation developed. This would include things such as height (using a clinometer), the basal diameter (using DBH tape), and the number of culms in a patch. Note: the exact measurements made will be dependent on the factors included in the allometric equation used.

SOP MEASUREMENT OF NON-TREE WOODY VEGETATION

Field Equipment:

Clip plot frame (see below for explanation) (for clip plot method only)

Measuring tape

Clippers and hand saw to remove vegetation (for clip plot method only)

5 kg hanging scale (for destructive sampling, appropriate size dependent on size of non-tree woody vegetation)

300 g hanging scale (for subsample)

Hanging scale

Durable plastic sheeting

Durable plastic tarp

Cloth or paper sample bags (for clip plot method only)

Compass

Calibration weights (see below) (for clip plot method only)

Laboratory Equipment:

Drying oven

Laboratory scale

Prior to Field Sampling

Prior to field sampling, it will need to be decided how non-tree woody vegetation, such as non-tree woody vegetation, will be measured in a given land cover class/stratum. Different methods of measurement may be used for different land cover classes. This SOP must be altered to describe the approach that must be used for the measurement of non-tree woody vegetation. This must include a detailed description of what types of vegetation are included within this vegetation type.

1. **Determine Sampling Method:** The two main methods that can be used to estimate non-tree woody vegetation biomass will be destructive sampling within a small area (referred to here as a 'clip plot') or through the use of an allometric equation. The development and use of allometric equations are best used where non-tree woody vegetation are large and are a dominant vegetation type. In land cover types where non-tree woody vegetation are small or very uncommon 'clip plots' can be used. 'Clip plots' can also be used to estimate non-tree woody vegetation biomass in areas where non-tree woody vegetation are common but where it is not possible to identify individual 'non-tree woody vegetation' or 'non-tree woody vegetation clumps'.

2. **Determine Vegetation types sampled:** Where 'clip plots' will be used to measure non-tree woody vegetation, it must be decided whether non-tree woody vegetation will be measured separately from non-woody vegetation and tree seedlings (trees smaller than a sapling) or if these will be measured together. Please note that certain regulatory and voluntary Standards (e.g. CDM, VCS, ACR) and Methodologies may provide explicit rules on how non-tree woody vegetation and non-woody vegetation may be measured. If non-tree woody, non-woody vegetation, and tree seedling vegetation will be measured separately, very clear rules will need to be created delineating what will be defined as a 'non-tree woody vegetation' and what will be defined as 'non-woody vegetation'. All field members must understand these definitions.

3. **Create Clip plot frames**: Clip plot frames can be made out of various materials and can be circular or rectangular. A square clip plot frame made of PVC pipe 50 cm x 50 cm is usually sufficient for sampling (see Figure below). The clip plot frame should ***not*** be one continuous piece of material. The pieces of PVC piping should ***not*** be glued together into a permanent square. Instead it must remain in pieces so that it can be constructed around existing vegetation. The 'elbows' used to connect two pieces of piping together may be glued to one piece of piping. This step is only required where the 'clip plot' method is to be used.

4. **Create 'calibration weights' to calibrate hanging scales:** Prior to going into the field, the scales that will be used to weigh samples must be calibrated. The ideal approach is to calibrate the hanging scales that will be used in the field with the laboratory scale that will be used to measure the dry weight of subsamples. Only required if 'clip plot' method will be used.
    a. Ensure the laboratory scales are calibrated
    b. Medium hanging scale (5 kg):
        ii. Find an item that weighs about 3 kg and does not change weight when wet (metal tool of some sort). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
        iii. Calibrate hanging field scale using this item and the average recorded weight. This can take place at a base camp and therefore does not have to take place at the site of the destructive sampling. Do this every day prior to weighing items in field.
    c. Small hanging scale (~300 g):
        iv. Find an item that weighs 100-250 g and does not change weight when wet (metal tool of some sort, stack of coins taped together). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
        v. Calibrate hanging field scale using this item and the average recorded weight. This can take place at a base camp and therefore does not have to take place at the site of the destructive sampling. Do this every day prior to weighing items in field.

Field Measurements - Clip Plot Method

1. Determine clip plot locations
    a. The design and establishment of clip plots shall be determined following SOP Plot Design and SOP Establishment of Plots.
    b. Where non-tree woody vegetation sampling is taking place in association with tree plots, sampling for non-tree woody vegetation can occur at a total of 4 clip plot locations as follows:
        i. If using the single tree plot design, sample 4 clip plot locations at each tree plot
        ii. If using the cluster tree plot design, sample one clip plot at each of the 4 tree plots within the cluster.
    c. Where sampling is taking place in a land cover class without tree plots, the initial point of sampling shall be determined prior to entering the field.
    d. Starting at the tree plot center or the sampling point, determine a random compass bearing. This can be done using various methods such as using a random number table. Another method is to use a watch that has a second hand. At a random moment one individual can look at his/her watch and then the direction that the second hand is facing will be used as the compass bearing.
    e. Using the compass bearing walk 30 paces from the tree plot center (e.g. outside the largest tree nest and thus tree plot boundary). If temporary tree plots are being used, it is allowable for the number of paces to be reduced, however, if permanent tree plots are being used clip-plots must be located outside the boundaries of the tree plot.
    f. Walk 5 more steps (These additional steps reduce bias in choosing the sampling location).
2. Place clip plot frame at this location (see Figure below). Clip plot frame may need to be placed around existing vegetation and then constructed. For example, a tree may be located within the clip plot location.
3. Identify which non-tree woody individuals have stems originating from inside the area of the clip plot. This non-tree woody vegetation shall be cut at ground level. Any non-tree woody vegetation which have branches hanging into the plot but whose stem base is located outside the area of the clip plot shall ***not*** be clipped and measured.
4. Weigh clipped vegetation. If other types of non-tree vegetation (eg non-woody, bamboo, palms) are being sampled separately from the non-tree woody vegetation, do not include these other types of vegetation when weighing the non-tree woody vegetation. Record the total fresh weight of non-tree woody vegetation within the clip plot.
5. If there is no non-tree woody vegetation within the clip plot area, the clip plots should *not* be moved. Instead the non-tree woody vegetation biomass shall be recorded on the data sheet as 'zero'.
6. Take a sub-sample of vegetation. This should be representative of the total sample and shall be made up of a mix of species and vegetation found within the total sample. Place vegetation temporarily in a sample bag.

7. Repeat steps 1-6 for the remaining three clip plot locations.
8. Combine the four sub-samples into one sub-sample bag. If a single tree plot design is used, these four subsamples will come from the 4 clip plots associated with the tree plot. Where clustered tree plot design is used, these four subsamples will come from the clip plot associated with each of the 4 tree plots.
    a. Weigh the subsample bag empty. Record weight.
    b. Combine the subsamples from all 4 clip plots into one subsample bag.
    c. Weigh the subsample bag with the subsample inside. The weight should be between 100-300 g. Record the actual weight.
    d. Label the subsample bag with the plot identification number, subsample identification number, and weight of subsample.
    e. Take the subsample bag and the subsample from field. Bring them to the laboratory and dry the subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the total dry weight of non-tree woody vegetation found within the clip plot.
9. It is allowable for there to be a delay between field data collection and laboratory analysis. However, cloth sample bags must be placed in a location that allows air drying to occur.

Figure: Clip plot on forest floor

Field Measurements - Allometric Equation Method

For non-tree woody vegetation species where the allometric equation method will be used, non-tree woody vegetation will be measured within plots of a known area.

1. Determine plot location
    a. The design and establishment of plots shall be determined following SOP Plot Design and SOP Establishment of Plots.
    b. Where non-tree woody vegetation sampling is taking place in association with tree plots, sampling for non-tree woody vegetation should occur within the tree plots. Non-tree woody vegetation shall be measured in either the 'medium' or 'large' nest size. This must be decided prior to field work taking place and non-tree woody vegetation measured in a consistent area for all tree plots measured. This will be dependent on the prevalence of non-tree woody vegetation.
    c. Where sampling is taking place in a land cover class without tree plots, the initial point of sampling shall be determined prior to entering the field. Plot sizes can vary, dependent on prevalence of non-tree woody vegetation, however, a 20 m radius circular plot or 35 m x 35 m is recommended. See 'SOP Plot Design' and 'SOP Establishment of Plots' for information on how to set up a plot.

2. For each individual non-tree woody plant within the plot, measure the required vegetation parameters. These vegetation parameters will depend on the allometric equation used.

SOP MEASUREMENT OF NON-WOODY VEGETATION (HERBACEOUS)

Field Equipment
Clip plot frame
Measuring tape
Clippers to remove vegetation
2-5 kg hanging scale (appropriate size dependent on density of non-tree vegetation)
300 g hanging scale (for subsample)
Durable plastic sheeting
Durable plastic tarp
Cloth or paper sample bags
Compass
Calibration weights (see below)

Laboratory Equipment:
Drying oven
Laboratory scale

Sampling for non-tree non-woody vegetation (e.g. herbaceous) may occur in a known small area in which all non-tree non-woody vegetation (herbaceous) is cut at the base and weighed. The average weight of non-woody vegetation within the land use area is then extrapolated based on the average biomass found within the areas sampled. This SOP must be altered to describe the approach that must be used for the measurement of non-woody vegetation.

Prior to Field Sampling

1. **Determine vegetation types sampled:** It must be decided what vegetation types will be sampled within the 'non-woody vegetation'. Clear rules will need to be created delineating what will be defined as a 'non-tree woody vegetation' and what will be defined as 'non-woody vegetation'. All field members must understand these definitions. Please note that certain regulatory and voluntary Standards (e.g. CDM, VCS, ACR) and Methodologies may provide explicit rules on how non-tree woody vegetation and non-tree non-woody vegetation may be measured.

2. **Create clip plots frames**: The small areas where vegetation is measured are here referred to as 'clip plots'. Clip plot frames can be made out of various materials and can be circular or rectangular. A square clip plot frame made of PVC pipe 50 cm x 50 cm is usually sufficient for sampling (see Figure below). The clip plot frame should ***not*** be one continuous piece of material. The pieces of PVC piping should ***not*** be glued together into a permanent square. Instead it must remain in pieces so that it can be constructed around existing vegetation. The 'elbows' used to connect two pieces of piping together may be glued to one piece of piping.

3. **Create 'calibration weights' to calibrate hanging scales:** Prior to going into the field, the scales that will be used to weigh samples must be calibrated. The ideal approach is to calibrate the hanging scales that will be used in the field with the laboratory scale that will be used to measure the dry weight of subsamples.
    d. Ensure the laboratory scales are calibrated
    e. Medium hanging scale (2-5 kg):
        vi. Find an item that weighs about half the maximum weight of the scale and does not change weight when wet (metal tool of some sort). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.

vii. Calibrate hanging field scale using this item and the average recorded weight. This can take place at a base camp and therefore does not have to take place at the site of the destructive sampling. Do this every day prior to weighing items in field.

f. Small hanging scale (~300 g):

viii. Find an item that weighs 100-250 g and does not change weight when wet or over time (metal tool of some sort, stack of coins taped together). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.

ix. Calibrate hanging field scale using this item and the average recorded weight. This can take place at a base camp and therefore does not have to take place at the site of the destructive sampling. Do this every day prior to weighing items in field.

Field Measurements

10. Determine clip plot locations
    a. The design and establishment of clip plots shall be determined following SOP Plot Design and SOP Establishment of Plots.
    b. Where non-tree woody vegetation samples have been taken in clip-plots, the same locations shall be used for non-woody vegetation sampling.
    c. Where non-woody vegetation sampling is taking place in association with tree plots, sampling for non-woody vegetation can occur at a total of 4 clip plot locations as follows:
        i. If using the single tree plot design, sample 4 clip plot locations at each tree plot
        ii. If using the cluster tree plot design, sample one clip plot at each of the 4 tree plots within the cluster.
    d. Where sampling is taking place in a land cover class without tree plots, the initial point of sampling shall be determined prior to entering the field.
    e. Starting at the tree plot center or the sampling point, determine a random compass bearing. This can be done using various methods such as using a random number table. Another method is to use a watch that has a second hand. At a random moment one individual can look at his/her watch and then the direction that the second hand is facing will be used as the compass bearing.
    f. Using the compass bearing walk 30 paces from the tree plot center (e.g. outside the largest tree nest and thus tree plot boundary). If temporary tree plots are being used, it is allowable for the number of paces to be reduced, however, if permanent tree plots are being used, clip-plots must be located outside the boundaries of the tree plot.
    g. Walk 5 more steps (These additional steps reduce bias in choosing the sampling location).
11. Place clip plot frame at this location (see Figure below). Clip plot frame may need to be placed around existing vegetation and then constructed. For example, a tree may be located within the clip plot location.
12. Identify which non-tree woody individuals have stems originating from inside the area of the clip plot. This non-woody vegetation shall be cut at ground level. Any non-woody vegetation which have branches hanging into the plot but whose stem base is located outside the area of the clip plot shall ***not*** be clipped and measured.
13. Weigh clipped vegetation. If other types of non-tree vegetation (eg non-woody, bamboo, palms) are being sampled separately from the non-woody vegetation, do not include these other types of vegetation when weighing the non-woody vegetation. Record the total fresh weight of non-woody vegetation within the clip plot.
14. If there is no non-woody vegetation within the clip plot area, the clip plots should *not* be moved. Instead the non-woody vegetation biomass shall be recorded on the data sheet as 'zero'.
15. Take a sub-sample of vegetation. This should be representative of the total sample and shall be made up of a mix of species and vegetation found within the total sample. Place vegetation temporarily in a sample bag.
16. Repeat steps 1-6 for the remaining three clip plot locations.
17. Combine the four sub-samples into one sub-sample bag. If a single tree plot design is used, these four subsamples will come from the 4 clip plots associated with the tree plot. Where clustered tree plot design is used, these four subsamples will come from the clip plot associated with each of the 4 tree plots.
    a. Weigh the subsample bag empty. Record weight.
    b. Combine the subsamples from all 4 clip plots into one subsample bag.
    c. Weigh the subsample bag with the subsample inside. The weight should be between 100-300 g. Record the actual weight.
    d. Label the subsample bag with the plot identification number, subsample identification number, and weight of subsample.

   e. Take the subsample bag and the subsample from field. Bring them to the laboratory and dry the subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the total dry weight of non-woody vegetation found within the clip plot.

18. It is allowable for there to be a delay between field data collection and laboratory analysis. However, cloth sample bags must be placed in a location that allows air drying to occur.

Figure: An example of measuring non-woody vegetation biomass within a clip plot in Indonesia and the weighing of a subsample in China

SOP MEASUREMENT OF LITTER LAYER

Field Equipment:
Clip plot
Machete or knife
Clippers to remove vegetation and cut litter along edge of plot
2 kg hanging scale (appropriate size dependent on density of non-tree vegetation)
300 g hanging scale (for subsample)
Durable plastic sheeting
Durable plastic tarp
Cloth or paper sample bags
Permanent marking pen
Compass
Calibration weights (see below)

Laboratory Equipment:
Drying oven
Laboratory scale

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

Clip plots should be used to sample litter and the clip plots can be the same as the ones used for non-woody vegetation material (see SOP for Non-woody Vegetation).

Sampling of litter may occur in a known small area in which all litter within the area is removed and weighed. The average carbon stock of litter within the land use area is then extrapolated based on the average weight found within the areas sampled and the assumed percent carbon of litter. This SOP must be altered to describe the approach that must be used for the measurement of litter.

Sampling can take place at the same location as sampling for non-woody vegetation (see SOP Measurement of Non-woody Vegetation).

Prior to Field Sampling

1. **Create clip plot frames**: The small areas within which litter is measured are called 'clip plots'. Clip plot frames can be made out of various materials and can be circular or rectangular (see Figure below). A square clip plot frame made of PVC pipe 50 cm x 50 cm is usually sufficient for sampling. The clip plot frame should ***not*** be one continuous piece of material. The pieces of PVC piping should ***not*** be glued together into a permanent square. Instead it must remain in pieces so that it can be constructed around existing vegetation (such as trees and saplings). The 'elbows' used to connect two pieces of piping together may be glued to one piece of piping.

2. **Create 'calibration weights' to calibrate hanging scales:** Prior to going into the field, the scales that will be used to weigh samples must be calibrated. The ideal approach is to calibrate the hanging scales that will be used in the field with the laboratory scale that will be used to measure the dry weight of subsamples.
    a. Ensure the laboratory scales are calibrated
    b. Medium hanging scale (2-5 kg):
        i. Find an item that weighs about half the maximum weight of the scale and does not change weight when wet (metal tool of some sort). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
        ii. Calibrate hanging field scale using this item and the average recorded weight. This can take place at a base camp and therefore does not have to take place at

the site of the destructive sampling. Do this every day prior to weighing items in field.

c. Small hanging scale (~300 g):
    i. Find an item that weighs 100-250 g and does not change weight when wet or over time (metal tool of some sort, stack of coins taped together). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
    ii. Calibrate hanging field scale using this item and the average recorded weight. This can take place at a base camp and therefore does not have to take place at the site of the destructive sampling. Do this every day prior to weighing items in field.

Field Measurements

1. Determine clip plot locations
    a. The design and establishment of clip plots shall be determined following SOP Plot Design and SOP Establishment of Plots.
    b. Where non-tree woody vegetation and/or non-woody vegetation samples have been taken in clip-plots, the same locations shall be used for soil sampling.
    c. Where non-tree woody vegetation sampling is taking place in association with tree plots, sampling for non-tree woody vegetation can occur at a total of 4 clip plot locations as follows:
        i. If using the single tree plot design, sample 4 clip plot locations at each tree plot
        ii. If using the cluster tree plot design, sample one clip plot at each of the 4 tree plots within the cluster.
    d. Where sampling is taking place in a land cover class without tree plots, the initial point of sampling shall be determined prior to entering the field.
    e. Starting at the tree plot center or the sampling point, determine a random compass bearing. This can be done using various methods such as using a random number table. Another method is to use a watch that has a second hand. At a random moment one individual can look at his/her watch and then the direction that the second hand is facing will be used as the compass bearing.
    f. Using the compass bearing walk 30 paces from the tree plot center (e.g. outside the largest tree nest and thus tree plot boundary). If temporary tree plots are being used, it is allowable for the number of paces to be reduced, however, if permanent tree plots are being used, clip-plots must be located outside the boundaries of the tree plot.
    g. Walk 5 more steps (These additional steps reduce bias in choosing the sampling location).
2. Place clip plot frame at this location (see Figure below). Clip plot frame may need to be placed around existing vegetation and then constructed. For example, a tree may be located within the clip plot location.
3. If needed, remove all vegetation to allow litter to be collected.
4. Collect all litter inside the clip plot frame. A knife can be used to cut pieces that fall on the border of the sampling frame. Place the litter on the plastic sheeting or tarp.
5. Weigh litter. Record the total weight of litter within the clip plot.
6. If there is no litter within the clip plot area, the clip plots should *not* be moved. Instead the litter shall be recorded on the data sheet as ‘zero’.
7. Take a sub-sample of litter. This should be a representative subset of the total sample and shall be made up of a mix of litter types found within the total sample. Place subsample temporarily in a sample bag.
8. Repeat steps 1-6 for the remaining three locations.
9. Combine the four sub-samples into one sub-sample bag. If a single tree plot design is used, these four subsamples will come from the 4 clip plots associated with the tree plot. Where clustered tree plot design is used, these four subsamples will come from the clip plot associated with each of the 4 tree plots.
    a. Weigh the subsample bag empty. Record weight.
    b. Combine the subsamples from all 4 clip plots into one subsample bag.
    c. Weigh the subsample bag with the subsample inside. The weight should be between 100-300 g. Record the actual weight.
    d. Label the subsample bag with the plot identification number, subsample identification number, and weight of subsample.
    e. Take the subsample bag and the subsample from field. Bring them to the laboratory and dry the subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the total dry weight of litter found within the clip plot.

10. It is allowable for there to be a delay between field data collection and laboratory analysis. However, cloth sample bags must be placed in a location that allows air drying to occur.

Figure: Example of litter clip plots

SOP SAMPLING SOIL CARBON

Field equipment
Soil corer or probe (for soil corer method only)
Non-breakable rod (for soil corer method only. Used to remove soil from corer/probe)
Soil bulk density rings (for soil pit method only)
Digging instrument (for soil pit method only)
Hammer (for soil pit method only)
Durable wood piece that covers diameter of bulk density rings (for soil pit method only)
Cloth bags (if soil core method is used, cloth bags must be at least ~40 cm length to accommodate total length of soil sample)
Durable plastic tarp
Permanent marking pen

Lab equipment
Drying oven
Laboratory scale
Capacity to analyze soil for C, dry combustion carbon analyzer preferred

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

Prior to Field Sampling

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

Field Measurements

1. Determine sampling location
    a. Where non-tree woody vegetation, non-woody vegetation, and/or litter samples have been taken, the same locations shall be used for soil sampling.
    a. Where soil sampling is taking place without sampling for litter and non-woody vegetation and it is in association with tree plots, sampling for soil can occur at 4 locations as follows:
        i. If using the single plot design, sample 4 locations at a single tree plot
        ii. If using the cluster plot design, sample one location at each of the 4 tree plots within the cluster.
    b. Where sampling is taking place in a land cover class without tree plots, the initial point of sampling shall be determined prior to entering the field. Sampling for soil should also occur at 4 locations around the initial point.
    c. Starting at the tree plot center or the sampling point, determine a random compass bearing. This can be done using various methods such as using a random number table. Another method is to use a watch that has a second hand. At a random moment one individual can

look at his/her watch and then the direction that the second hand is facing will be used as the compass bearing.

   d. Using the compass bearing walk 30 paces from the tree plot center (e.g. outside the largest tree nest and thus tree plot boundary). If temporary tree plots are being used, it is allowable for the number of paces to be reduced, however, if permanent tree plots are being used, sampling point must be located outside the boundaries of the tree plot.
   e. Walk 5 more steps (These additional steps reduce bias in choosing the sampling location).

2. Remove all vegetation and litter from the sampling location. Because the carbon concentration of organic materials is much higher than that of the mineral soil, including even a small amount of surface material can result in a serious overestimation of soil carbon stocks.
3. There are two options for sampling the soil: using a standard soil corer (option 1) or digging a small pit (option 2). Sampling forest soils with a standard soil corer can often present difficulties as the corer can hit roots frequently, which makes it difficult to extract a full core.
4. Option 1 – Soil corer method
   a. Insert the soil corer/probe steadily to standard depth of 30 cm.
   b. If the soil is compacted, use a rubber mallet to fully insert. If the probe will not penetrate to the full depth, do not force it as it is likely that a stone/root is blocking its route and if forced the probe will be damaged. If blocked withdraw the probe, clean out any collected soil, and insert in a new location.
   c. If depth of soil at sampling point is less than standard depth measured, then the depth of the soil sampled must be recorded.
   d. Carefully extract the probe and put soil into a cloth bag. Assign bag a unique ID number.
   e. To reduce variability, repeat steps a-d at a total of 4 points as per step 1b above.
   f. Mix all four samples thoroughly to a uniform color and consistency. It is important to take special care to remove pieces of litter and charcoal from samples at any sites.
   g. Place one thoroughly mixed subsample into a labeled sample bag. Ensure total weight of soil in bag is greater than the minimum soil weight required by the soil laboratory (if soil is very wet, this should be taken into consideration in determining mass of soil contained in soil sample bag).
   h. At each sampling location, take two additional cores for determination of bulk density. When taking cores for measurements of bulk density, care should be taken to avoid any loss of soil from the cores.
   i. Each sampling plot (e.g. single tree plot or cluster plot) will have three soil samples: 1 bag for soil carbon estimation, and 2 bags containing soil for bulk density determination.
5. Option 2- Soil pit method

   Four small pits, one at each of the four sampling locations, will be dug and aggregated into one sample.
   a. Dig a soil pit 30 cm deep, making sure that one of the walls is perpendicular to the soil surface. A folding entrenching shovel (military type, with a flat shovel) is usually light and versatile for digging the pit, however any digging instrument can be used.
   b. Using the shovel take a slice of soil from one of the walls of the soil pit. The slice should be uniform throughout the 30 cm profile, i.e. an equal amount of soil should be collected from the first 15 cm as the last 15 cm. Soil carbon usually decreases with depth, and if the slice collected contains more soil from the top of the pit versus the bottom the soil carbon estimate will be biased.
   c. Repeat steps a-c at the other 3 sampling locations.
   d. Mix all four samples thoroughly to a uniform color and consistency. It is important to take special care to remove pieces of litter and charcoal from samples at any sites.
   e. Place one thoroughly mixed subsample into a labeled sample bag. Ensure total weight of soil in bag is greater than the minimum soil weight required by the soil laboratory (if soil is very wet, this should be taken into consideration in determining mass or soil contained in soil sample bag).
   f. For each sampling plot, four measures of bulk density shall be taken using a bulk density ring. This should take place at each of the 4 sampling locations.

i. After removing the soil for carbon measurements, place the bulk density ring over the mid-point of the soil pit. This would normally be at 15 cm (see figure).
ii. Cover the ring with a piece of wood and hammer the ring into the side of the soil pit (avoid compacting the soil).
iii. When the ring is flush with the side of the soil pit dig around the ring until the soil ring can be removed along with all the soil inside. If soil falls out of the ring, the process must be repeated.
iv. Carefully place the soil contained in the bulk density ring into a sample bag and label

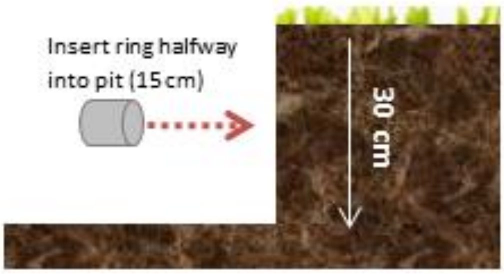

Figure Inserting a bulk density ring

j. Therefore, each sampling plot will have two soil samples: 1 bag for soil carbon estimation and 1 bag containing 4 rings of soil for bulk density estimation.

6. It is allowable for there to be a delay between field data collection and laboratory analysis. However, sample bags must be placed in a location that allows air drying to occur.
7. Promptly send soil samples to a professional lab for analysis.

References:

Nelson, D.W., and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. p. 961-1010. In: D.L. Sparks et al. (eds.) Methods of soil analysis. Part 3.Chemical methods.SSSA, Madison, WI.

SOP MEASUREMENT OF STANDING DEAD WOOD

Field Equipment:
DBH tape
Clinometer
Laser range finder (OPTIONAL)
Relascope (OPTIONAL)
Measuring tape

Laboratory Equipment:
None

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 5 cm DBH and taller than 1.3 m). However, standing dead wood generally also includes dead wood stumps from trees that were greater than 5 cm DBH when alive but have a current height of less than 1.3 m. This SOP must be altered to describe the definition of deadwood that will be used and the exact approach that must be used for the field measurement of standing dead wood.

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

Standing dead wood can be measured within the permanent or temporary plots used to measure live trees. Generally, measurements of standing dead wood take place concurrently with live tree measurements. It is recommended that standing dead trees be measured in the medium tree nest size. Each standing dead trees should be classified into two classes (see Figure below):

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

Class 2: Dead trees containing large branches or no branches at all, including stumps.

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

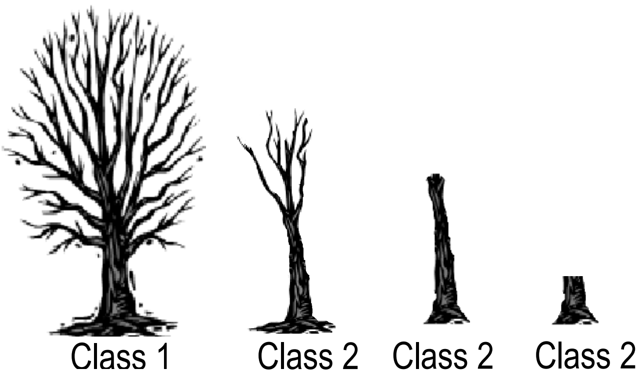

Figure: Example of trees in Class 1 and Class 2

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.

Class 1 trees:

1. Follow the same measurement protocols as for the measurement of live trees, including the measurement of tree variables (eg DBH, H) (see SOP Measurement of Trees). If species/genus specific allometric equations require different field measurements, rules must be included in this SOP stating which field measurements will be made for which type of dead tree (for example – for all Class 1 dead trees, the 'other' tree allometric equation will used and DBH of dead trees will be measured.) If nested plots are used, it is recommended that dead trees be measured in the medium nest. 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. Measure all dead trees in medium nest.
3. Measure the diameter at the base of the tree. ($\mathbf{D}_{base}$)
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 (eg when dead wood is less than 2 m high)
5. Measure diameter at top of stump ($\mathbf{D}_{top,}$) 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.

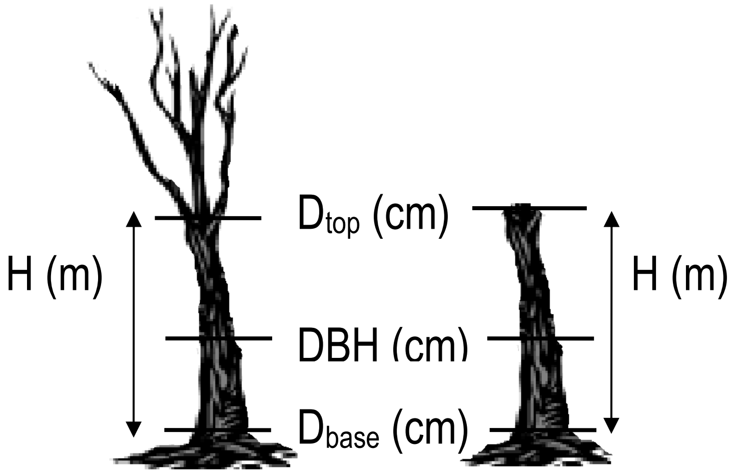

Figure2 Standing dead tree measurement locations

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).

1. Option 1: Diameter at top (Dt_{op}) was measured directly:

   Volume estimated assuming tree is a truncated cone:

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

2. Option 2: Diameter at top (Dt_{op}) was measured using a Relascope:

   Volume estimated assuming tree is a truncated cone:

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

3. Option 3: Diameter at top (Dt_{op}) 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:

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

4. Option 4: Diameter at top (Dt_{op}) 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 LYING DEAD WOOD

Field Equipment:
Calipers (preferred) or DBH tape
Measuring tape
Two 50 m long ropes (with 25 m marked) or two 25 m long ropes
Machete

Laboratory Equipment:
None

Other:
Dead wood density estimates (see SOP Measurement of dead wood density)

Lying dead wood is measured using the line-intersect method outlined in Harmon and Sexton (1996)[4]. Lying dead wood is defined as all woody material on the ground with a diameter $\geq$10 cm. Smaller diameter pieces of wood are sampled as part of the litter pool (see SOP of Litter Layer).

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

Prior to Field Sampling

Using the following method, dead wood is grouped into three dead wood classes: sound, intermediate, and rotten. Prior to field measurements, samples of each dead wood class shall be collected for demonstration purposes. So that consistent measurements are made throughout sampling, all field members must be trained on what type of dead wood will be considered in each class.

Field Measurements

The location of plots shall follow SOP Plot Design. It is common to locate lying dead wood transects in association with tree plots, however this is not required. If permanent tree plots are used, it is best practice to locate the line transect outside the permanent tree plot. This prevents damage inflicted on plot area through measurement from impacting lying dead estimates.

1. Starting at the tree plot center (or the sampling point when lying dead wood measurements are not associated with tree plots), determine a random compass bearing. This can be done using various methods such as using a random number table. Another method is to use a watch that has a second hand. At a random moment one individual can look at his/her watch and then the direction the second hand is facing will be used as the compass bearing.
2. Using the compass bearing, walk 100 paces from the plot center. (For permanent tree plots, sampling must take place outside the tree plot boundary. For temporary tree plots, the sampling can take place within the tree plot boundary)
3. Walk 5 more steps (These additional steps reduce bias in choosing the sampling location)
4. Lay out two 50 m lines at right angles outside plot. Determine the direction of the first line using same random compass angle as above and place the other line at right angle to first. If necessary, 4 25 m lines can be laid out. However, the lines should not overlap or cross into tree plot. (see Figure below)

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[4]Harmon, M. E. and J. Sexton. 1996. Guidelines for measurements of woody detritus in forest ecosystems. Publication no. 20. U.S. Long-term Ecological Research (LTER) Network Office, University of Washington, Seattle, Washington, USA

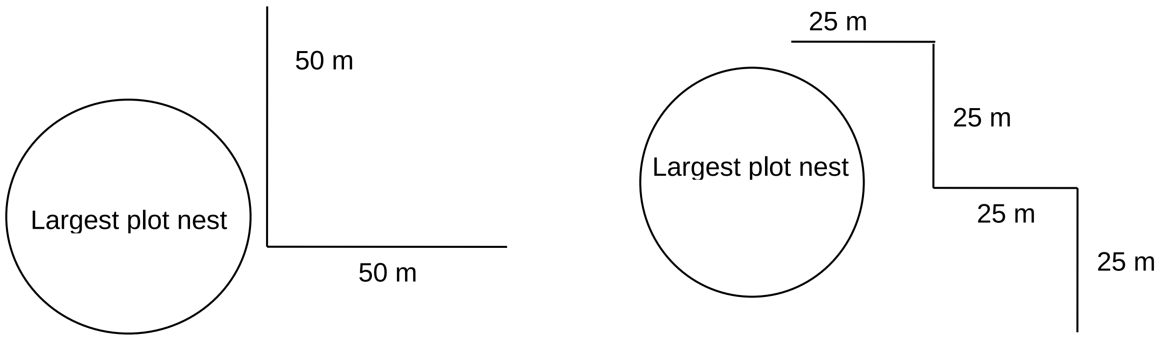


Figure: Two examples of the location of line transects to be used to estimate lying dead wood

5. Along the length of the line, measure the diameter of each intersecting piece of coarse dead wood (≥ 10 cm diameter) (see Figure below). Calipers work best for measuring the diameter. When measuring the diameter of dead wood it is not always possible to place a tape around the log. It can also be dangerous because logs are usually home to snakes, spiders, etc. If you are going to measure the diameter of the piece of dead wood with a diameter tape, make sure the route is clear before placing your hand underneath the log.

Figure: Use of callipers to measure the diameter of lying deadwood along line transect

6. A piece of dead wood should only be measured if: (a) more than 50% of the log is aboveground, and (b) the sampling line crosses through at least 50% of the diameter of the piece—see figures below. Some examples are displayed in the Figure below.

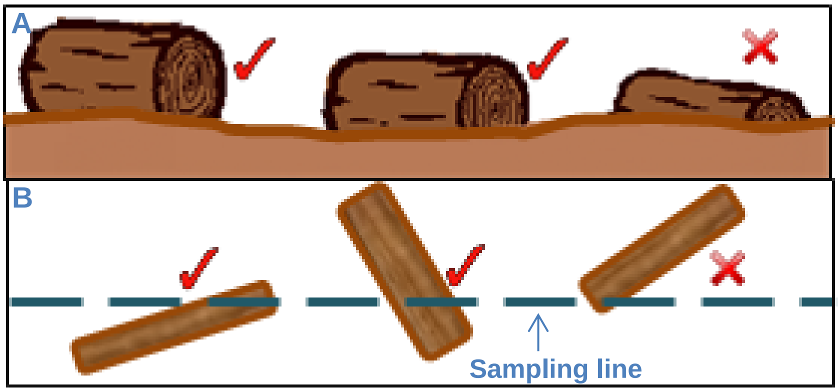


Figure A: Schematic of which dead wood should be measured. The first two logs should be measured because the log is more than 50% above ground, but the third log should not be measured. The horizontal line represents the soil surface.

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

7. If the log is hollow at the intersection point, measure the diameter of the hollow; the hollow portion in the volume estimates is excluded.
8. Assign each piece to one of three density states: sound, intermediate, or rotten. To determine what density class a piece of dead wood fits into, each piece will be struck with a machete. If the machete does not sink into the piece (bounces off), classify it as sound. If the machete sinks partly into the piece, and there has been some wood loss, classify it as intermediate. If the machete sticks into the piece, if there is more extensive wood loss, and the piece is crumbly, classify as rotten. Record on data sheet.
9. The volume of lying dead wood and then carbon stocks will be estimated using the diameters of each piece of wood and the length of the line transect.

SOP MEASUREMENT AND ESTIMATION OF DEAD WOOD DENSITY CLASSES

Field Equipment:
Measuring tape
Chainsaw or handsaw
Cloth bags
Permanent marking pen

Laboratory Equipment:
Drying oven
Laboratory scale
1L Graduated cylinder with milliliter markings and wide mouth
Very fine elongated rod/needle

--TO BE CONDUCTED ONE TIME ON EVERY STRATUM DURING FIELD SAMPLING--

In the field, dead wood is classified into three dead wood density classes. This SOP provides the field measurement, laboratory measurements, and data analysis methods that shall be used to estimate the average density that will be assigned to each dead wood density class.

This field work and analysis needs to take place one time during a field sampling effort. This must take place for each stratum where dead wood will be measured. If only the standing dead wood pool is being measured, then only the density of ‘sound wood’ needs to be estimated. After the densities are determined, this SOP does not need to be repeated unless a new stratum is identified and measured.

Prior to Field Sampling:

1. Determine which type(s) of dead wood will be measured (standing and/or lying).
2. Determine where samples will be collected. The location where samples are collected should be representative of the stratum, however it is not necessary for samples to be collected in a random distribution throughout the stratum.
3. Randomly collect a small amount of around 30 samples of dead wood at various stages of decomposition from each of the stratum. These pieces will only be used to agree upon density classes and therefore can be collected close to any base camp directly prior to field measurements taking place.
4. All dead wood will be classified into three density classes: sound, intermediate, and rotten. These classes can be determined using the ‘machete test’. The ‘machete test’ consists of raising the machete up to shoulder height and allowing it come down to the dead wood piece with the force of gravity. No additional force should be applied to the motion of the machete.
    a. Sound: : Machete does not sink into the piece (bounces off)—this does not necessarily mean the wood shows no sign of decomposition—lying dead wood can lose all the sapwood and bark but yet the heartwood is still sound—this would be classified as sound
    b. Intermediate: Machete sinks partly into the piece, and there has been some wood loss
    c. Rotten: Machete sticks into the piece, there is more extensive wood loss, and the piece is crumbly—the key here is that the dead wood is decomposed throughout and very soft and crumbly
5. Agreement shall be made on which pieces of wood fit into which dead wood density class. All field team members must be trained on all agree on consistent classes of dead wood.

Field measurements:

Collect wood samples for each density class for density determination (dry weight per green volume). The number of wood samples will depend on the variability between tree species within the forest. A minimum of 10 samples should be collected for each density class of each species group. For example, for a forest containing mixed broadleaf and palm species , a minimum of 10 samples of dead wood from each tree group should be collected per density class—for a total number of 30 samples for broadleaf species and 30 for palms.

1. For sound class of dead wood:
    a. Using a chainsaw or a handsaw, cut a complete disc from the selected piece of dead wood.
    b. Measure the diameter (L1 and L2) and thickness (T1 and T2) of the disc to estimate volume (Figure below). The dimensions of the sample should be recorded on data sheet. The fresh weight of the disc does not have to be recorded.
    c. All samples shall be placed in a labeled cloth bag.
    d. Samples shall be stored in location in manner that allows for air drying to take place prior to laboratory measurements.
    e. This sample will then be taken to the laboratory

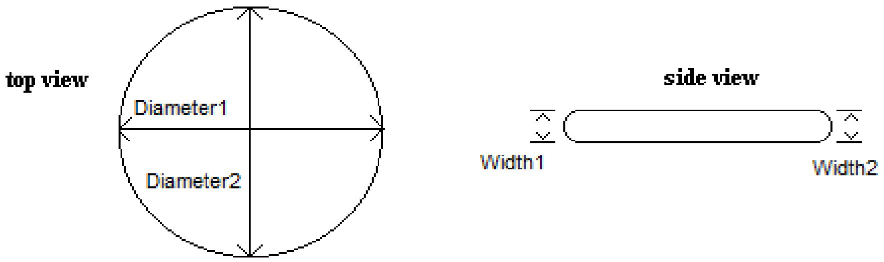


Figure: Measurements to be taken on disc cut from coarse dead wood samples

2. For intermediate and rotten classes:
    a. Collect a contiguous sample of the dead wood that is not too small nor too large (i.e. that fit in the graduated cylinder).
    b. Place sample in a bag, label the bag. Make sure sample doesn't break into smaller pieces when transporting it. If the sample is very crumbly, it can be placed on a piece of clear plastic wrap (e.g. cling wrap as used in food storage), and tightly wrapped around the piece of wood.
    c. This sample will be taken to the laboratory. Carefully transport sample to laboratory where it volume will be measured.
3. Train all field crew members on how different pieces of dead wood are should be classified, based on the sampling that was conducted.

Laboratory Measurements and Data Analysis:

1. Dry Weight: Place samples in drying oven at 70ºC until sample reaches constant weight (i.e. all moisture is evaporated). Record the dry weight (g).
2. Volume: If the wood disc sampled from the field is a regular shape (eg circular disk) the 'calculated volume' method below can be used. If the wood disc is an irregular shape, the 'water displacement volume' method shall be used.
    a. Calculated Volume Estimate Method:
        i. Calculate the volume using the measurements taken in the field:

$$Volume = \pi * \left(\frac{Diameter_1 + Diameter_2}{2} \Big/ 2 \right)^2 * \left(\frac{Width_1 + Width_2}{2} \right)$$

Where:

Volume = Volume of sample;cm^3
$Diameter_1$ = First diameter of sample; cm
$Diameter_2$ = Second diameter of sample; cm
$Width_1$ = First width of sample; cm
$Width_2$ = Second width of sample; cm

ii. Calculate density using the following formula:

$$\text{Density} = \frac{Dry\_weight}{Volume}$$

Where:

Density = Density of sample; g/cm^3
Volume = Volume of sample; cm^3
Dry Weight = measured dry weight of sample; g

iii. Calculate the mean the density for that wood density class.

b. Water Displacement Method: The most commonly used technique to measure the volume of irregularly shaped objects.
   i. Create a subsample from the wood sample brought from the field. This subsample must fit inside the graduated cylinder to be used.
   ii. Weigh the subsample created and record weight.
   iii. Fill the graduated cylinder to a known volume (e.g. 1L). Make sure there is enough water to submerge the piece and enough empty room in the graduated cylinder to allow water to rise without spilling over.
   iv. Place dead wood sample inside the graduated cylinder.
   v. Using the very fine elongated needle, push sample under the water until completely submerged. Make sure water doesn't spill over or rise above the last milliliter marking on the graduated cylinder.
   vi. On the data sheet, record the volume of water displaced by submerging the sample. That is the volume of the sample collected.
   vii. Calculate density using the following formula:

$$\text{Density} = \frac{Dry\_weight}{Volume}$$

Where:

Density = Density of sample; g/cm^3
Volume = Volume of sample; cm^3
Dry Weight = measured dry weight of sample; g

c. Calculate the mean the density for that wood density class.

SOP DESTRUCTIVE SAMPLING OF TREES, SAPLINGS, PALMS, BAMBOO, AND NON-TREE WOODY VEGETATION

Field Equipment:
Professional chainsaw operator
Chainsaw
Handsaws
Machetes
DBH tape
Clinometer
Laser Range Finder or measuring tape (to measure height)
Tree corer
50 kg scale
5 kg scale
~300 g scale
Durable, but thin plastic sheeting ~2 m x 2 m
Durable plastic tarp ~2 m x 2 m
Cloth or paper sample bags for subsamples
Flagging tape
'Diameter fork' (see below)
Marker (to label bags and samples)
10 m of rope, 1 – 2 cm thick (to tie up scale and to weigh branches)
'Calibration weights' (see below)

Laboratory Equipment:
Drying oven
Laboratory scale

Biomass regression equations or 'allometric equations' are commonly used to estimate biomass based on one or more vegetation variables, such as diameter of trunk at 1.3 m. Different equations give different estimates for biomass because each one is designed for a specific type of forest and climate type. The existence of allometric equations that may be applicable to the species or vegetation type should be properly investigated. It must be determined if a species specific or vegetation-type specific allometric equation will be used. To either develop a new biomass regression equation or to check the appropriateness of an existing one, it is necessary to destructively sample the vegetation. The following methods describe how to destructively sample the vegetation. However, additional guidance is required to create a biomass equation.

Prior to Field Sampling

1. **Create 'calibration weights' to calibrate hanging scales:** Prior to going into the field, the scales that will be used to weigh samples must be calibrated. The ideal approach is to calibrate the scales that will be used in the field with the laboratory scale that will be used to measure the dry weight of subsamples.
    a. Ensure the laboratory scales are calibrated
    b. Large hanging scale (50 kg):
        i. Find an item that weighs about 10-30 kg and does not change weight when wet (e.g. metal tool of some sort) or over time. Weigh this item using the laboratory scale 5 times. Record weights and take average weight.

   ii. Calibrate hanging field scale using this 'calibration weight' item and the average recorded weight. Do this every day prior to weighing items in field. This can take place at a base camp and therefore does not have to take place at the site of the destructive sampling. Ideally the item used to calibrate the scale should be a piece of field or base-camp equipment of an appropriate weight.

c. Medium hanging scale (5 kg):
   i. Find an item that weighs about 3 kg and does not change weight when wet (metal tool of some sort). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
   ii. Calibrate hanging field scale using this item and the average recorded weight. This can take place at a base camp and therefore does not have to take place at the site of the destructive sampling. Do this every day prior to weighing items in field.

d. Small hanging scale (~300 g):
   i. Find an item that weighs 100-250 g and does not change weight when wet (metal tool of some sort, stack of coins taped together). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
   ii. Calibrate hanging field scale using this item and the average recorded weight. This can take place at a base camp and therefore does not have to take place at the site of the destructive sampling. Do this every day prior to weighing items in field.

2. **Create Diameter Fork:** Create a diameter fork that has two openings equating to the size classes that will be used during destructive sampling (see Figure below). For example: 20 cm wide and 10 cm wide. Or create different diameter forks – eg one 20 cm opening and another with a 10 cm opening. The 'diameter fork' can be made out of plastic or aluminum, anything that is relatively stiff and will not break apart easily.

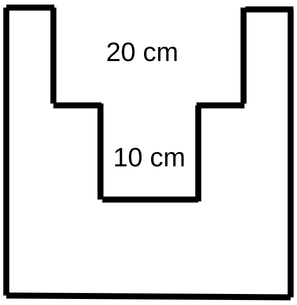


Figure Example of a diameter fork

Destructive Sampling of Trees

To ***verify the applicability*** of an existing selected biomass regression equation, select 5 trees to be destructively sampled. These trees should focus on the upper range of trunk diameters found in the sample population and must contain at least two large trees (if possible at least greater than 60-70 cm DBH). For large trees, the weight of the main bole of the tree will be estimated by measuring the volume and estimating the density of the tree. The branches of the tree are weighed directly by cutting the tree into parts and weighing the branches.

When developing ***new biomass regression equations*** (recommended for trees with unique forms or densities or for forests dominated with only 1-2 species), ***at least*** 30 trees covering the full range of diameter classes need to be harvested (if the 30 trees do not result in a significant equation with high r-squared, then additional trees will need to be harvested). Harvesting sufficient numbers of trees to develop new regression equations is very time intensive and one needs to make sure that none of the existing equations from the literature will suffice. Sampling locations should be selecting using a two-staged stratified sampling approach, as described in SOP Stratification, Sampling Design and Layout.

Prior to cutting down any tree, it is essential to obtain all necessary permits and secure authority to cut down the trees. Where possible, it is highly advisable to implement the destructive sampling of trees in locations where trees are being commercially harvested. It is recommended that a professional undertake the task of cutting the tree down. Felling trees is dangerous work, and everyone participating should observe the highest safety standards. To minimize the risk, it is recommended that information on the condition of the bole be ascertained by the chain saw user (generally common practice by professionals). If for example, the center of a tree is rotten, cutting into it with a chainsaw can cause the tree to collapse suddenly. If possible, have the tree cutter fell the tree in a location that will make measurements easy to obtain but above all in a safe location. People who are not cutting the tree should receive direction from the professional tree cutter and stand very far away from the tree in case it starts to fall in an unexpected direction.

If the diameter of the tree to be measured is less than 20 cm, then the size classes of tree components can be altered to include leaves, twigs, and branches <10 cm in diameter, and branches 10-20 cm in diameter.

Determining trees to destructively sample

Once the sampling point has been randomly identified (through a stratified two-stage sampling approach), assign each sampling location the tree size classes to be sampled. Navigate to the sampling location and find the GPS point. From the GPS point, using a compass, find direct north and start walking north. Destructively sample the first tree of the tree size class within 20 m of the line walking north. If the randomly selected tree of the correct size class cannot be safely felled, select the next closest tree within the same size class.

Prior to Tree felling

Before the tree is cut down, measure all tree parameters used in all potential biomass regression equations that may be applicable (e.g. DBH, total height, height to first branch, species). Care must be taken to measure all tree parameters using the exact same methods that would normally be used in the field.

8. Assign one person to record the data
9. Measure all the tree parameters that will be potentially used in the allometric equation to be developed and those in existing equations (eg DBH, DSH, H) for the tree to be destructively sampled prior to felling. For trees with more than one stem, the parameters for each stem must be measured separately and the weight of each stem must be measured separated. The height of the bole prior to branching must also be measured. It is important that the diameter tape is used properly using the following steps to ensure consistency of measurements:
    f. Record the name of the tree, based on tree naming system developed prior to field data collection.
    g. **Tree Pole placement**: For each tree, place the Tree Pole (1.3 m plastic pole) against the tree to indicate the location of measurement (eg 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).
        vi. **Slope:** Always place tree pole and measure diameter on the *upslope* side of the tree

vii. **Leaning tree**: Always measure the height of a measurement (1.3 m) parallel with the tree, *not* perpendicular to the ground. Therefore, if the tree is leaning, measure underneath the lean, parallel with angle of tree. If a tree is not straight, a tape measure must be used to measure the bole distance from ground to DBH.

viii. **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 (ie 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.

ix. **Multi-stem tree**: If the tree is multi-stemmed with forking below the point of measurement (eg 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.

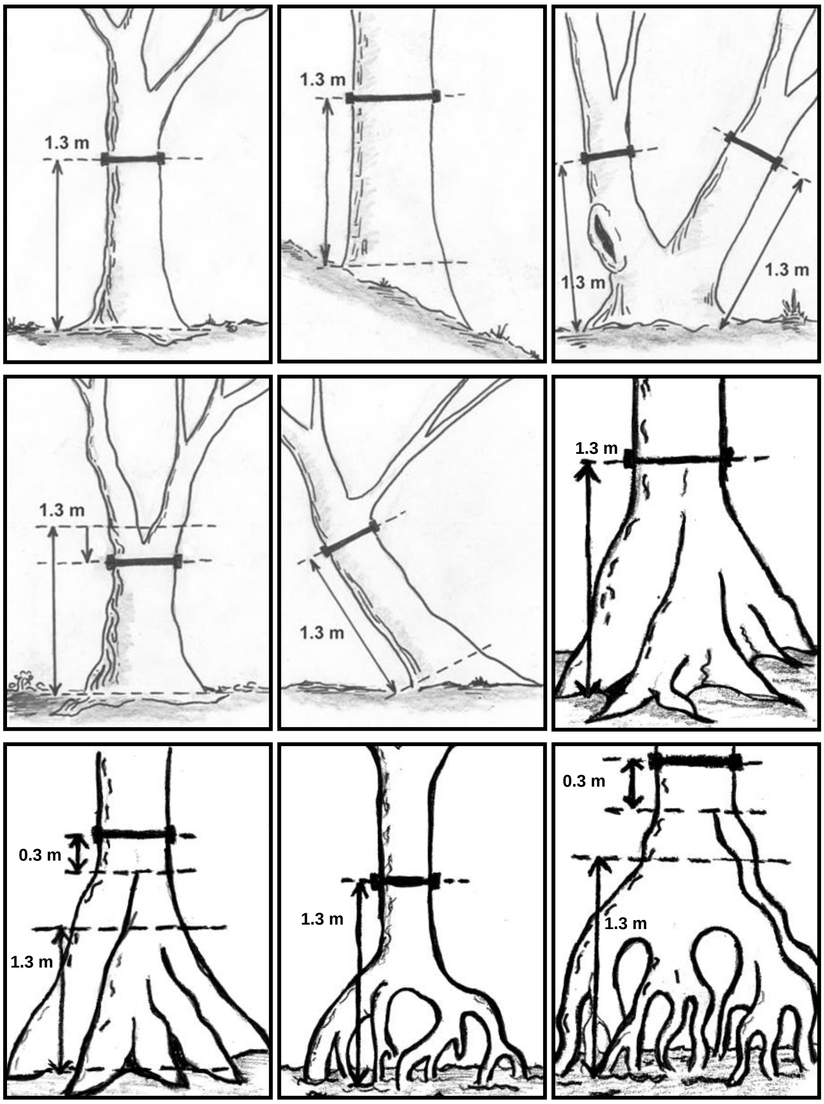


Figure: Proper placement of diameter tape

x. **Buttressed tree**

1. If the buttress is shorter than 1.3 m, measure the DBH at the standard (1.3 m) height.
2. If the buttress is taller than 1.3 m, measure the diameter at 30 cm above top of buttress as shown in figure below. In cases where buttress is too tall and out of reach, the following procedure shall be followed:

i) Use portable retractable ladder and lean ladder against tree to allow for measurement of DBH 30 cm above from the top of the buttress.

ii) If ladder is unavailable, and 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.

iii) If ladder is unavailable, and climbing is considered unsafe, retractable poles should be use. 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** 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.

Note: The distance between poles shall be measured linearly, and thus proper measuring tape shall be used. 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).

h. **Diameter measurement:** Tree diameter should be measured to the nearest 0.1 cm (eg diameter of 10.2 cm *not* 10 cm).

iv. 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)

v. 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.

vi. Place chalk mark on the tree to indicate to crew members that the tree has been measured.

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

i. **Other tree parameters:** Measure all other tree parameters included in the biomass regression equation to be used. If the allometric equation to be used requires height as an input for each tree/palm measured, two measurements of height should be taken to improve the precision of measurements, especially if it is difficult to identify the top of the tree/palm measured. See *SOP Measurement of Height* on how to measure tree height.

Tree Felling

1. Calibrate hanging scales at start of each day with 'calibration weights'.
2. A chainsaw operator must undertake the task of cutting the tree down and cutting the tree into components
3. After the tree is cut down the following measurements need to be made (see Figure below):
   a. Length of tree (from the stump to the top of the crown) (in meters to the nearest 0.01 m)
   b. Length of bole (from the stump to the first main branch) (in meters to the nearest 0.01 m)
   c. Diameter of stump (in cm to the nearest 0.1 cm)
   d. Diameter at breast height (in cm to the nearest 0.1 cm)
   e. Diameter at the center of bole (in cm to the nearest 0.1 cm)
   f. Diameter at top of bole (in cm to the nearest 0.1 cm)
   g. Where possible, after these measurements are made, the chainsaw operator should cut, or mark, the length of the bole that would be extracted for timber.
   h. Length of the commercial log and the diameter at both ends of the log (in meters to the nearest 0.01 m)

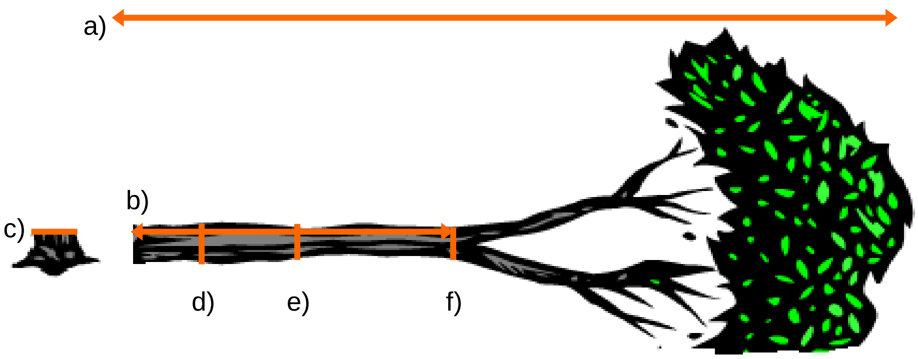


Figure Location of measurements following cutting down of tree

4. Attach a 50-kilogram (kg) scale to either a tripod or a strong branch (if the tree is smaller, a smaller scale can be used)
5. Divide tree into size classes and estimate weights:
   a. **Bole**: The bole is the main trunk of the tree, from the stump to the first major branch. To estimate bole biomass, volume measurements will be taken and a density value applied.
      i. Measurements to estimate volume of bole (see Figure below):
         a) Measure the total length of the bole
         b) Measure the diameter at ~5 m intervals along the bole to the first branch. Record the diameter and the length of each interval. Be sure to measure the diameter at the bottom and the top of the bole.

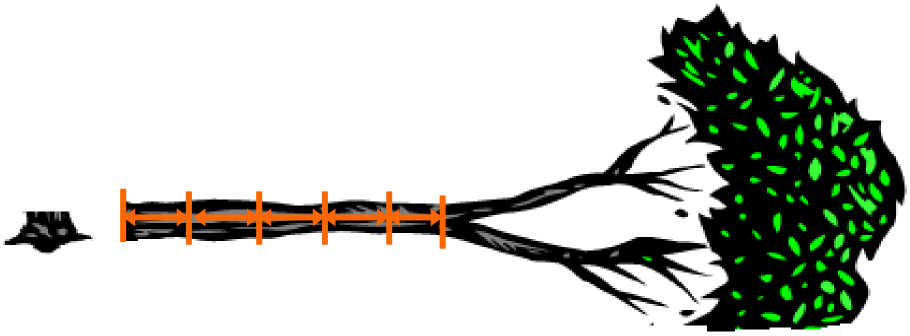


Figure Measurements of diameter and length along the bole of tree

1.

ii. Estimate Wood Density:

a) If verifying applicability of existing equation AND published wood density of species exists, the published wood density estimates will be used. No field measurements of wood density shall be taken. (See *SOP Wood Density* Reyes et al. 1992)

b) If creating new equation OR no published wood density of species exists, samples must be taken to estimate wood density. Disk samples must be taken from the main bole at several locations along its length.

i) Cut 5 disc samples from different sections of bole(if a commercial log will be extracted from tree then it may be difficult to obtain a sample from several places—instead collect a sample from top of the stump and bottom on the crown.)

ii) Record the dimensions of the disc (see Figure below). If the discs are too big to fit into any of the cloth or paper subsample bags, after the dimensions are measured carefully cut the disc into pieces and place the pieces into one bag. Try to minimize the wood fiber loss when cutting the discs. It is better to avoid cutting the disc if possible.

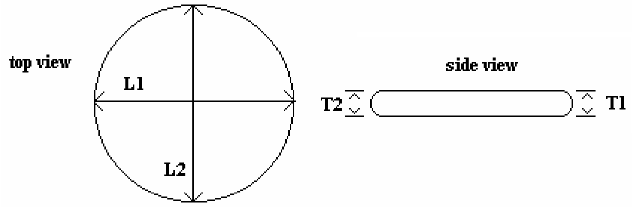


Figure: Wood disc measurement locations

iii) If the discs are too large and heavy to return to the laboratory they can be subsampled: either halved or quartered. Field sheets need to be annotated to this effect. The volume of the subsection will be estimated as either a quarter or half of the total volume estimated from the diameter and thickness measurements.

iv) Until samples are taken to the laboratory, place samples in location that allows air drying to occur.

v) Take discs to laboratory to estimate density. The fresh weights of disc samples do not need to be taken.

vi) Subsamples must be dried until a constant weight and weighed. To estimate density, divide dry subsampled weight by fresh volume of subsample. Alternatively, density may be estimated using the water displacement method. The calculated density will be used to estimate the weight of the entire bole.

b. Buttress:

i. If there is a buttress, the weight will need to be estimated.

ii. Cut the buttress into pieces and weigh on the scale. Record weight of each piece
iii. Take 2 sub-samples:
   a. Cut two ‘pie pieces’ out of the buttress (be sure both the center and edge of the buttress is included in a ‘pie piece’)
   b. Weigh each ‘pie piece’
   c. Label each subsample and record weight
   d. Take subsample from field. Until samples are taken to the laboratory, place samples in location that allows air drying to occur. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the entire buttress.

c. Stump:

i. If stump is relatively small:
   a. After the bole and the other parts of the tree are measured cut the stump as close to the ground as possible.
   b. Cut the stump into pieces and weigh on the scale.
   c. Take 2 sub-samples:
      i. Cut two ‘pie pieces’ out of the buttress
      ii. Weigh each ‘pie piece’
      iii. Label the subsample bag with the tree name, tree identification number, subsample identification number, and weight of subsample
      iv. Take subsample bag and subsample from field. Until samples are taken to the laboratory, place samples in location that allows air drying to occur. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the entire stump.
ii. If it is too big to cut up and weigh, estimate the volume of the stump through measurements. Measure the diameter at the base and top of the stump, along with the length of the stump. Tree density obtained from the bole measurements can be used to estimate the density of the stump.

d. Branches from 10-20 cm in diameter.

ii. Use the diameter fork to select branches that have a diameter from 10 to 20 cm.
iii. Use a chainsaw or hand saw to cut the branches and place them in a pile on the large plastic tarp
iv. Weigh the branches.
   a. Take a ~2 m x 2 m piece of plastic and weigh only the plastic. Record this weight
   b. Branches can be then placed on plastic and weighed.
   c. Alternatively, some branches can be weighed directly on scale.
v. Record the weights of all branches on the data sheet, noting if branches weighed on plastic or if were weighed directly.
vi. Take 5 sub-samples:
   d. Each subsample should weigh about 200-500 g. Each subsample should be made up of a mix of the sizes of branches found.
   e. Weigh the subsample bag empty. Record weight.
   f. Weigh the subsample bag with the subsample inside. Record weight.
   g. Label the subsample bag with the tree name, tree identification number, subsample identification number, and total weight of subsample and subsample bag.
   h. Take subsample bag and subsample from field. Until samples are taken to the laboratory, place samples in location that allows air drying to occur. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of all branches 10-20 cm in diameter.

e. Leaves and branches < 10 cm in diameter:

i. Lay a large plastic tarp on the ground. Collect all the branches with a diameter <10 cm and all leaves. Note: the leaves **do not** need to be removed from the branches. Place vegetation on plastic tarp.
ii. Take a ~2 m x 2 m piece of plastic and weigh only the plastic. Record this weight
iii. Put a pile of the small branches and leaves onto the plastic and weigh. Record weight
iv. Repeat until all small branches and leaves have been weighed
v. Take 5 sub-samples:
   a. Each subsample should weigh about 200-500 g. Each subsample should be made up of a mix of the sizes of branches and leaves.
   b. Weigh the subsample bag empty. Record weight.
   c. Weigh the subsample bag with the subsample inside. Record weight.
   d. Label the subsample bag with the tree name, tree identification number, subsample identification number, and weight of subsample
   e. Take subsample bag and subsample from field. Until samples are taken to the laboratory, place samples in location that allows air drying to occur. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of all the leaves and branches <10 cm in diameter.

Destructive Sampling of Palms

To *verify the applicability* of an existing selected biomass regression equation, select >5 individuals to be destructively sampled. These individuals should focus on the upper range of sizes found in the sample population. When developing ***new biomass regression equations***, ***at least*** 30 individuals covering the full range of sizes need to be harvested (if the 30 individuals do not result in a significant equation with high r-squared, then additional trees will need to be harvested).

1. Before cutting the palm, measure the palm parameters included in the equation to be verified. If a new equation is being created, measure all parameters that may serve as a good indicator of biomass. This would include: DBH, height of each stem, total height of each stem, number of palm fronds, and number of stems. Care must be taken to measure all parameters using the exact same methods that would normally be used in the field.
2. Calibrate hanging scales at start of each day with 'calibration weights'.
3. Cut it down and remeasure all the parameters possible, such as height of each stem and total height of palm.
4. Divide the palm into stem and palm fronds.
5. **Stem:**
   a. Weigh each stem.
   b. Cut stems into sections where needed.
   c. Record weight of each stem
   d. Take total of 5 sub-samples of stems from palm:
      i. Each subsample should weigh about 200-500 g. Each subsample should be made up of a mix of the sizes of stems.
      ii. Weigh the empty subsample bag. Record weight of just the bag.
      iii. Weigh the subsample bag with the subsample inside. Record weight.
      iv. Label the subsample bag with the palm identification number, subsample number, and weight of subsample
      v. Take subsample bag and subsample from field. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the palm.
6. **Fronds:**
   a. Weigh all palm fronds.
   b. Record weight of each frond
   c. Take a total of 5 sub-samples of fronds from palm:

i. Each subsample should weigh about 200-500 g. Each subsample should be made up of a mix of the sizes of fronds.
ii. Weigh the empty subsample bag. Record weight of just the bag.
iii. Weigh the subsample bag with the subsample inside. Record weight.
iv. Label the subsample bag with the palm identification number, subsample number, and weight of subsample
v. Take subsample bag and subsample from field. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the palm fronds.

Destructive Sampling of Bamboo

To ***verify the applicability*** of an existing selected biomass regression equation, select >5 samples to be destructively sampled. When developing ***new biomass regression equations***, ***at least*** 30 samples covering the full range of sizes need to be harvested (if the 30 individuals do not result in a significant equation with high r-squared, then additional individuals will need to be harvested).

If a new equation is being developed an assessment shall be made to determine what sampling strategy may be used to estimate bamboo biomass. This will vary depending on the growth structure of a given bamboo species. For some bamboo types, it may be determined that bamboo biomass will be estimated using the 'SOP Measurement of Non-woody Vegetation'. In this case a regression equation is not used and this step should not take place.

1. If an existing equation is being verified all variables included in the equation shall be measured. If a new equation is being created, measure all variables that may serve as a good indicator of biomass. This would include such things as: diameter at 0.30 cm, DBH, total height of each stem, number of stems, and basal area of culm. Care must be taken to measure all parameters using the exact same methods that would normally be used in the field.
2. Calibrate hanging scales at start of each day with 'calibration weights'.
3. Cut down all stems in sample
4. Weigh each stem and re-measure each stem. Record weights and height of each stem.
5. Weigh all stems
6. Take total of 5 sub-samples of stems from sample:
    a. Each subsample should weigh about 200-500 g. Each subsample should be made up of a mix of the sizes of stems.
    b. Weigh the empty subsample bag. Record weight of just the bag.
    c. Weigh the subsample bag with the subsample inside. Record weight.
    d. Label the subsample bag with the bamboo identification number, subsample number, and weight of subsample
    e. Take subsample bag and subsample from field. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the bamboo.

Destructive Sampling of Non-tree woody vegetation (shrubs)

See 'SOP Measurement of Non-tree Woody Vegetation' for a discussion on when the creation of an allometric equation for non-tree woody vegetation shall be created.

Prior to the creation of a new non-tree woody vegetation equation, research shall be conducted to determine whether any non-tree woody vegetation equations applicable to the non-tree woody vegetation found within the land use class exist. It must also be determined if a species specific or a general 'non-tree woody vegetation' allometric equation will be created.

To *verify the applicability* of an existing selected biomass regression equation, select >5 individuals to be destructively sampled. These individuals should focus on the upper range of sizes found in the sample population. When developing ***new biomass regression equations***, ***at least*** 30 individuals covering the full range of sizes need to be harvested (if the 30 individuals do not result in a significant equation with high r-squared, then additional individuals will need to be harvested).

1. If an existing equation is being verified all parameters included in the equation shall be measured. If a new equation is being created, measure all parameters that may serve as a good indicator of biomass. Care must be taken to measure all parameters using the exact same methods that would normally be used in the field. This would include such things as:
    a. diameter of each stem at 0.30 cm
    b. DBH of each stem
    c. total height of each stem
    d. number of stems
    e. total height of non-tree woody vegetation
    f. diameter of the crown in North-South direction and East-West direction
    g. diameter at narrowest point and diameter at widest point.
2. Cut down entire individual and weigh
3. Take total of 5 sub-samples from sample:
    a. Each subsample should weigh about 200-500 g. Each subsample should be made up of a mix of the sizes of stems and leaves.
    b. Weigh the empty subsample bag. Record weight of just the bag.
    c. Weigh the subsample bag with the subsample inside. Record weight.
    d. Label the subsample bag with the non-tree woody vegetation identification number, subsample number, and weight of subsample
    e. Take subsample bag and subsample from field. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the non-tree woody vegetation.

Destructive Sampling of Regenerating Vegetation / Fallow Cropland

Regenerating vegetation following cropping is often comprised of a variety of vegetation types, and therefore will require destructive sampling of saplings, small diameter trees, as well as non-tree woody vegetation. Prior to the undertaking of field data collection, a comprehensive assessment of shifting cultivation regimes should be conducted on shifting cultivation systems, fallow lengths, and geophysical conditions to determine appropriate strata. This process may elucidate the need to create specific allometric equations for different types of fallow cropland altogether.

At least five sites should be sampled per stratum, and vegetation classes should be delineated into woody herbaceous vegetation, bamboo, saplings, and trees. To ***verify the applicability*** of an existing selected biomass regression equation, select >5 samples of each vegetation class (i.e. woody herbaceous vegetation, bamboo, etc.) to be destructively sampled. When developing ***new biomass regression equations***, ***at least*** 30 samples covering the full range of sizes need to be harvested. If the 30 individuals do not result in a significant equation with high r-squared, then additional individuals will need to be harvested.

Trees

Although trees will likely be present in some fallow cropland areas, it is unlikely that large diameter trees will be growing in fallow cropland. Trees across the range of diameter classes should be targeted for measurement, including the upper range of DBH sizes.

Prior to Tree Felling

1. Assign one person to record the data
2. Measure all the tree parameters that will be potentially used in the allometric equation to be developed and those in existing equations (eg DBH, DSH, H) for the tree to be destructively sampled prior to felling. It is important that the diameter tape is used properly and protocols for tree measurement defined in *SOP Destructive Sampling of Trees* are followed.

Tree Felling

1. Calibrate hanging scales at start of each day with ‘calibration weights’.
2. A chainsaw operator must undertake the task of cutting the tree down and cutting the tree into components
3. After the tree is cut down the following measurements need to be made (see Figure below):
   i. Length of tree (from the stump to the top of the crown) (in meters to the nearest 0.01 m)
   j. Length of bole (from the stump to the first main branch) (in meters to the nearest 0.01 m)
   k. Diameter of stump (in cm to the nearest 0.1 cm)
   l. Diameter at breast height (in cm to the nearest 0.1 cm)
   m. Diameter at the center of bole (in cm to the nearest 0.1 cm)
   n. Diameter at top of bole (in cm to the nearest 0.1 cm)
   o. Where possible, after these measurements are made, the chainsaw operator should cut, or mark, the length of the bole that would be extracted for timber.
   p. Length of the commercial log and the diameter at both ends of the log (in meters to the nearest 0.01 m)

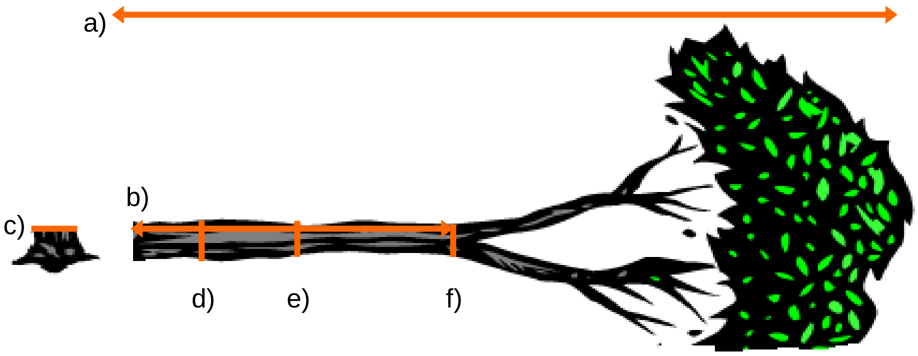


Figure Location of measurements following cutting down of tree

4. Attach a 50-kilogram (kg) scale to either a tripod or a strong branch
5. Divide tree into size classes and estimate weights:

    b. **Bole**: The bole is the main trunk of the tree, from the stump to the first major branch. To estimate bole biomass, volume measurements will be taken and a density value applied.

    iii. Measurements to estimate volume of bole (see Figure below):

    a) Measure the total length of the bole

    b) Measure the diameter at ~5 m intervals along the bole to the first branch. Record the diameter and the length of each interval. Be sure to measure the diameter at the bottom and the top of the bole.

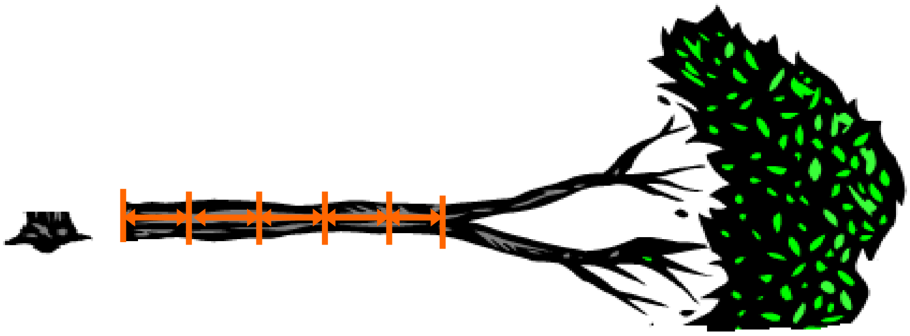


Figure Measurements of diameter and length along the bole of tree

2.

iv. Estimate Wood Density:

c) If verifying applicability of existing equation AND published wood density of species exists, the published wood density estimates will be used. No field measurements of wood density shall be taken. (See *SOP Wood Density* Reyes et al. 1992)

d) If creating new equation OR no published wood density of species exists, samples must be taken to estimate wood density. Disk samples must be taken from the main bole at several locations along its length.

vii) Cut 5 disc samples from different sections of bole(if a commercial log will be extracted from tree then it may be difficult to obtain a sample from several places—instead collect a sample from top of the stump and bottom on the crown.)

viii) Record the dimensions of the disc (see Figure below). If the discs are too big to fit into any of the cloth or paper subsample bags, after the dimensions are measured carefully cut the disc into pieces and place the pieces into one bag. Try to minimize the wood fiber loss when cutting the discs. It is better to avoid cutting the disc if possible.

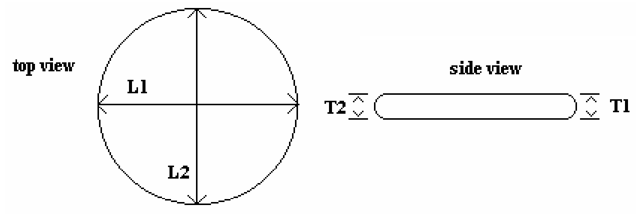


Figure: Wood disc measurement locations

ix) If the discs are too large and heavy to return to the laboratory they can be subsampled: either halved or quartered. Field sheets need to be annotated to this effect. The volume of the subsection will be estimated as either a quarter or half of the total volume estimated from the diameter and thickness measurements.
x) Until samples are taken to the laboratory, place samples in location that allows air drying to occur.
xi) Take discs to laboratory to estimate density. The fresh weights of disc samples do not need to be taken.
xii) Subsamples must be dried until a constant weight and weighed. To estimate density, divide dry subsampled weight by fresh volume of subsample. Alternatively, density may be estimated using the water displacement method. The calculated density will be used to estimate the weight of the entire bole.

f. Buttress:

iv. If there is a buttress, the weight will need to be estimated.
v. Cut the buttress into pieces and weigh on the scale. Record weight of each piece
vi. Take 2 sub-samples:
   a. Cut two 'pie pieces' out of the buttress (be sure both the center and edge of the buttress is included in a 'pie piece')
   b. Weigh each 'pie piece'
   c. Label each subsample and record weight
   d. Take subsample from field. Until samples are taken to the laboratory, place samples in location that allows air drying to occur. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the entire buttress.

g. Stump:

iii. If stump is relatively small:
   d. After the bole and the other parts of the tree are measured cut the stump as close to the ground as possible.
   e. Cut the stump into pieces and weigh on the scale.
   f. Take 2 sub-samples:
      i. Cut two 'pie pieces' out of the buttress
      ii. Weigh each 'pie piece'
      iii. Label the subsample bag with the tree name, tree identification number, subsample identification number, and weight of subsample
      iv. Take subsample bag and subsample from field. Until samples are taken to the laboratory, place samples in location that allows air drying to occur. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of the entire stump.
iv. If it is too big to cut up and weigh, estimate the volume of the stump through measurements. Measure the diameter at the base and top of the stump, along with the length of the stump. Tree density obtained from the bole measurements can be used to estimate the density of the stump.

h. Branches from 10-20 cm in diameter.

vii. Use the diameter fork to select branches that have a diameter from 10 to 20 cm.

viii. Use a chainsaw or hand saw to cut the branches and place them in a pile on the large plastic tarp
ix. Weigh the branches.
    i. Take a ~2 m x 2 m piece of plastic and weigh only the plastic. Record this weight
    j. Branches can be then placed on plastic and weighed.
    k. Alternatively, some branches can be weighed directly on scale.
x. Record the weights of all branches on the data sheet, noting if branches weighed on plastic or if were weighed directly.
xi. Take 5 sub-samples:
    l. Each subsample should weigh about 200-500 g. Each subsample should be made up of a mix of the sizes of branches found.
    m. Weigh the subsample bag empty. Record weight.
    n. Weigh the subsample bag with the subsample inside. Record weight.
    o. Label the subsample bag with the tree name, tree identification number, subsample identification number, and total weight of subsample and subsample bag.
    p. Take subsample bag and subsample from field. Until samples are taken to the laboratory, place samples in location that allows air drying to occur. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of all branches 10-20 cm in diameter.

i. Leaves and branches < 10 cm in diameter:

vi. Lay a large plastic tarp on the ground. Collect all the branches with a diameter <10 cm and all leaves. Note: the leaves **do not** need to be removed from the branches. Place vegetation on plastic tarp.
vii. Take a ~2 m x 2 m piece of plastic and weigh only the plastic. Record this weight
viii. Put a pile of the small branches and leaves onto the plastic and weigh. Record weight
ix. Repeat until all small branches and leaves have been weighed
x. Take 5 sub-samples:
    f. Each subsample should weigh about 200-500 g. Each subsample should be made up of a mix of the sizes of branches and leaves.
    g. Weigh the subsample bag empty. Record weight.
    h. Weigh the subsample bag with the subsample inside. Record weight.
    i. Label the subsample bag with the tree name, tree identification number, subsample identification number, and weight of subsample
    j. Take subsample bag and subsample from field. Until samples are taken to the laboratory, place samples in location that allows air drying to occur. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the dry weight of all the leaves and branches <10 cm in diameter.

ESTIMATION OF CARBON STOCK DAMAGE FROM SELECTIVE LOGGING SOPS

Selective logging is the harvesting of a portion of the trees in a stand or forest. When specific trees are cut, there will usually be additional damage to the forest area resulting in a change in various carbon pools. This includes damage and/or death of other trees and other vegetation types and the creation of new trails, roads, and logging decks. Following selective logging, the annual biomass accumulation rate in the remaining forest may also be affected.

The calculation of forest carbon stock damage from selective logging involves the use of two SOPs:

- SOP Carbon Stock Damage in Logging Gaps Due to Tree Felling
- SOP Area Damaged due to log extraction

By following this framework, emission factors can be created between the volume of timber extracted and the change in carbon pools. Once created, such emission factors can be used to estimate the change in carbon pools based on the volume of timber extracted and length of infrastructure constructed to allow extraction.

Field methods to estimate the long term impact of selective logging on tree biomass accumulation in the area directly impacted by the logging are included in the SOP:

- SOP Measurement of the Regrowth after Selective Logging

These field methods are designed to estimate carbon stock damage only under logging with specific criteria:

- Selective logging areas remain above the definition of a forest after logging has taken place. If logging is extensive and results in either areas that are heavily degraded or do not meet the country definition of a forest, this method is unlikely to produce reliable estimates.
- The tree top/crown remains in the forested area and is not removed
- The logging practice does not pile and/or burn logging slashes.

Prior to data collection, the sampling design strategy and the area where sampling will take place must be determined. This sampling design must include steps for identifying which roads, skid trails, and tree felling areas will be measured. This SOP must be altered to describe the sampling design approach and rules.

Where selective logging takes place within known and delineated areas (such as logging blocks), sampling can take place within randomly or systematically chosen sub-areas of the selective logging area (population of interest). Within the population of interest, sampled trees maybe selected using a random or systematic with random start approach (for example: 'every 3rd logging gap will be measured').

It is highly recommended that data collection take place immediately after felling timber-tree, prior to substantial regrowth of vines and non-woody vegetation that may obscure damaged trees and trails. In many moist-wet tropical areas, such sampling is recommended to occur within three months of tree felling.

It is also recommended to have the field crew include individual(s) that participated in the selective logging operations that took place or who are familiar with the logging and management practices of the selectively logged area. Such an individual may serve either as a guide or as a field crew member.

This method is dependent on being able to accurately estimate the DBH of the tree, and the volume of log removed from each individual timber tree cut. Volume is estimated by measurement of the diameters of the timber tree and the length of the timber removed. Therefore, the measurement of DBH, diameters, and length of the log should be directly measured prior to removal of the log from the site. If necessary, the measurement of DBH and log length and the other measurements can take place at different times.

The sampling design developed must include what procedures to follow in instances when the actual log has been removed or moved prior to field measurements taking place. This will require methods to estimate the volume of the log removed. If the crown of the timber-tree has also been moved by equipment, or it has slid/fallen down a slope, it may be impossible to estimate the length of the log. It is allowable for the sampling design rules to indicate that no measurements shall take place in logging gaps where the log has been removed and/or when the crown of the tree has been moved.

The methods provided can also be used to estimate the volume of potentially merchantable timber that is not currently removed for timber (e.g "avoidable wood waste"). If this estimate is desired, the minimum size diameter accepted by the sawmill must be known prior to field data collection.

SOP CARBON STOCK DAMAGE IN LOGGING GAPS DUE TO TREE FELLING

Field Equipment:

Flagging
Machete or knife
GPS receiver
DBH tapes
Measuring tape
Saw or blade to cut wood discs and branches
50 kg scale
Clippers to remove vegetation
~5 kg Hanging scale (will be dependent on expected weight of vegetation)
300 g Hanging scale (for subsamples)
Durable plastic sheeting
Durable plastic tarp
Paper or cloth sampling bags
Permanent marking pen
Compass
Analog watch (e.g. one with hands)
Calibration weights (see below)

Laboratory Equipment:

Drying oven
Laboratory scale

This SOP describes methods for estimating the biomass of the timber tree(s) felled and the biomass of any other trees that are killed or damaged when the timber tree is felled. The concept underlying these methods is based on the “Gain-Loss” method described by the IPCC (2006). The measurements taken within this SOP can be used to create a relationship between the volume of timber removed and the reduction in live tree biomass from such logging activities. This relationship can then be used to estimate the change in live tree biomass in logging gaps from measurements of timber volume extracted.

The sampling design must include steps for determining which felled tree spots will be measured. Under selective logging, the cutting of one or more trees for timber at a given spot is here referred to as a ‘logging gap’. The portion of the timber-tree extracted out of the forest for commercial use and/or processing is referred to as the ‘log’. This SOP must be altered to describe the specific rules that will be followed.

Estimating carbon emissions due to selective logging practices consists of an investigative activity, where field technicians must take accurate measurements. Amongst the measurements taken in the field, **DBH** and the **volume of timber removed** are especially **important**. These measurements must be accurate and reflect the real conditions in the field (see figure below).

The measurement of DBH and the field measurements to estimate volume of the timber log should be taken directly prior to the removal of the log(s) from the site. This requires that the log must have been cut and not removed when field measurements occur. Therefore, interactions between the logging activity and field measurements must be well coordinated. When necessary, the measurement of tree DBH and of the log, and the other measurements of damage presented below can take place at different times. When this occurs, the stump of each logged tree measured must be tagged and extreme care must be taken to ensure that the correct log measurements are matched with the respective felled timber-tree damage measurements. If the log has been removed and no measurements of DBH and log length have been taken, alternative measurements are presented below to estimate these attributes. However, this is strongly discouraged as it may increase uncertainties.

Prior to Field Sampling

1. **Establish sampling design:** Prior to field sampling, the sampling design must be established. This should include the area where sampling will occur and steps for choosing which logging gaps to measure.
2. **Establish arrangements with logging operators:** Since some field measurements must take place prior to the removal of the log itself, all activities must be coordinated between those responsible for the logging and those taking field measurements to ensure safety.
3. **Identify timber volume estimation methods:** In locations where the volume of timber extracted is well inventoried, identify the field methods used to estimate timber volume. These measurement methods shall be repeated in the field. This SOP shall be altered to include these measurement steps.
4. **Create 'calibration weights' to calibrate hanging scales:** Prior to going into the field, the scales that will be used to weigh samples must be calibrated. The ideal approach is to calibrate the scales that will be used in the field with the laboratory scale that will be used to measure the dry weight of subsamples.
    a. Ensure the laboratory scales are calibrated
    b. Large hanging scale (50 kg):
        i. Find an item that weighs about 10-30 kg and does not change weight when wet (e.g. metal of some sort) or over time. Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
        ii. Calibrate hanging field scale using this 'calibration weight' item. Do this every day prior to weighing tree-parts in field. This can take place at a base camp and therefore does not have to take place at the site of sampling. Ideally the item used to calibrate the scale should be a piece of field or base-camp equipment of an appropriate constant weight.
    c. Medium hanging scale (5 kg):
        i. Find an item that weighs about 3 kg and does not change weight when wet (metal of some sort). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
        ii. Calibrate hanging field scale using this 'calibration weight' item. This can take place at a base camp and therefore does not have to take place at the site of sampling. Do this every day prior to weighing items in field.
    d. Small hanging scale (~300 g):
        i. Find an item that weighs 100-250 g and does not change weight when wet (metal of some sort, stack of coins taped together). Weigh this item using the laboratory scale 5 times. Record weights and take average weight.
        ii. Calibrate hanging field scale using this 'calibration weight' item a. This can take place at a base camp and therefore does not have to take place at the site of sampling. Do this every day prior to weighing items in field.

Establishing Logging Gap to be measured:

1. Once the logging gap has been identified, walk around the area to determine how many felled timber trees are located within the specific logging gap. The felled timber trees and all killed and/or damaged trees caused by tree felling will be measured as one logging gap plot. Measurements must be taken for each felled timber tree.
2. Where the log has been removed prior to data collection (if allowed in sampling design):
    a. Locate the stump and crown of each felled tree. Be sure to verify that the crown is from the selected stump by determining the angle of the tree fall, species and reasonable distance from stump.
    b. Determine if it appears whether one or more of the timber-tree crowns have moved from the point of felling. This would include being moved by a piece of equipment or simply through sliding down a steep slope. Under some conditions is possible to determine the original location of the crown even after it has been moved. For example, a long line of sawdust. If it is suspected one or more crowns have moved, follow the sampling design rules. These rules may indicate that the particular logging gap should not be measured.

   c. Depending on the sampling design rules, if the crown of one felled tree has been moved or cannot be located, the entire logging gap shall not be measured.
3. At one of the timber-tree stumps within the logging gap, mark a 'waypoint' on GPS and record GPS coordinates, accuracy, elevation, and waypoint number on data sheet. To record a GPS location, place the GPS at the location and let it record for > 5 minutes prior to marking a 'waypoint'. The minimum precision level should be ±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 is the final location of waypoint. 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. For more information, see SOPs on the use of GPS and the manual of the GPS being used[5].
4. Label the plot based on SOP Labeling Plots. All felled timber-trees and incidental damage within one logging gap should be labeled under the same plot.
5. Label each timber-tree within the plot. If measurements of the timber log and other field measurements are taken separately, then the stump of each timber tree must be tagged.
6. 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, rocky outcroppings, and the existence of steep slope.

Measurements on Felled Tree(s) to Estimate Tree Biomass and Volume of Timber:

1. These measurements must be taken for each felled timber-tree in the logging gap.
2. All measurements should be measured to the nearest 0.1 cm
3. Locate stump and crown of the logged tree. Identify all sections of the log that will be extracted and of the timber tree bole and buttress that are not part of the log to be extracted and will remain in the forest.
4. Record tree species
5. Measure timber-tree DBH (and/or other tree attributes used in tree allometric equation to estimate biomass, e.g. height)
   a. If log is still present and the stump is tall enough, measure DBH directly according to SOP Measurement of Trees (including rules for the measurement of DBH on buttressed trees).
   b. If log is still present and the stump is too short to measure DBH on the stump, follow SOP Measurement of Trees, to attempt to determine the location of DBH prior to the felling of the tree. This may include measuring the height of the stump and section(s) of bole until 1.3 m is reached. For example, if the stump height (H_{stump}) is 0.850 m and the first bole section is 2.3 meters, measure the diameter of the bole section at 0.450 m (0.850 m + 0.450 m = 1.3 m).
   c. If the log has been extracted and DBH would have been located on the log, the data sheet should indicate that no DBH measurement could be taken.
6. If the tree is buttressed, measure the height where the buttress ends ($H_{Buttress}$) and the diameter of the bole directly above the buttress ($d_{buttress}$).
7. Measurements on the stump of the tree:
   a. Measure the height of the remaining stump (H_{Stump}).
   b. Measure the diameter at the top of the stump (d_S).
      i. If the tree is not buttressed at the top of the stump, measure the diameter of the stump as a tree (wrapping the tape around the stump) (see SOP Measurement of Trees).
      ii. If the tree is buttressed at the top of the stump, measure the diameter of buttressed stump using a compass and watch and taking three measurements total: 12 to 6, 2 to 8, 4 to 10, where 12 o'clock always points due north when diameter

[5] 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 for more information)

measurement is horizontal. Record all three measurements on the datasheet. During data analysis, the average of these three measurements will be the diameter of the top of the stump (d_S)

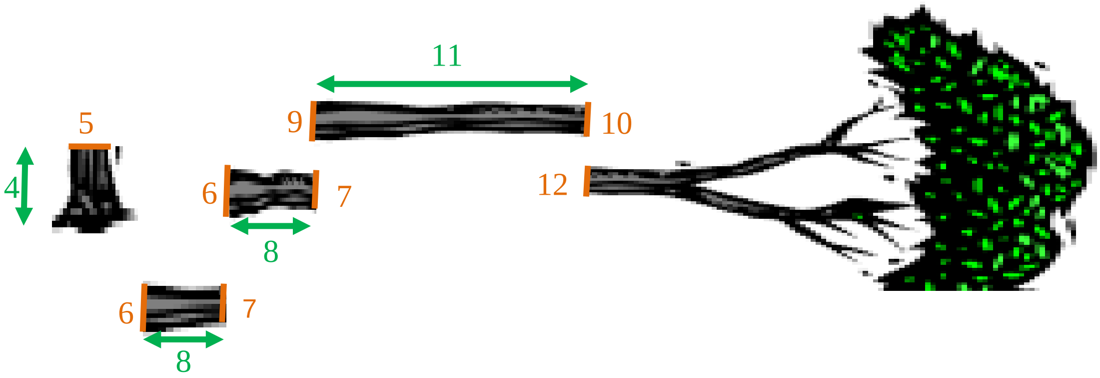
8. Measurements on buttress and bole sections remaining in forest:
    a. For each section of the buttress and/or bole of the tree cut and left in the forest (i.e. will not be removed for timber), take measurements to estimate the volume. Measure the length ($l_{Piece,n}$) and the diameter at the bottom ($d_{Piece\text{-}B,n}$) and top of the piece ($d_{Piece\text{-}T,n}$).
    b. If the piece is buttressed at the top or bottom, measure the buttress diameter using a watch and taking three measurements total: 12-to 6, 2 to 8, 4 to 10, where 12 o'clock always points due north when diameter measurement is horizontal, or upward to the sky when diameter is vertical (i.e. piece lying on the ground).
9. Measurements on log(s) that will be extracted for timber:

    The following measurements shall be taken to estimate the volume of timber that will be removed from the forest. If the bole of timber-tree has been cut into more than one piece, take measurements on each piece so that the volume of each log can be calculated.
    a. Measure the diameter at the base ($d_{log\text{-}B}$) and top ($d_{log\text{-}T}$) of log.
    b. Measure the length of log (l_{Log}). The length of the log is the length that will be extracted for timber.
        i. If the log is still present, take measurements on the log itself directly.
        ii. If log has not yet been removed and the bottom and top cuts of the log have not yet been made, the field crew must assess location where bole will be cut at the bottom (if lower portion of bole will not be taken as a log) and at the top (at the base of the crown), and then measure this distance, which represents the length of the log. Expert knowledge will be necessary to accurately ascertain the location these cuts – this should be attained by consulting with the chainsaw operator that will cut the bole into a log, or based on expert judgment of harvesting operations manager if available onsite.
        iii. If the log has already been extracted, the length of the log is the length between the top section of the piece remaining and the bottom of the crown left in the forest. If the entire bole is removed, the length of the log is the distance measured from the stump to the bottom of the crown of timber-tree left in the forest. If sections of the bole remain, rules must be delineated to state how this distance will be estimated. The most accurate procedure will be somewhat dependent on the logging practices. (For example, this distance can be estimated as the distance from the top of the stump to the bottom of the crown, minus the total length of each tree piece and buttress section left in the forest.)
10. Measurements on tree crown:

    Measure the diameter of the bole at the top cut (d_{Top}). Above this point is the remaining bole and crown that are not extracted from the forest.
11. Measurements on 'merchantable waste':

    It is also possible to estimate the volume of merchantable waste left in the forest. To do this, take measurements of each piece of bole and branch that meets the minimum diameter accepted by sawmills. Measure the diameter at the bottom ($d_{AMW\text{-}B,n}$) and top of each piece ($d_{AMW\text{-}T,n}$) along with the length of each piece ($l_{AMW,n}$). (Please note: these measurements are only used to estimate merchantable waste and therefore are not required to estimate the damage from logging.)
12. Logging practice timber volume measurements:

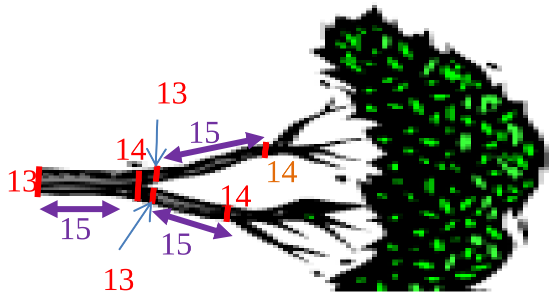
    Take all field measurements that are taken normally by timber crews to estimate the volume of timber extracted. This section of the SOP shall be altered to include information on how to collect this field data.



Where:

1. DBH (cm)
2. Height at top of buttress (cm)
3. Diameter directly above buttress ($d_{buttress}$)
4. Height of the stump (H_{Stump}) (m)
5. Diameter of the top of stump (D_{Stump}) (cm)
6. Diameter of the bottom of piece *n* ($d_{Piece-B}$) (cm) (only if exists)
7. Diameter of the top of piece *n* ($d_{Piece-T}$) (cm) (only if exists)
8. Length of piece *n* (l_{Piece}) (cm) (only if exists)
9. Diameter of bottom of timber bole (d_{Log-B}) (cm)
10. Diameter of top of timber bole (d_{Log-B}) (cm)
11. Length of the bole (l_{Log}) (m)
12. Diameter at the top cut (d_{Top}) (cm)

Figure: Measurements required in a logging plot. All heights and lengths should be measured in meters and all diameters in centimeters. All measurements should be measured to the nearest 0.1 cm (e.g. 13.242 m or 34.5 cm)



Where:

13. Diameter at the bottom of the avoidable merchantable waste piece *n* ($d_{AMW-B,n}$) (cm)
14. Diameter at the top of the avoidable merchantable waste piece *n* ($d_{AMW-T,n}$) (cm)
15. Length of avoidable merchantable waste piece *n* ($l_{AMW,n}$) (m)

Figure: Measurements required to estimate merchantable waste. All measurements should be measured to the nearest 0.1 cm (e.g. 13.242 m or 34.5 cm)

Incidental damage measurements:

When a timber-tree is felled, it incidentally damages the residual stand in two main ways: 1) by knocking down or breaking other trees and essentially killing them and 2) breaking off large branches of surviving trees. Measurements of incidental damage should be conducted as follow:

1. Walk along the area where the timber tree fell in a clockwise direction starting from the stump and walking around the entire crown, and identify all trees significantly damaged and branches broken off due to felling of the timber-tree.
2. For all trees (with DBH ≥10 cm) that have been either uprooted or the bole snapped off:

   a. Classify the tree as either:
      i. Uprooted, lying on ground (G)
      ii. Crown snapped off (S)

      Note: Bent or leaning trees are assumed to not be dead and will survive.
   b. Measure the DBH and note the species. If tree was snapped below 1.3m, either attempt to locate 1.3 m of the snapped tree or measure diameter at the highest point on the remaining trunk. Follow good practices outlined in 'SOP Measurements of Trees' for measuring DBH. Do not measure any pre-existing dead trees.
3. Measure the branches (base diameter of branch ≥10 cm) that have been snapped off living trees due to the felling the timber tree. Please note: It is very important that any branches on the forest floor be clearly identified as originating from a surviving tree and not from an already measured damaged tree or the timber tree to prevent double counting. Efforts must also be taken to ensure branches were snapped during tree fall and do not represent down dead wood predating the harvest. Such branches should be sound, and have evidence of being relatively recently fallen (e.g. presence of leaves, twigs, complete bark, etc.).
   Branches are measured using either of the following methods. The first method is preferred.
   a. Estimate weight of entire branch directly with proper scale, and take subsample to estimate dry weight:
      If branches can be weighed directly, measure the weight following the destructive sampling concept outlined in SOP for Destructive Sampling of Trees, Saplings, Palms and Bamboo. A brief description of the destructive sample methods are as follow:
      i. Weigh branch using calibrated hanging scale
      ii. Take a representative subsample and weigh. The subsample should weigh between 100-300 grams.
         1. Weigh the subsample bag empty. Record weight.
         2. Weigh the subsample bag with the subsample inside. Record weight.
         3. Label the subsample bag with the plot identification number, subsample identification number, and weight of subsample
         4. Take subsample bag and subsample from field. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the total dry weight of all non-woody vegetation in the clip plot.
   b. Estimate weight using volume and density:
      This method can be used where the branch is too large to weigh directly.
      i. Cut off end smaller branches that are small enough to weigh directly.
         1. Weigh branch using scale
         2. Take a representative subsample and weigh. The subsample should weigh between 100-300 grams.
            a. Weigh the subsample bag empty. Record weight.
            b. Weigh the subsample bag with the subsample inside. Record weight.
            c. Label the subsample bag with the plot identification number, subsample identification number, and weight of subsample
            d. Take subsample bag and subsample from field. Bring to laboratory and dry subsample. Reweigh subsample. This subsample will be used to create a wet-to-dry ratio. This ratio will then be used to estimate the total dry weight of all non-woody vegetation in the clip plot.
      ii. Estimate the volume of the portion of the branch too large to weigh.
         1. Measure the diameter at both ends of the branch
         2. Measure the length of the branch.
         3. These measurements will be used to calculate the volume.

$$Volume = \pi * \left[\frac{(d1 + d2)}{4}\right]^2 * length * \pi$$

         4. The volume of each branch will then be multiplied by a species specific wood density to estimate biomass.

SOP AREA DAMAGED DUE TO LOG EXTRACTION

Field Equipment:
GPS receiver
Laser Range Finder or Measuring tape

This SOP describes the methods used to estimate the area of land where carbon stocks are damaged due to the removal of logs from the forest, such as: skid trails, new haul roads, and logging decks. The methods will be more accurate when done soon after trees are harvested and removed from the forest area. This most often will be done in conjunction with 'SOP Carbon Stock Damage in Logging Gaps Due to Tree Felling'.

Definitions:

Skid trail: a temporary trail traveled by ground skidding equipment or manual clearing while moving logs to road or loading area. The machinery or manual clearing used to create the skid trail often will be able to push over and kill smaller trees but will have a maximum sized tree it is able to knock down. All larger trees will remain standing and the trail path will avoid such trees. The skid trails are not traveled by other vehicles, such as logging trucks.

Logging road: a temporary or more permanent road constructed to allow the transportation of logs to pre-existing roads. The logging road is used by trucks and other vehicles. Generally the path of the road is not altered to avoid trees. Instead, all trees and non-tree vegetation is cleared during the creation of the road.

Logging deck: an area cleared of all trees and non-tree vegetation, or in some cases cleared of brush and smaller trees only. This is the centralized area where logs are gathered, delimbed and cut to length if necessary, and loaded onto log trucks for transport.

Prior to Field Sampling

Prior to field sampling, the sampling design will need to be determined. This will include steps to identify which skid trails, roads, and logging decks will be measured and the distance between such measurements. The area where sampling will take place must also be clearly delineated within GIS and known by field crews. Extreme care must be taken to ensure all skid trails, roads, and logging decks area measured within the delineated sampling area. It is allowable to sample skid trails only within a known and GIS delineated sub-set of the total sampling area.

Determine the logging management practices for the construction of skid trails, roads, and logging decks. Where possible, obtain all maps and GIS data available for the logging area. Clear rules will need to be developed to differentiate between a skid trail and a logging road for the sampling area.

Determine what types of equipment are used in the construction of skid trails and roads. Where different types of techniques and equipment are used to create skid trails, skid trails may need to be grouped into skid trail types/strata. Likewise, if different types of roads are created, roads may also need to be grouped into road types. If a consistent type of machinery is used to create the skid trails, the width of the skidder plow should be measured. In addition, a survey may be conducted to determine what the maximum size each type of skidder equipment is able to knock over. The logging management plan may also indicate the maximum size skidders are allowed to knock over.

This SOP must then be altered to describe the approach that will be used.

Field Measurements

Skid trails:

Option 1: Carbon damage related to area of skid trails created.

To be used in most situations. This method assumes the area of the skid trail is completely cleared of vegetation:

1. Estimate average width of skid trails: Using a random or systematic sampling approach, measure the width of selected skid trails at different points along the selected skid trail.

Figure: Skid trail in Guyana. Skid trail is completely cleared of vegetation so Option 1 should be used for field measurements.

Option 2: Carbon damage estimated through measuring biomass of trees killed during skid trail creation

This method can only be used in areas where skid trails are narrow paths into the forest with live vegetation on the floor of the skid trail.

1. Estimate average biomass of trees killed by skid trail within certain length:
    a. Use a random or systematic sampling approach to select which skid trail to measure and where along the skid trail measurements should be taken.
    b. At first sampling point, using a measuring tape, lay out a 100 m transect following the skid trail.
    c. Measure the DBH and species of all trees clearly damaged (snapped or uprooted) due to skid trails construction along the 100 m of the skid trail.
    d. Repeat at next sampling point.
2. Estimate length of skid trails: Using the tracking feature of the GPS, track entire length of skid trails within the entire sampling area. It is important to ensure all skid trails within a given delineated area have been measured. Often it will assist measurements to indicate that a trail has been measured (e.g. mark skid trail entrance with spray-paint, chalk or flagging tape).
3. The total area of skid trails sampled can then be estimated by multiplying the average skid trail width by the total length of skid trails within the sampling area.
4. The calculation methods and rules will determine how carbon stock damage due to skid trails is estimated.

Figure: Skid trail in Brazil. Skid trail is narrow and contains live vegetation so Option 2 should be used for field measurements.

Logging decks:

Care must be taken to ensure *all* logging decks within the sampled area are measured.

Option 1a or 1b will be used in most situations. This method assumes the area of the logging deck is completely cleared of vegetation:

Option 1a: Direct area measurement

Measure the area of the logging deck by breaking the area down into simple geometric and non-overlapping shapes. Shapes must be either: oval, circle, rectangle or square. They cannot be complex shapes. Draw shapes onto data sheet. Measure and record the length and width of each shape with either the Range Finder or the tape measure. **Remember** – to measure the area of an oval, one must measure diameter of major axis *and* minor axis

Option 1b: Area measurement using GPS

Turn on polygon feature of GPS and walk around the edge of the entire logging deck. Choose close polygon option after returning to starting point and save polygon in GPS accordingly. The area of each logging deck will be measured within GIS.

Option 2: Carbon damage estimated through measuring biomass of trees killed during logging deck creation

This method can only be used in areas where logging decks are cleared areas that still have multiple trees standing within them.

1. Within the deck, measure the DBH and species of all the trees that were clearly damaged during the clearing of the deck (snapped or uprooted).
2. Estimate the biomass of the damaged trees using an appropriate allometric equation and sum the biomass of all the trees to determine the total impact.

Figure: Logging deck in Guyana. The deck is completely cleared of vegetation so either option 1a or 1b should be used for field measurements.

Figure: Logging deck in Colombia. The deck contains many trees and so should use option 2 for field measurements.

Logging Roads

1. Estimate average width of logging roads: Using a predetermined random or systematic sampling approach, measure the width of selected roads at different points along the selected road.
2. Estimate length of all logging roads: Using the tracking feature of the GPS, track entire length of roads within the entire sampling area. It is important to ensure all roads within a given delineated area have been measured. Alternatively, where the resolution is sufficient and cloud-cover is low, remote sensing imagery may be used to delineate length of roads.
3. Collect GPS waypoints at beginning and end of each road

Figure: Logging road in Republic of Congo

SOP MEASUREMENT OF THE REGROWTH AFTER SELECTIVE LOGGING

Field Equipment:
Flagging tape
GPS receiver
Clinometer (to measure slope)
Measuring tape
Machete or knife
Data sheets and pencils
Permanent marking pen

For plot establishment:
Right Angle
Measuring tape
Rope
Stakes
Hammer

For measuring trees (see SOP Tree Measurement)
Tree name list
Diameter tapes
Tree poles: Small-diameter PVC piping cut the exact length of diameter measurements (eg 1.3 m if DBH will be measured)
Chalk sticks
Clinometer

This SOP provides an innovative approach to estimating growth (ingrowth and regrowth) induced as a result of canopy opening due to selective logging. These measurements are conducted in a "Regrowth Plot".

This SOP provides an approach to estimating growth induced as a result of canopy opening due to selective logging. The selective logging of trees can result in "anthropogenic induced" growth in trees affected by the removal of the timber tree. This is because by felling a tree, the competition for resources amongst other trees is reduced. These resources include, but are not limited to light, water, nutrients, etc.

The approach is based on establishing a chronosequence of logging gaps for biomass sampling that are established in the same stratum (based on logging practice and extraction rate) at various points in time in the past. The change in biomass over the several years sampled will indicate the rate of growth (ingrowth and regrowth) of the regenerating forest.

To ensure that a standard approach is used for each regrowth plot, the method is designed to accommodate plots with one felled tree only. It is possible that the logging gaps could be stratified by the number of trees in the gap, and if such occurrence is common then the gaps need to be stratified. However, if the occurrence of such gaps is low (<10% of all gaps), this is not cost effective. Also it is likely that gaps created by two to three felled trees could have faster rates of regrowth as the gaps would be larger, thus by not including these gaps the regrowth rates obtained could be underestimate—this would result in net emission from logging to be higher and thus producing a conservative result.

This SOP requires documentation on the year(s) logging took place within the sampling area. Logging gaps formed across a sequence of ages will be used to estimate the change in biomass over time. Prior to field sampling, a sampling design will need to be created. This sampling design will include steps to determine what logging areas will be sampled, the dimensions of the 'regrowth plot', the number of logging gaps required, and within each logging area, which logging gaps will be measured. The length and width of the logging plot shall be based on the common total length of the felled trees (determined from results of the field data from the logging gaps; SOP Carbon stock in logging gaps due to tree felling). The SOP Measurement of Trees shall be used to measure trees within sampling plots.

The following methods for plot selection and establishment shall be applied:

Field measurements

1. Identify a logging gap based on sampling design—it is important that the gap be based on a clearly identifiable stump of a felled tree
    a. Make sure the plot does not overlap a road or logging deck
    b. If the plot dimensions overlap a skid trail, this plot shall be excluded
2. Temporary rectangular plots will be established.
   Establish a rectangular biomass plot covering the entire area of the gap opening and a portion of the shaded area immediately adjacent to opening. Based on previous field assessments, rectangular plots 8m wide and the length determined from the field data from logging gaps (SOP Carbon stock in logging gaps due to tree felling) are generally adequate. If plot size is changed for any reason, it is important that plot size be recorded for calculation of the scaling factor to be used in analysis.
    a. Plot shape:
        i. The long sides of rectangle shall be parallel to the direction the tree fell (see Figure below; in this example the common length of felled trees was 40 m)).
        ii. The stump of the felled tree must be 2 meters inside of the plot on the short side of the rectangle. The center of the circumference of the stump shall be 4 meters away from either edge of the plot defining the long side of the rectangle.
        iii. A sapling plot shall also be placed within the regrowth plot. This plot will be placed two meter from the front of the stump, in line perpendicular to the short side of the rectangle. At 2 meters in front of the stump, a rectangular plot of 2m x 2m will be placed. The same definition of sapling as presented in 'SOP Measurement of Trees' shall be used.

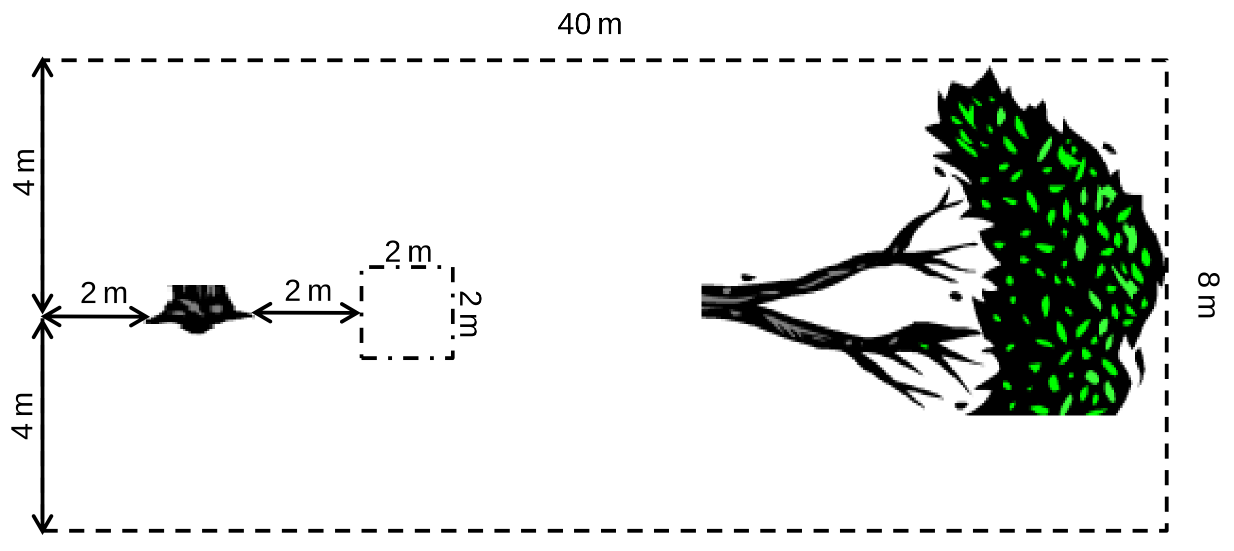


Figure Diagram of regrowth plot establishment

3. At the stump of the felled tree, mark a 'waypoint' on GPS and record GPS coordinates, accuracy, elevation, and waypoint number on data sheet. To record a GPS location, place the GPS at the plot center/corner and let it record for > 5 minutes prior to marking a 'waypoint'. The minimum precision level should be ±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 accurate 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[6] .

4. Label the plot based on SOP Labeling Plots
5. If the slope is greater than 10%, measure and record the exact slope using a clinometer. See SOP Use of a clinometer. The person using the clinometer first identifies the eye-level sight in a partner of approximately the same height. This person should stand at one end of the plot and the partner should go to the other end of the plot. The person with the clinometer shall then aim at the eye-level location in the partner and record the angle reading displayed in the clinometer. This angle is the slope angle and could be recorded as degrees (unit should be delineated in field sheets).
6. 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.
7. Measure all trees inside the rectangular plot with DBH>5 cm following the methods outlined in SOP Measurement of Trees. Trees do not need to be tagged.

[6] 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 for more information)

VARIOUS CANOPY COVER STUDY-SPECIFIC SOPS

The following SOPs are only to be used for specific and known purposes. These SOPs have been developed by Winrock for specific studies estimating canopy cover. These SOPs only should be implemented with known purpose and study developed.

SOP Measurement of Canopy Cover

SOP Area of Canopy Opening

SOP Crown Area from the Ground

SOP MEASUREMENT OF CANOPY COVER

Field equipment
Densitometer (e.g. GRS Densitometer, http://grsgis.com/densitometer/index.htm)
Measuring tape
Rope

To measure canopy cover, measurements of presence or absence of canopy cover will be made at different points within a square sampling plot. These sampling plots do not need to be located in association with tree plot measurements. The location of each sampling location must be determined prior to entering the field.

1. Navigate to sampling location using a GPS.
2. Walk an additional 10 steps in the direction of travel. This will be the first sampling point.
3. Starting at this point, determine a random compass bearing. This can be done using various methods such as using a random number table. Another method is to use a watch that has a second hand. At a random moment one individual can look at his/her watch and then the direction the second hand is facing will be used as the compass bearing.
4. Using this compass bearing, lay out a 15 m transect.
5. A measurement of the presence/absence of canopy will be made every 3 m along this transect.
6. Starting at 0 cm, use the Densitometer to determine the presence/absence of vegetation.

   Looking through the densitometer you can see two spirit levels. When both are centered you are looking directly overhead. In the center of the field of vision there is a small circle. If you can see vegetation (leaves, branches, twigs, etc), mark the data sheet to indicate the presence of canopy cover.
7. Move forward 3 m and repeat until reaching 15 m (6 recordings)
8. Move tape measure 3 m to your right and repeat measurements along transect. Move tape measure 4 more times until 6 transects have been completed. A total of 36 presence/absence measurements should be taken at each sampling location.

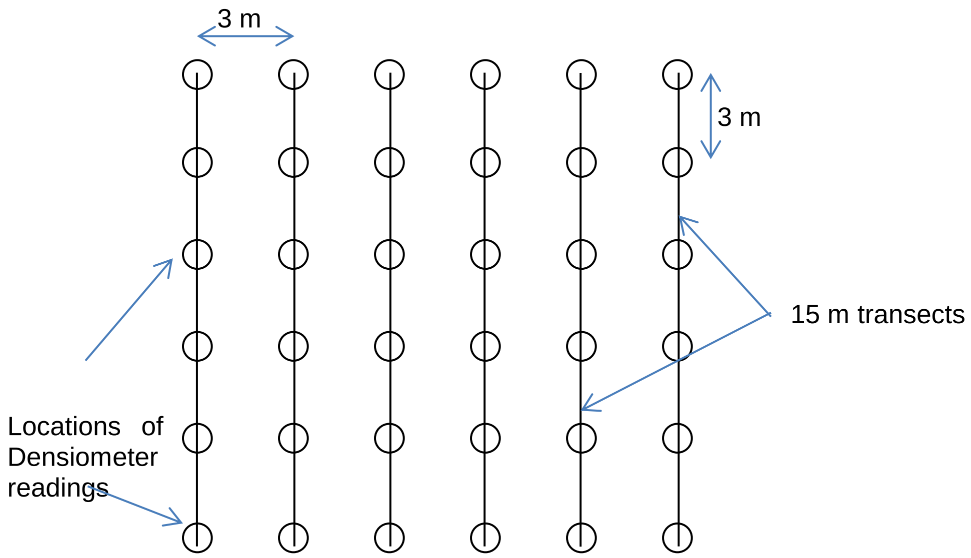


Figure 3 Layout of transects and location of densiometer readings along transects (lines indicate transects and circles represent densitometer reading locations)

SOP AREA OF CANOPY OPENING

Field Equipment:
Laser Range Finder or 50 m tape

This SOP is used to estimate the area of canopy opening created when a logging tree(s) are selectively logged in a forest.

This SOP must be done in conjunction with 'SOP Framework for Estimation of Carbon Stock Damage from Selective Logging' and 'SOP Carbon Stock Damage in Logging Gaps Due to Tree Felling'. See the logging gap SOP for information on locating and establishing the logging gap.

1. Once the logging gap has been identified, walk around the area to determine how many felled timber trees are located within the specific logging gap. The felled timber trees and all killed and/or damaged trees caused by tree felling will be measured as one logging gap plot. Measurements must be taken for each felled timber tree.
2. Locate the stump and crown of each felled tree. Be sure to verify that the crown is from the selected stump by determining the angle of the tree fall, species and distance from stump.
3. Walk around the entire gap, locating every section of canopy gap formed. Mentally divide the gap into different *non-overlapping* ovals or rectangles. Shapes must either be either: oval, circle, rectangle or square. They cannot be complex shapes unless detailed angles are taken). Draw shapes onto data sheet.
4. Measure and record the length and width of each shape with either the Range Finder or the tape measure. **Remember** – to measure the area of an oval one must measure diameter of major axis *and* minor axis.

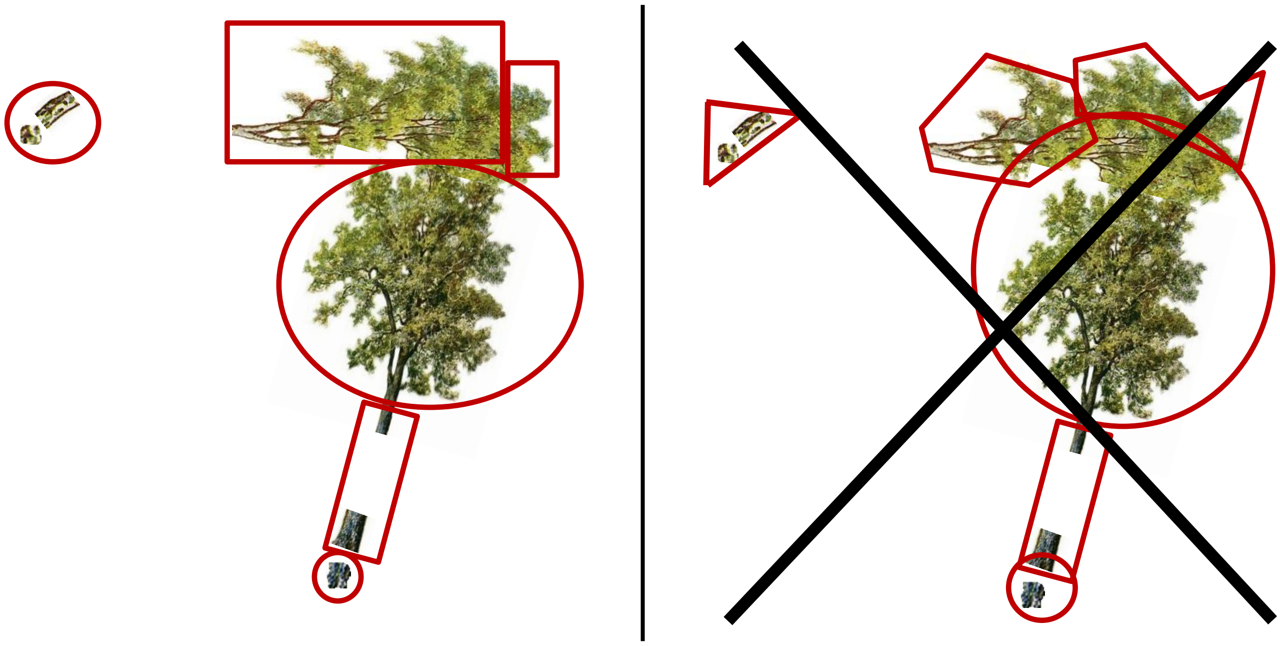


Figure: Division of logging gap canopy opening. Proper measurement on left, incorrect measurement on right

SOP TREE CROWN AREA FROM THE GROUND

Field Equipment:
Clinometer
Laser Range Finder

This SOP is used to estimate the crown area of a tree. These measurements are used for specific purposes including formulating relationships between tree biomass and crown area for use in aerial imagery analysis. The purpose of the field measurements must be clearly delineated and a sampling design created prior to implementation of this SOP. The sampling design must include steps for determining which trees will be measured.

1. For each tree to be measured, measure the DBH and species of tree using the procedures in SOP Measurement of Trees.
2. At each tree to be measured a total of four measurements of the angle and distance to canopy should be taken.
    a. For each cardinal direction stand with your back to the tree trunk. If clearer sight of the first branch with leaves is not aligned with a cardinal direction, be sure the subsequent three sides are perpendicular to each other. Using the clinometer, estimate the angle in degrees to the first branch with leaves ($\angle_1$).
    b. Use the range finder, measure the distance from the eye of the person measuring the trunk to the branch (d_1) in meters. Be certain that the distance measured is horizontal and not along a slope.
3. To calculate the area of the canopy from the measurements:

$$Canopy\ Area = \left(\frac{\left(\left(\cos\left(\frac{\angle_1 * \pi}{180}\right) * d_1\right) + \left(\cos\left(\frac{\angle_3 * \pi}{180}\right) * d_3\right) + \left(\frac{dbh}{100}\right)\right)}{2}\right) * \left(\frac{\left(\left(\cos\left(\frac{\angle_2 * \pi}{180}\right) * d_2\right) + \left(\cos\left(\frac{\angle_4 * \pi}{180}\right) * d_4\right) + \left(\frac{dbh}{100}\right)\right)}{2}\right)$$

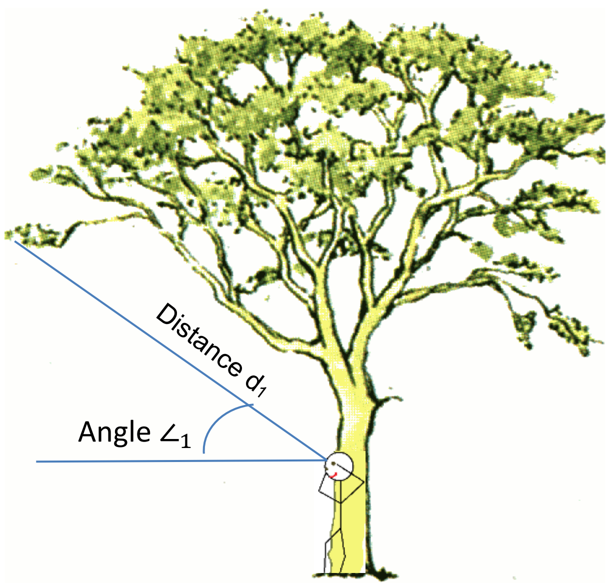


Figure: Example of angle measurement with clinometer and distance measurement with laser range finder

APPENDIX I: GUIDANCE ON ALLOMETRIC EQUATION DEVELOPMENT

APPENDIX II: EXAMPLE DATASHEETS

1. Nested Tree plot Radius Correction Table
2. Carbon stock measurements
   Includes: trees, saplings, standing dead wood, lying dead wood, non-tree vegetation, litter, and soil
3. Dead wood density datasheet
4. Sapling weight datasheet
5. Destructive sampling datasheet
6. Logging plot datasheets
7. Canopy cover datasheet

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

LIVE BIOMASS AND SOIL MEASUREMENT AND SAMPLING DATA SHEET

Plot ID #:_____________ Location:_______________ Land cover type:________________ Crew chief:____________ Data recorded by:_________ # people in crew: __________
Date:__________/_________/_________Start Time:__________________ End time:___________________ Total Time: ______________________
GPS Datum: __________GPS Waypoint:______ Lat:_______________ Long:______________ Precision: _________ Elevation: ________
Slope (%): _____________ Photo Number(s):_________________
Notes:

Saplings:
# of Saplings: ___________ Sapling Plot dimensions (m): ___________
LIVE TREE MEASUREMENTS.

TREES

Nested Plot radius (m): small:__________ medium:_________ large:_________

Nested plot tree diameter sizes (cm): small:____________ medium:____________ large:_____________

Tree #	Species	DBH (cm)	Tree #	Species	DBH (cm)	Tree #	Species	DBH (cm)

PALMS, Tree Ferns, Bamboo

Palm Plot Radius (m):_____________

Tree Fern Plot Radius (m):_____________

Bamboo Plot Radius (m):_____________

Tree #	Species	Height (m)	Clinometer angle +	-	Eye to tree (m)	Equipment Used

Plot ID #:_____________

CLASS 2 STANDING DEAD WOOD MEASUREMENTS:

Diam at base (at 0.1 m) (cm)	DBH (at 1.3 m) (cm)	Diameter at top (cm) (if measured directly)	Height (m) (if measured directly)	Height Measurement 1				Height Measurement 2			
				Clinometer angle (%) +	Clinometer angle (%) -	Distance from eye to tree (m)	Height of eye (m)	Clinometer angle (%) +	Clinometer angle (%) -	Distance from eye to tree (m)	Height of eye (m)

SOIL

Soil C
Sample ID # _____________
Sample method: ____________
Sample volume (cm^3): ______
Sample depth (cm): _______

Bulk density
Sample ID# ________
Sample method: ____________
Sample volume (cm^3): ______
Sample depth (cm): _______

Sample ID# ________
Sample method: ____________
Sample volume (cm^3): ______
Sample depth (cm): _______

NON-TREE WOODY VEGETATION (CLIP PLOTS)

Clip-plot dimensions: _________ (if clustered tree plots, only 1 measurement per plot)

Weight of bag or sheet (g)	Weight of bag + material (g)	Clip-plots subsample ID #	Weight of subsample bag (g)	Weight of subsample bag + subsample material (g)

LITTER CLIP PLOTS

Clip-plot dimensions: _________ (if clustered tree plots, only 1 measurement per plot)

Weight of bag or sheet (g)	Weight of bag + material (g)	Clip-plots subsample ID #	Weight of subsample bag (g)	Weight of subsample bag + subsample material (g)

LYING DEADWOOD MEASUREMENTS:

(wood greater than 10 cm diameter) Transect length (m) = _____

Diam (cm)	Density Class (S,I,R) S=Solid, I=Intermediate, R=Rotten	Hollow diam (cm)

DEAD WOOD DENSITY DATA SHEET

Stratum: ___________ Location:______________________

Date: ______/______/______ Data recorded by:______________

Notes:

A minimum of 10 samples should be collected for each density class at the beginning of the field sampling effort. Diameter and width should be recorded for each sample. Empty bag weight should be recorded.

Photo #	Dead Wood ID	Wood Density Class: S, I, R*	Diameter2 (cm)	Diameter2 (cm)	Width1 (cm)	Width2 (cm)	Volume (cm^3)	Bag weight (g)

* S = sound, I = intermediate, R = rotten

DATA SHEET FOR SAPLINGS

Stratum:__________ Location:_____________________

Date:__________ Data recorded by:________________

Notes:

At least 30 saplings must be cut and weighed.

Plot ID	Sapling ID	Total Wet Weight (g)	Weight of empty subsample bag (g)	Subsample Wet Weight + Bag (g)

DESTRUCTIVE SAMPLING DATA SHEET

Plot ID:____________Location:_______________GPS Lat:__________ Long:________________
Date:____________ Team Leader:_________________Timestart:____________Time end:_____________
Tree ID: ______________Stratum:___________________ Photo ID: _________________________

(ADD ADDITIONAL NOTES TO BACK OF LAST PAGE OF DATA SHEET)

MEASUREMENTS BEFORE TREE CUT

Species: ___________________
DBH: ________________ cm
Tree Height:

Height Measurement 1				Height Measurement 2			
Clinometer angle (%) +	-	Distance from eye to tree (m)	Height of eye (m)	Clinometer angle (%) +	-	Distance from eye to tree (m)	Height of eye (m)

*Enter in degrees (º) when percentage is greater than 90%.

MEASUREMENTS AFTER TREE CUT

Bole measurements

Diameter at bottom of bole: ________cm
Diameter at top of bole: ________cm
DBH of bole: ________cm
Length of bole: ________cm
Length of tree: ________m

Starting at the bottom of the bole, divide the bole into 2-m sections and list the dimensions of each section below:

Section #	Lower diameter (cm)	Upper diameter (cm)	Length of section (cm)	Section #	Lower diameter (cm)	Upper diameter (cm)	Length of section (cm)

For density determination:

Subsample disc 1
Label: ___________
L1: _________ cm
L2: _________ cm
T1: _________ cm
T2: _________ cm

Subsample disc 2
Label: _________
L1: _________ cm
L2: _________ cm
T1: _________ cm
T2: _________ cm

Subsample disc 3
Label: ___________
L1: _________ cm
L2: _________ cm
T1: _________ cm
T2: _________ cm

Stump measurements

- If entire stump is weighed:
  Total fresh weight: ______kg   Partial weights (kg): (write total at left)

Subsamples for determination of dry:wet ratio:

<u>Subsample 1</u>:
Bag Label: ____________
Fresh weight: ____________ kg

<u>Subsample 2</u>:
Bag Label: ____________
Fresh weight: __________ kg

- If stump is cut and part of it is estimated by volume rather than weighing the whole stump:
  Draw shape of cut stump to the right, note its dimensions and weigh the remaining pieces and report as fresh weight above.)

Dimensions of stump: Length 1: __________cm Width 1: ____________cm
Length 2: __________cm Width 2: ____________cm

Dimensions of cross section sample for determining density:
L1: __________ cm W1: _________ cm
L2: __________ cm W1: _________ cm

<u>Buttress Measurements</u>:

Total fresh weight: ________ kg   Partial weights: (write total at left)

Subsamples for determination of dry:wet ratio:

Subsample 1:
Bag Label: ____________
Fresh weight: ____________ kg

Subsample 2:
Bag Label: ____________
Fresh weight: __________ kg

<u>Tree Crown Measurements:</u>

Leaves and branches <10 cm:

Total fresh weight: ________ kg   Partial weights: (write total at left)

Subsamples for determination of dry:wet ratio:

Subsample #	Bag Label	Fresh Weight (kg)
1		
2		
3		
4		
5		

Branches 10-20 cm:

Total fresh weight: ________ kg   Partial weights: (write total at left)

Subsamples or determination of dry:wet ratio:

Subsample #	Bag Label	Weight (kg)
1		
2		

3
4
5

Branches >20 cm:

- If entire branch is weighed in pieces:

  Total fresh weight: _______ kg   Partial weights: (write total at left)

  Subsamples for determination of dry:wet ratio:

Subsample #	**Bag Label**	**Weight (kg)**
1		
2		
3		
4		
5		

- If volume is estimated instead of weight for branches >20 cm, then mentally divide the branch into sections and list the dimensions of each section below:

Branch #	**Section #**	**Bottom diameter (cm)**	**Top diameter (cm)**	**Length of section (cm)**

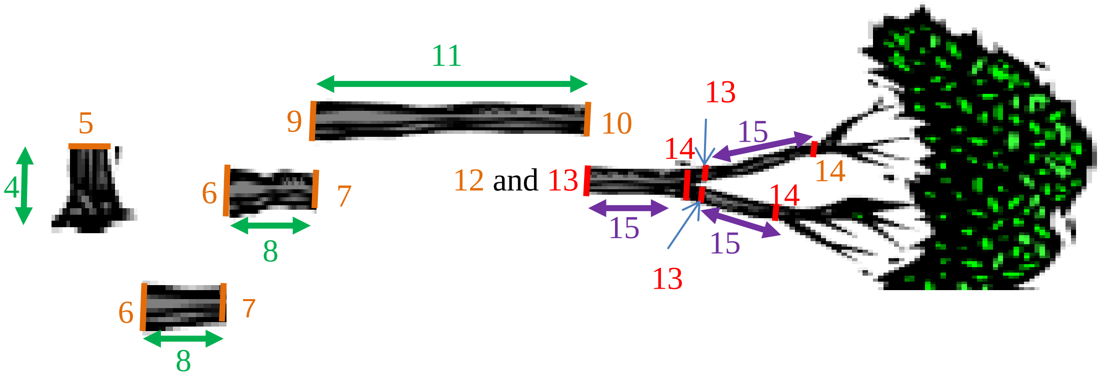
For density determination, cut 5 representative discs:

	Disc 1	**Disc 2**	**Disc 3**	**Disc 4**	**Disc 5**
Label					
L 1 (cm)					
L2 (cm)					
T1 (cm)					
T2 (cm)					

NOTES FOR DESTRUCTIVE SAMPLING MEASUREMENTS

LOGGING PLOT REFERENCE GUIDE

Measurements for timber tree:



Where:

1. DBH (cm)
2. Height at top of buttress (cm)
3. Diameter directly above buttress ($d_{buttress}$)
4. Height of the stump (H_{Stump}) (m)
5. Diameter of the top of stump (D_{Stump}) (cm)
6. Diameter of the bottom of piece *n* ($d_{Piece-B}$) (cm)
7. Diameter of the top of piece *n* ($d_{Piece-T}$) (cm)
8. Length of piece *n* (l_{Piece}) (cm)
9. Diameter of bottom of timber bole (d_{Log-B}) (cm)
10. Diameter of top of timber bole (d_{Log-T}) (cm)
11. Length of the bole (l_{Log}) (m)
12. Diameter at the top cut (d_{Top}) (cm)
13. Diameter at the bottom of the avoidable merchantable waste piece *n* ($d_{AMW-B,n}$) (cm)
14. Diameter at the top of the avoidable merchantable waste piece *n* ($d_{AMW-T,n}$) (cm)
15. Length of avoidable merchantable waste piece *n* ($l_{AMW,n}$) (m)

Classes of Damaged Trees:

Snapped (S):

Uprooted (U):

Branch fallen off (B):

TIMBER TREE MEASUREMENTS

Date:______________________________

Plot ID#:____________________ Location: ________________Coordinate System: __________

Crew chief: ___________________ Data recorded by: ________________# of people in crew: _____

Start Time: ___________________End Time: _________________________ Total Time: _____________minutes

Camera Number: ______________Photo Number(s):____________________

Forest Type: ______________________________

Additional notes describing plot area (number of sections, number of logs, etc):

Timber Tree 1:

Species: ________________GPS Accuracy: ______(m)

GPS Coordiantes: E/W: _____ N/S: ________________

Tree Buttressed: ☐ Yes ☐ No

Height of the buttress ($H_{Buttress}$) ______ (cm)

Diameter of stump top (d_S): ______ (cm)

Height of the stump (H_S): ______ (cm)

DBH(DBH): ______ (cm)

Log Section 1:

Diam. bottom ($d_{Piece-B}$): ______ (cm)

Diam. top ($d_{Piece-T}$): ______ (cm)

Length (l_{Piece}): ______ (cm)

Log Section 2:

Diam. bottom ($d_{Piece-B}$): ______ (cm)

Diam. top ($d_{Piece-T}$): ______ (cm)

Length (l_{Piece}): ______ (cm)

Length of Log (l_{Log}): ______

Log: ☐ Present ☐ Absent

Diameter at top cut (d_T): ______ (cm)

Length of avoid. merchant waste (l_{AMW}): ______ (m)

Diam. Top of avoid. merchant waste (d_{AMW-T}): ______ (cm)

Timber Tree 2:

Species: ________________ GPS Accuracy: _______(m)

GPS Coordinates: E/W: ___ N/S: _____________

Tree Buttressed: ☐ Yes ☐ No

Height of the buttress ($H_{Buttress}$): _____ (cm)

Diameter of stump top (d_S): _____ (cm)

Height of the stump (H_S): _____ (cm)

DBH(DBH): ______ (cm)

Log Section 1:

Diam. bottom ($d_{Piece-B}$): ______ (cm)

Diam. top ($d_{Piece-T}$): ______ (cm)

Length (l_{Piece}): _____ (cm)

Log Section 2:

Diam. bottom ($d_{Piece-B}$): ______ (cm)

Diam. top ($d_{Piece-T}$): _____ (cm)

Length (l_{Piece}): _____ (cm)

Length of Log (l_{Log}): ______ (cm)

Log: ☐ Present ☐ Absent

Diameter at top cut (d_T): ______ (cm)

Length of avoid. merchant waste (l_{AMW}): ______ (m)

Diam. Top of avoid. merchant waste (d_{AMW-T}): ______ (cm)

Sketch of canopy gap: Canopy opening dimensions:

DAMAGED TREES MEASUREMENTS

Damage type: (S) snapped, (U) uprooted, or (B) branch (if larger than 10 cm in diameter)

Species	DBH	Type	Species	DBH	Type	Species	DBH	Type	Branches	D1	D2	Length

SKID TRAIL DATA SHEET

Skid Trail ID: ________________ Location: ________________ Date: ______/_______/_______

Crew Chief: ________________ Coordinate System:__________

Skid Trail total length:_________

Area method:

Skid Trail width: (m)

Damage method:

Transect ID:______________

Fatally damaged trees: (S) snapped, (U) uprooted

Species	DBH	Type	Species	DBH	Type	Species	DBH	Type	Species	DBH	Type

---

Skid Trail ID: ________________ Location: ________________ Date: ______/_______/_______

Crew Chief: ________________ Coordinate System:__________

Skid Trail total length:___________

Area method:

Skid Trail width: (m)

Damage method:

Transect ID:______________

Fatally damaged trees: (S) snapped, (U) uprooted

Species	DBH	Type	Species	DBH	Type	Species	DBH	Type	Species	DBH	Type

LOGGING DECK DATA SHEET

Date: _________/________/_________

Logging Deck ID: ________________________ Location: ______________________
Polygon ID: (Using polygon feature of GPS) **OR**
Coordinate System:____GPS Waypoint E/W: _______________N/S:________________
Area method:
Logging Deck dimensions: ______________________Sketch of Logging Deck:

Damage method:
Fatally damaged trees: (S) snapped, (U) uprooted

Species	DBH	Type	Species	DBH	Type	Species	DBH	Type	Species	DBH	Type

Logging Deck ID: ________________________ Location: ______________________
Polygon ID: (Using polygon feature of GPS) **OR**
Coordinate System:____GPS Waypoint E/W: _________________N/S:_____________
Area method:
Logging Deck dimensions: ______________________Sketch of Logging Deck:

Damage method:
Fatally damaged trees: (S) snapped, (U) uprooted

Species	DBH	Type	Species	DBH	Type	Species	DBH	Type	Species	DBH	Type

ROAD DATA SHEET

Road Track ID: ________________Location: ________________ Date: _____/_____/_______
Road Type: __________________Crew Chief: __________________
GPS Number: ________ Coordinate System:______
Road Width: (m)

Road Track ID: ________________Location: ________________ Date: _____/_____/_______
Road Type: __________________Crew Chief: __________________
GPS Number: ________ Coordinate System:______
Road Width: (m)

Road Track ID: ________________Location: ________________ Date: _____/_____/_______
Road Type: __________________Crew Chief: __________________
GPS Number: ________ Coordinate System:_______
Road Width: (m)

LOGGING REGROWTH PLOTS

Date: __________/_________/_________

Plot ID #:____________________ Location: ________________GPS Number: _____ Coordinate System: _______: E: _______________ N: _______________

Crew chief: ____________________ Data recorded by: _____________________ # people in crew: __________

Start Time: ___________________End time: ____________________Total Time: ______________minutes

Approximate. Stump age: __________Slope (%): _____________ Camera Number: _______________

Photo Number(s):_________________

Forest type (e.g. mixed, swamp)

Notes (including gap shape and size, and possibly measurements from densiometer):

SAPLINGS:

of Saplings: ___________ Plot dimensions (m): ___________

LIVE TREE MEASUREMENTS

Plot dimensions (m): L: _________W:__________ **Diameter break points (if relevant):_________________________**

←--FOR TREES---→←-------------FOR PALMS, TREE FERNS, BAMBOO------------→

Species	DBH (cm)

Species	DBH (cm)

Species	DBH (cm)

Species	Height (m)	Clinometer angle +	-	Eye to tree (m)	Equipment Used

CANOPY COVER DATA SHEET

Plot ID #:______ Location:__________ GPS Number:_____ Lat:_______ Long:_______ Elev: _______
Land cover type:______________________ Crew chief:__________________ Date:_________/________/________
Notes:

Presence/Absence (P/A):

	1	2	3	4	5	6
1						
2						
3						
4						
5						
6						

Plot ID #:______ Location:__________ GPS Number:_____ Lat:_______ Long:_______ Elev: _______
Land cover type:______________________ Crew chief:__________________ Date:_________/________/________
Notes:

Presence/Absence (P/A):

	1	2	3	4	5	6
1						
2						
3						
4						
5						
6						

Plot ID #:______ Location:__________ GPS Number:_____ Lat:_______ Long:_______ Elev: _______
Land cover type:______________________ Crew chief:__________________ Date:_________/________/________
Notes:

Presence/Absence (P/A):

	1	2	3	4	5	6
1						
2						
3						
4						
5						
6						