UN-REDD PROGRAMME

Guidelines on

Destructive Measurement for Forest Biomass Estimation

For Technical Staff Use

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Version for discussion

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Acronyms

AR CDM	Afforestation/Reforestation in Clean Development Mechanism
AGB	Above Ground Biomass
BGB	Below Ground Biomass
BEF	Biomass Expansion Factor
BCEF	Biomass Conversion and Expansion Factor
C	Carbon
CO_2	Carbon dioxide
COP	Conference of Parties
DBH	Diameter at Breast Height (at 1.3 m from the ground level)
DME	Distance Measurement Equipment
DNA	Designated National Authority
FAO	Food and Agriculture Organization
FIPI	Forest Inventory and Planning Institute
FSIV	Forest Science Institute of Vietnam
GHG	Green House Gas
GPS	Global Positioning System
IPCC	Inter-government Panel on Climate Change
REDD	Reducing Emission from Deforestation and Forest Degradation
RS	Root to Shoot Ratio
SOC	Soil Organic Carbon
TNU	Tay Nguyen University
UNFCCC	United Nations Framework Convention on Climate Change
VFU	Vietnam Forestry University
VNForest	Vietnam Forest Administration
VRO	Vietnam REDD Office
WD	Basic Wood Density at a moisture content of 0%

Introduction

Emission of GHGs from land use change, particularly the conversion of forestland to non-forestland, and unsustainable forest management, are claimed to contribute to as much as 20 per cent of global GHG emissions. The increase of GHG emission is seen as the underlying cause for global climate change.

In the effort towards mitigating global climate change, the initiative of reducing emission from deforestation and forest degradation (REDD) was proposed in COP 13 in Bali, Indonesia in 2007 and this initiative was formally adopted as a measure contributing to climate change mitigation. Under the REDD mechanism, countries will need to measure and monitor the emissions of CO_2 resulting from deforestation and degradation within their borders.

UN-REDD programs are being carried out in a numbers of countries including Vietnam. The UN-REDD Vietnam program started in 2009, and addresses efforts for raising MRV capacity in Vietnam, and assisting Vietnam to reach Tier 2 for producing data on emission factors, during the piloting phase (Phase II) and Tier 3 for the full implementation phase (Phase III).

This Guideline on destructive measurement of forest biomass estimation has been prepared within the UN-REDD Vietnam. The Guideline provides technical guidance to implement measurement of trees biomass, forest floor biomass, litter and deadwood biomass and soil sampling for soil organic carbon analysis in the field, towards development of allometric equations, necessary for generating emission factors at Tier 2 and 3 levels.

The development of allometric equations involves the measurements/estimation of all five carbon pools. In the development of allometric equations currently being undertaken by the UN-REDD Programme for Vietnam, only one carbon pool of above ground biomass (AGB) is being measured, as measurements and analysis for other carbon pools would require considerably more input (time and funds). At this point the allometric equations development of the UN-REDD Programme relies on the use of default factors to estimate the amount of carbon in other pools. Nevertheless, the Guidelines also introduce the methods for measurement of other carbon pools, for reference.

This Guideline has been prepared as a preliminary version for review and revision. The Guideline is intended to be improved with use and to serve as a reference tool in the development of allometric equations for Vietnam and for other regional countries.

All comments and feedback on this Guideline are welcomed, and should be sent to the following email address before 1st June 2013:
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Glossary of basic terms

A glossary of the following key terms is adapted from Good Practice Guidance for Land Use, Land Use Change and Forestry[1].

1. Biomass

Organic material both above ground and below ground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc. Biomass includes the pool definition for above and below ground biomass.

2. Biomass of forests

Biomass is defined as the total amount of aboveground living organic matter in trees expressed as oven-dry tons per unit area (tree, hectare, region, or country). Forest biomass is classified into above ground biomass and below ground biomass.

Above ground biomass is living biomass above the soil including stem, stump, branches, bark, seeds, and foliage.

Below ground biomass is all living biomass of live roots. Fine roots of less than (suggested) 2 mm diameter are sometimes excluded because these often cannot be distinguished empirically from soil organic matter or litter.

3. Basic wood density

Ratio between oven dry mass and fresh stem wood volume without bark. It allows the calculation of woody biomass in dry matter mass. Basic wood density is normally expressed in gram/cm3 or ton/m3.

4. Biomass Expansion Factor (BEF)

A multiplication factor that expands growing stock, or commercial round wood volume, or growing stock volume increment data, to account for non-merchantable biomass components such as branches, foliages, and non-commercial trees.

5. Carbon fraction

Carbon fraction is a carbon content expressed in per cent (%) in dry oven mass of certain component of forests (stem, branches, foliage, root, etc).

6. Carbon pools

Carbon pool is reservoir containing carbon. There 5 carbon pools in a forests considered for forest carbon estimation that are: carbon in live trees (above and below ground), carbon in dead trees and wood, carbon stock in under-storey vegetation (seedlings, shrubs, herbs, grasses), carbon stock in forest floor (woody debris, litter, humus) and soil organic carbon.

7. Carbon stock

Carbon stock is the quantity of carbon in a pool.

8. Forest

Forest is a minimum area of land of 0.05 – 1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10 – 30 per cent with trees with the potential to reach a minimum height of 2 – 5 meters at maturity in situ (in place). A forest may consist either of closed forest formations where trees of various stories and undergrowth cover a

[1] IPCC, 2003. Annex A Glossary. In: Good Practice Guidance for Land Use, Land Use Change and Forestry. Institute for Global Environmental Strategies (IGES). Japan.

high portion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10 – 30 per cent or tree height of 2 – 5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily un-stocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest.

FAO provides the definition of a forest which is land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use[2].

Vietnam now uses the forest definition given by FAO. However, in AR CDM, the forest is defined by DNA as follows: forest is an area that meets the following criteria: i) has a minimum tree crown cover of 30%; ii) has a minimum tree height of 3 meter at maturity; and iii) has a minimum area of 0.5 hectare;

9. Quality Assurance (QA)

QA activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process to verify that data quality objectives were met, ensure that the inventory represents the best possible estimation of emission and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the quality control program.

10. Quality Control (QC)

QC is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to: i) provide routine and consistent checks to ensure data integrity, correctness, and completeness; ii) identify and address errors and omissions; and iii) document and archive inventory material and record all QC activities.

11. Root to shoot ratio (RS)

RS is defined as a ratio of below ground biomass of trees to above ground biomass of trees. RS is normally used to estimate below ground biomass of trees if above ground biomass of trees is known.

[2] FAO, 1998. FRA 2000 Terms and Definition. FRA Working Paper 1. FAO Forestry Department.

Procedures for the destructive measurement of tree biomass

As of 31 December 2009, forest area in Vietnam is 13.3 millions hectare, covering 39.9 percent of total country's inland area in which natural forest is 10.3 million hectare and planted forest is 2.9 million hectare[3]. There are 10 major forest types in Vietnam[4] that are: i) Evergreen and semi-evergreen broad leave forests. This forest distributes commonly across the country and is estimated to be about 60 percent of total forest area; ii) Deciduous forest which mainly distributes in Central highland and South east regions and covers about 6 percent of total forest area; iii) Bamboo forests which covers about 8 percent of total forest area; iv) Mixed wood and bamboo forest covering about 5.3 percent of total forest area; v) Conifer forests which occupies about 1.8 percent of total forest area; vi) Mixed conifer and broad leaf forests account for about 0.7 percent of total forest area; vii) Limestone forests which is estimated at about 3 percent of total forests; viii) Mangrove forest is about 1.3 percent of total forests; and ix) Planted forests which covers about 13 percent of total forests.

This part of the Guideline provides key procedures to carry out destructive measurement of tree biomass for development of allometric equations for estimation of forest's biomass, in mainly natural woody forests.

1. Preparation of tools and other materials

The followings tools and materials are required for the measurement of fresh tree biomass.

- GPS or handy compass
- Measuring tape (50 or 100 m)
- DBH measurement tape
- Chain saw
- Digital measuring scale 200 - 500 kg, with 0.1 kg precision
- Hanging scale up tp 20 kg, with 0.05 kg precision
- Chemical scale 600 g for weighing samples, with 0.01 g precision
- Materials: 1.3 m pole, paint, markers, poly bags, ropes, stakes and field data forms for record keeping.

Depending on the measurement plan, the tools and materials should be prepared adequately before the field work takes place. It is suggested to have one piece of each required tools for one team and adequate materials for measurement.

2. Sample plot establishment

The size and shape of the sample plots is a trade-off between accuracy, precision, time, and cost of measurement. The most appropriate size and shape may also be dependent on the vegetation type found in the sampling area. In this Guideline, a typical sample plot of 1 ha is applied for each forest type. The plot size is square with size of 100 m x 100 m. This sample plot is suitable for areas with slope gradient of less than 20 degrees. Alternatively in steep areas it is suggested to set up four sub-sample plots of 0.25 ha each (50 m x 50 m) in the sampling area.

[3] MARD, 2010. Decision No. 2140/QD-BNN-TCLN dated on 9 August 2010.
[4] Nordeco, 2010. Development of the National REDD program in Vietnam.

Setting a sample plot for measurement should follow standard plot sampling method. The establishment of sample plots needs to meet the following criteria: i) representativeness of the forest types being studied; ii) representativeness for topographic conditions; and iii) covering a number of different trees sizes. It is suggested to set up sample plots on less disturbed forests where large sized trees are available (preferably in rich forests, and as a minimum in medium (quality) forests[5]).

In the case of applying the 0.25 ha sample plot, it is suggested that at the centre of sampling area, walk 50 m in four directions (North, East, South and West) to set up one sample plot in each direction for forest measurement.

To set up the sample plots, 3 technicians and 2 laborers are suggested.

The followings steps are suggested:

1. In the sampling areas, with stake, set the start point;
2. One person stands at start point and uses a GPS or a compass to indicate the direction for the sides of the square plot following Pythagorean theorem;
3. Another person using the measuring tape measures the distance from start point following the direction of plot sides. The sides must be horizontal. Set a stake at every 10 – 20 m.
4. To make sure the plot is a square, the corner formed by two sides at the start point must be 90 degrees and at the middle of each side, use the measuring tape to check the length of horizontal distance between the middle point of the square sides. The horizontal distance between two pairs of plot sides is 100 m.
5. After setting up the plot with stake makers at every 10 m or longer - depending on topographical conditions - on each side of the square plot, use poly rope to mark the plots through the stake makers.
6. Record general information (location, coordinates at plot centre) in the **Field data form for plot measurement of woody forests Annex 01**.

3. Measurement of tree DBH and names in sample plot

All live trees with DBH from 5 cm and above in the sample plots will be measured. The information to collect include: i) tree species (Vietnamese and scientific names); and ii) DBH of trees.

The measured data will be used for: i) analyzing tree species composition; ii) distribution of DBH class of the trees and species; iii) standing volume of the forests.

The measurement team should include 3 technicians. One person to record the data and all others for identifying trees species, measuring DBH of trees and marking trees after completion of identifying and measuring. Laborers may also assist in clearing ground vegetation for tree access.

The suggested steps for measurement are:

1. Identifying tree species (tree name) should be done first before starting the measurement of DBH;
2. Using a 1.3 m pole, mark measuring position for DBH measurement;

[5] According to Circular 34/TT-BNN issued by MARD, a rich forest is a forest with a standing wood volume of 201 – 300 m^3/ha and that of medium forest is 101 – 200m^3/ha.

3. Using a measuring tape, measure circumference of tree at marked position;
4. Record all information collected (number of stumps; buttress diameter; height of buttress etc) and note any irregularities if any. Use **Field data form for plot measurement of woody forests Annex 01**.

4. Destructive measurement of fresh biomass of sample trees

Once the measurement of tree DBH and tree names is completed, the measurement of fresh biomass of sample trees is carried out as follows:

1. Enter the data on DBH in excel spread sheet and group DBH data of trees into DBH class. The interval of DBH class is 10 cm, and DBH classes are: 5 – 15 cm; 15 – 25 cm; 25 – 35 cm; 35 – 45 cm; 45 – 55 cm; 55 – 65 cm; 65 – 75 cm; etc.
2. Select randomly the sample trees in each DBH class in the sample plots. The total number of sample trees for harvesting is 50 trees for each forest type. At least five sample trees should be harvested for each DBH class, and an equal number of sample trees to be allocated for each DBH class.
3. After selection of sample trees for each DBH class, use chain saw to cut down the tree at its base following logging procedures.
4. Once the sample tree is cut down, accurately measure:
    a. Diameter at stump;
    b. DBH at 1.3 m;
    c. Total tree height (from the stump to the top of the crown).
    d. Length of tree bole - from the stump to the first main branch;
    e. Length of tree bole - from the stump to the point where diameter becomes 10 cm;
    f. If tree with buttress, measure diameter and height of the buttress
5. Separate the cut trees into different parts (e.g. bole, branches and leaves).
6. Use scale to measure immediately the weight of stem, branches, leaves and buttress if tree with buttress. [6]

[6] Alternative methods for the measurement of large diameter trees may be considered more appropriate, depending on the conditions in the field. The following provides an example of measurement techniques to be considered for incorporation into this Guideline. (For further consideration.)
"For the larger branches and main stem (>10 cm diameter), it is generally not practical to weigh these fresh in the field. Instead, they should be cut into sections and the volume of each section calculated. The oven-dry-weight of these sections is determined as the product of volume and density (oven-dry-weight per unit of green volume). To estimate density, a disk of wood from each section should be removed. The volume of the disk can be calculated as the cross-sectional area of the disk times the thickness (measured at four points, 90° to each other) or by the water-displacement method. The water-displacement method is based on the principle that an immersed object displaces its own volume of water. The disk is carefully immersed in a container of water (pushing it down with a sharp pointed object), and the increase in water level when the disk is fully immersed is used to measure the increase in volume. To improve accuracy the container of water can be made absolutely full and as the disk is immersed all the water displaced by the disk is collected in a previously weighed container. The weight of the water displaced is weighed in grams and equals the volume of the disk in cm3, because 1 g of water has a volume of 1 cm3. Thus if the weight of the water displaced is 20 g, then the volume of the disk is 20 cm3. After volume measurement the disk is oven dried to constant weight at 105°C; this weight divided by its volume gives density. The weight of the stem and branches is then calculated, making sure all the measurements are in the same units (volume in cm3 and density in g/cm3)."(FAO, 1997. FAO FORESTRY PAPER 134 Estimating Biomass and Biomass Change of Tropical Forests: a Primer. http://www.fao.org/docrep/W4095E/w4095e00.htm#Contents)

7. Carefully record all information on destructive measurement of sample trees in the **Field data form for destructive measurement of tree biomass Annex 02**.

5. Sampling for analysis of dry oven mass and wood density

Sampling for dry mass analysis can be taken immediately after completion of measurement of fresh weight of each tree components. The following steps are suggested to be carried out for sampling:

1. Sample for dry mass analysis: collect three samples per tree of stem, branches and leaves. Samples taken for each tree part should be a representative sample. Therefore, when taking the sample for dry mass analysis, always be noted that:
   a. The sample should be taken from different positions of the stem, and different parts of branches and leaves. To prepare a stem sample, take two to three discs (and if too large, radial sections of the discs) amounting to about 0.2 % of the total stem fresh weight. For branch sample, take 4 small disks from branches amounting to about 0.5 to 1.0 kg[7].
   b. Put sample of the tree parts (stem, branches and leaves) into poly bags and tightly tied to prevent evaporation.
   c. The estimated weight of each sample is suggested to be 0.5 – 1.0 kg for stem and branches; 0.3 – 0.5 kg for leaves.
2. Samples for wood density analysis will be four wood discs samples for the bole. The sampling procedures are as follows:
   a. Mark the position for sampling. The sampling position is at stump level (0.0 m), at 1/4 of bole length; 1/2 of bole length and 3/4 of bole length.
   b. Take one wood disc or radial section of the discs if big bole for each sampling position with wood disc thickness of 5 – 10 cm.
3. All samples for dry mass and wood density analysis should bear a label for later identification.
   a. For samples for dry mass analysis, after putting the sample into poly bag, use permanent pen to write information on sample. The information should include: i) Plot code; ii) Tree name; iii) DBH size; iv) Sample name (stem, branch or leaves).
   b. Information on samples for wood density analysis include: i) Plot code; ii) sample tree code; iii) sample position (0.0 m, 1/4 of bole length, 1/2 of bole length, 3/4 bole length);.
4. The samples for dry mass analysis must be weighted immediately and carefully using a chemical scale (either on site, or off-site, but within the same day) to determine the exact fresh weight of each sample taken in the field.
5. All samples should be sent to a qualified laboratory in time for analysis;
6. All information on samples collection for dry mass and wood density analysis must be recorded fully in the field data form **Annex 02**.

[7] ICRAF, 2011. Guidelines for establishing regional allometric equations for biomass estimation through destructive sampling.

Procedures for the destructive measurement of bamboo biomass

There are several types of bamboo forests in Vietnam. The common bamboo forests are: i) Nua (Schizostachyum sp); ii) Luong (Dendrocalamus barbatus); iii) Vau (Indosasa sp).

This part of the Guideline presents the main procedures to carry out destructive measurement of bamboos to generate allometric equations for estimation of bamboo forests biomass.

1. Preparation of tools and other materials

The followings tools and materials are required for the measurement of fresh bamboo biomass:

- GPS or handy compass
- Measuring tape (50 or 100 m long)
- DBH measurement tape
- Hand saw
- Measuring scale 50 – 100 kg, with 0.1 kg precision
- Chemical scale 600 g for weighing samples, with 0.01 g precision
- Materials: 1.3 m pole, paint, markers, poly bags, ropes, stakes and field data forms for record keeping.

2. Sample plot establishment

The following steps are suggested for setting up the sample plots for measurement of bamboo forest:

1. Use stratified sampling method. Sample plots can be square or rectangle.
2. Use a 0.5 ha sample plot for flat area and four sample plots of 0.25 ha each for steep slopy area.
3. If using sample plots of 0.5 ha, it is suggested to divide the sample plot into sub-plots for detailed measurement. If using sample plots of 0.25 ha, further sub-division is not recommended. The measurement will be done for entire plot.

3. Measurement of bamboo

In the sample plots, measure all live bamboo with DBH over 2cm. Measurement of bamboo forest is suggested as follows:

1. Use DBH tape to measure DBH and determine age class of each bamboo in the sample plots.
2. After measurement of bamboo, use white paint to mark the measured bamboo to avoid missed or repeated measurements.
3. Carefully record all information on bamboo measurement, i.e. DBH and height using **Field data form for plot measurement of bamboo forests Annex 03**.

4. Destructive measurement of fresh biomass of sample bamboo

Once the measurement of bamboo DBH and height is completed, the measurement of fresh biomass of sample bamboos is carried out as follows:

1. Classify and group into DBH classes. The interval of DBH class is 2 cm, and DBH classes should be: 2 – 4 cm; 4 – 6 cm; 6 – 8 cm; 8 – 10 cm; 10 – 12 cm; 12 – 14 cm; 14 – 16 cm; 16 – 18 cm, etc.
2. Select randomly the sample bamboo from each DBH class following the criteria below. The total number of samples for harvesting is 100. Criteria for selection of sample bamboo:
    a. Samples should be representative of the age class. Three age classes are recommended for sampling are: i) young (1-2 years); ii) medium age (3-4 years); and iii) old (more than 3 – 4 years);
    b. Samples should be allocated as equally as possible for each DBH class.
    c. The number of samples would be determined based on the number of DBH classes identified, and the bamboo age.
3. After selection of sample bamboos for each DBH class, use hand saw to cut down the bamboo.
4. Once the sample bamboo is felled, measure DBH (at 1.3 m) and height. The measurement of height is total height of the bamboo stem.
5. Separate the stem, branches and leaves and use scale to immediately measure weight.
6. Record carefully all information on destructive measurement of sample bamboos using **Field data form for destructive measurement of bamboo forests Annex 04**.

5. Sampling for analysis of dry mass

For bamboo forests, only sampling for dry mass analysis is undertaken, whereas wood density analysis is not done due to feasibility issues. Sampling for dry mass analysis should be taken immediately after completion of measurement of fresh weight of each bamboo component. The total sample for dry mass analysis is 6 per each sample in which four samples are for stems, one sample for branches and one sample for leaves. The following steps are suggested to carry out for sampling:

1. Out of 100 sample bamboos for fresh biomass measurement, select 50 samples for sampling of dry mass analysis. The selected bamboos for sampling should be representative of each age group and DBH class.
2. Mark the sampling position on the stem of the sample bamboo. The position for sampling is at stump level (0.0 m), 1/4 of stem length; 3/4 of stem length and at the top of stem;
3. Take the samples at sampling positions. Four samples for stems, one sample for branches and one sample for leaves. The estimated weight of each sample is suggested to be 0.5 – 1.0 kg for stem and branch samples, and 0.3 – 0.5 kg for leaves.

4. The samples of tree parts (stem, branch and leaves) must be put into poly bags and tightly tied to prevent evaporation.
5. Use permanent marker pen to label for each sample for later identification. The information needed for label is: i) Plot code; ii) Name of bamboo; iii) DBH; iv) Sample part (stem, branch or leaves).
6. The samples must be weighted immediately and carefully using a chemical scale (either on site, or off-site, but within the same day) to determine the exact weight of each sample taken in the field.
7. Promptly send samples to a qualified laboratory for the analysis of dry mass.
8. Record fully all information on samples collected for dry mass analysis using the **Field data form for destructive measurement of bamboo forests Annex 04**.

Procedures for the measurement of forest floor vegetation, dead wood, and litter and sampling of soil organic carbon

1. Measurement of forest floor vegetation

1.1. Tools and materials

Prepare the following tools and materials for the field measurements:

- GPS or handy compass
- Measuring tape (20m long);
- Measuring scale 50 kg, with 0.05 kg precision;
- Chemical scale 600 g, with 0.01 g precision;
- Materials: Scissors, permanent pens, poly sheet, stake, ropes, poly bags, field data forms for record keeping etc;

1.2. Sample plot establishment

The sample plot should be set up randomly. Sample plots can be rectangle or square. Steps for setting up sample plots are suggested as follows:

1. In the main sample plot of 1 ha, use a measuring tape and a GPS or a handy compass to make a square sub-plot of 25 m^2.
2. Establish four sample plots at the corner of the main sample plot and one at the centre of the main sample plot;
3. Use stakes and poly rope to mark the sub-plot for easy measurement;

1.3. Destructive measurement of forest floor vegetation

1. In each sub-plot, use knife and/or scissors to cut all floor vegetation in the plots;
2. Separate cut vegetation into: stems, branches and foliage;
3. Use scale to measure fresh weight of each component. Do this immediately;
4. Take representative samples from each component (stems, branches and foliage);
5. Use chemical scale to measure the weight of samples and place the samples into poly bags;
6. Tightly seal poly bags and label each sample. All samples should be promptly sent to a qualified laboratory for dry mass analysis.
7. Record all information on measurements using **Field data form for measurement of forest floor vegetation Annex 05**.

2. Operation for measurement of dead wood

2.1. Tools and materials

Prepare the following tools and materials for the field measurements:

- GPS or handy compass;
- Height measurement tool;
- Measuring tape;
- Measuring scale of 100 - 200 kg, with 0.1 kg precision;
- Chemical scale600 g, with 0.1 g precision;
- Chainsaw;
- Materials: Permanent pens, poly sheet, stake, ropes, poly bags, field data forms for record keeping etc.

2.2. Sample plot establishment

The measurement of dead wood biomass includes measurement of standing dead wood and fallen dead wood. For standing dead wood, use the same sample plot of 1 ha used for AGB (c.f. Procedures for the destructive measurement of tree biomass. Section 1.). The measurement of fallen dead wood follows the line-intersect method of Harmon and Sexton 1996[8]. The steps for setting up the measurement plot are as follows:

1. Identify the centre of the sample plot of 1 ha;
2. At centre of the plot, use poly rope to randomly lay out twp 50 m lines.

2.3. Measurement of dead wood biomass

1. Measurement of standing dead wood:
    a. In the sample plot delineated, mark all standing dead trees;
    b. Use measuring tape and height measurement tool to measure DBH and tree height;
    c. Record all information on standing dead wood in **Field data form for measurement of dead wood biomass Annex 6.**
2. Measurement of fallen dead wood:
    a. Along the length of the line drawn, measure the diameter of each intersecting piece of coarse dead wood with diameter of or over 10 cm.
    b. Classify each piece of dead wood into one of three density states: **sound, intermediate, or rotten**. To determine the density class of a piece of dead wood, strike each piece 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 results in some wood loss, classify as intermediate. If the machete sinks into the piece with extensive wood loss, and the piece is crumbly, classify as rotten.

[8] Harmon and Sexton, 1996. Guidelines for measurements of woody detritus in forest ecosystems. US LTER Publication No. 20. U.S. LTER Network Office, University of Washington, College of Forest Resources, Seattle, WA. 73 pp.

c. Take wood sample for each density state (sound, intermediate and rotten) for wood density analysis for later calculation of dead wood biomass. The samples should be promptly sent to a qualified laboratory for analysis.

d. Record all information on measurements using **Field data form for measurement of dead wood biomass Annex 06**.

3. Operation for measurement of litter

3.1. Tools and materials

Prepare the following tools and materials for the field measurements:

- Clip plot frame
- Machete or knife
- Handy compass
- Clippers to remove vegetation
- Hanging scale
- Materials: Permanent marking pens, poly sheet, stake, ropes, poly bags, field data forms for record keeping etc.

3.2. Sample plot establishment

A clip plot of 1 m^2 should be used for measurement of litter. Five sub-plots should be set up randomly in the sample plot of 1 ha for measuring litter as follows:

1. In the sample plot, select randomly five places.
2. Use stake to mark the selected points for later measurement;

3.3. Measurement of litter

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. The measurement of litter is as follows:

1. Place clip plot frame at the selected point;
2. Collect all litter inside the frame. A knife can be used to cut pieces that fall on the border of the sampling frame;
3. Use hanging scale to weigh entire the collected litter;
4. Mix the litter thoroughly and collect a representative sample of approximately 100 - 200 g for dry mass analysis;
5. Use balance to weigh sample and place sample in poly bag with label;
6. Record all information on litter measurement in all five clip plots using **Field data form for measurement of litter biomass Annex 07**.

4. Operation for soil carbon sampling

4.1. Tools and materials

Prepare the following tools and materials for the field measurements:

- Soil corer or probe;
- Volumetric cylinder of 100 cm3;
- Cloth bags;
- Durable plastic tarp;
- Non-breakable rod (to remove soil from corer/probe);
- Materials: Permanent pens, poly sheet, stake, ropes, poly bags, field data forms for record keeping etc.

4.2. Sample plot establishment

In the sub-sample plot area, randomly select five points for sampling soil carbon. Depending on the objectives of the survey, the number of soil carbon sampling may be subject to change.

4.3. Sampling soil carbon

Soil carbon is estimated by collecting soil to a certain depth and then analyzing it 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. If at some sampling points the soil depth is shallower than the standard depth chosen, the depth of soil sampled is measured and included in the calculation of soil carbon stocks. The following steps are suggested to sample soil carbon[9]:

1. At each sampling point, clear the surface by removing all vegetation and litter.
2. Insert the soil corer/probe steadily to the standard depth (e.g. 30 cm).
    a. If the soil is compacted use a rubber mallet to fully insert.
    b. If the probe will not penetrate to the full depth, do not force it as it is likely that a stone is blocking its route and if forced the probe will be damaged.
    c. If blocked withdraw the probe, clean out any collected soil, and insert in a new location.
    d. If depth of soil at sampling point is less than standard depth measured, then the depth of the soil sampled must be recorded.
3. Carefully extract the probe and put soil into a cloth bag. Assign bag a unique label for later interpretation.
4. At each sampling point take, use a volumetric cylinder to take soil sample for bulk density analysis. After taking the sample, remove all soils in a volumetric cylinder and determine its weight immediately by chemical scale.
5. All information on soil samples for soil carbon and buck density analysis must be labeled carefully and promptly sent soil samples to a professional lab for analysis.

[9] Winrock International, 2010. Manual Technical Issues Related to Implementing REDD+ program in Mekong Conutries. Asia Regional Biodiversity Conservation Program.

Laboratory work and data analysis for development of allometric equations

1. Laboratory work

1. All plant samples of harvested trees, forest floor vegetation, dead wood, litter and soils should be analyzed by professional laboratory to ensure the accuracy of the analysis. The required equipments for analysis are:

- Drying oven
- Laboratory scale
- Capacity to analyze soil for C (NC analyzer)

2. The analysis includes the following:

- Dry weight of samples using oven drier at a temperature of 105OC until samples reach constant weight ;
- Basic wood density of all wood discs at the moisture content of 0%;
- Buck density of soil samples;
- Soil carbon content, preferably use dry combustion carbon analyzer;

3. All analytical data must be recorded carefully in a spreadsheet format. Annex 08a through Annex 10 provide templates for analytical data record keeping Annex 11a and 11b provide templates for synthesis.

2. Data entry and analysis

The data entry and analysis are very important for further development of allometric equations. The following work needs to be carried during and/or after completion of the field measurements.

1. Enter all field data from field measurement into excel spreadsheet files. This includes data on plot measurements and biomass measurements. It is strongly recommended for quality control (QC) to enter data by a third person who did not take part in the measurements to reduce the occurrence of mistakes during transferring data from field data forms to digital format.
2. After entering the field data into the spreadsheet file, the analysis of forest structure for each surveyed forest type is required. The analysis focuses on forest structure which include:
    a. Tree species composition;
    b. Distribution of DBH by species and number of trees;
    c. Wood volume per ha and per DBH class;
    d. Tree density
3. During the sample analysis, it is advised to carry out QA&QC (quality assurance and quality control);
4. After analysis of oven dry mass and wood density work is completed, check and use such data for dry biomass calculation for all sample trees and other pools (floor vegetation, dead wood, litter etc). The general calculation of dry biomass is as follows:

a. *Total dry weight (TDW) for each organ of the sample tree:*

Total dry weight for each organ of sample tree is calculated based on the total fresh weight of each organ measured in field and the ratio of dry weight to fresh weight calculated for each organ in the laboratory. The formula for TDW calculation is as follows:

$$TDW = TFW \frac{SDW}{SFW}$$

Where: *TDW* is total dry weight; *TFW* is total fresh weight; *SDW* is absolute dry sample weight and *SFW* is fresh sample weight.

b. Wood density:

Wood density of every wood disc for each sample tree species is analyzed in the laboratory and is calculated by the following formula:

$$WD = \frac{SDWc}{SV}$$

Where: *WD* is wood density in g/cm^3; *SDWc* is dry weight of sample cube and *SV* is volume of sample cube.

c. Carbon stock in biomass:

Carbon stock in each biomass pool will be calculated based on oven dry biomass of each pool and carbon fraction. The general formula for calculation of carbon stock in biomass is as follows:

$$CSi = TDWi * CFi$$

Where: *CSi* is carbon stock of component *i* in kg; *TDWi* is total oven dry weight of component *i* in kg; and *CFi* is carbon content in biomass of component *i* in percent.

In case there is no analysis of carbon content in each biomass component (stems, branches and leaves), it is suggested to use the default carbon fraction provided by IPCC. This value is between 0.47 and 0.50.

Total carbon stock for each sample tree will be calculated as the sum of carbon stock of each tree component.

d. Soil organic carbon

Soil organic carbon stock is calculated based on soil bulk density and the calculation soil depth. The general formula for SOC calculation is as follows:

$$SOC = CF * BD * SD$$

Where: *CF* is carbon content in the soil in percent; *BD* is soil bulk density in ton/m^3 and *SD* is the depth of calculation layer in cm.

3. Regression analysis

One method for estimating forest carbon stocks is the use of allometric equations. A class of allometric equations that are used for carbon stock estimation are called "biomass regression" equations. Allometric or biomass regression equations are mathematical models representing the relationship between selected values of variables (x) and observed values of the other (y). This permits the prediction of the most probable values of y using the selected values of x.

For example, a biomass regression equation can be used to estimate the total biomass of a tree (including bole, branches and sometimes roots) from only a measurement of DBH. The reason is that there is normally a relationship between DBH and total biomass (as DBH increases, total biomass also increases and vice-versa). Biomass regression equations are typically applied to plot level data collected during inventory data collection. They can use DBH, height, or a combination of the two. But without plot level data, biomass regression equations cannot be used to make a carbon stock estimate.

To develop allometric equations, it is suggested as follows:

1. Use excel spreadsheet or other professional software (e.g. SPSS) to analyze the regression;
2. The regression should be analyzed by different regression types. It is suggested to analyze the most common regression forms that are linear, power, logarithms.
3. Make the regression analysis with different variables. However, it is suggested to use DBH, tree height, stem wood volume for regression analysis. The commonly suggested correlation forms are: i) $y = X^b$; ii) $ln(y) = a + b*ln(X)$; and iii) $ln(y) = a + b*ln(X_1) + C*ln(X_2)$.
4. After completion of regression analysis, assess and select the best equations for biomass estimation. Use the equations with highest correlation index and smallest error.

4. Preparation of a report and data store

After completion of field work and data analysis, prepare a technical report on destructive measurement of forest biomass. The report should cover the following parts: i) Description of survey site (forest types, forest use and management, bio-physical conditions, etc); ii) Methods used (sampling methods, sampling size; data analysis etc); iii) Results and discussions (tree species composition; distribution of species by DBH; dry mass analysis; wood density analysis; regression analysis etc); iv) Conclusion; and v) Annexes (all data associated with the results).

It is very important to have a good data store for cross check whenever needed. It is good practice to have all raw data be entered in a spreadsheet format following the given appropriate templates and all field data forms filled.

Annexes

Annex 01. Field notes for plot measurement of woody forests

Annex 02. Field notes for destructive measurement of tree biomass

Annex 03. Field notes for plot measurement of bamboo forests

Annex 04. Field notes for destructive measurement of bamboo biomass

Annex 05. Field notes for measurement of forest floor vegetation

Annex 06. Field notes for measurement of dead wood biomass

Annex 07. Field notes for measurement of litter biomass

Annex 08a. Analytical data record on oven dry mass of woody sample trees

Annex 08b. Analytical data record on oven dry mass of sample bamboos

Annex 09. Analytical data record on wood density

Annex 10. Analytical data record on soil samples

Annex 11a. Synthesis of destructive measurement data of bamboo forests

Annex 11b. Synthesis of destructive measurement data of woody forests

Annex 01. Field data form for plot measurement of woody forests

Survey date:		Plot code:	
Name of survey team members			
Administration location of plot:			
Coordinates of plot centre	Longtitude:	Latitude:	
Altitude (m)		Average slope:	
Plot area		Plot size:	
Forest types:			

ID	Vietnamese name of trees	Scientific name of trees	Circular at 1.3m (cm)	DBH (cm)	Remarks
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
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32					
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34					
35					
36					
37					
38					
39					
40					
41					
etc					

Annex 02. Field data form for destructive measurement of tree biomass

Survey date:		Plot code:	
Name of survey team members:			
Administration location of plot:			
Name of sample tree			
Sample tree number:			

Diameter of sample tree at the stump, 0.0m (cm)	
Diameter of sample tree at 1.3 m (cm)	
Diameter of sample tree at centre of bole (cm)	
Diameter of sample tree at tope of bole (cm)	
Length of tree from stump to the top of the crown (m)	
Length of tree from stump to the first branch (m)	
Length of tree from stump to the point with diameter of 10 cm (m)	
Diameter of butress if tree with butress (m)	
Height of butress if tree with butress (m)	

A- Fresh biomass measurement of sample tree

ID	Weighing time	Fresh weight by tree components (kg)			Weight of butress if any
		Bole	Branches	Leaves	
1					
2					
3					
4					
5					
6					
7					
Total (kg)					

B - Samples taken for dry mass and wood density analysis

Samples for dry mass analysis	Fresh weight of sample (gram)		
	Bole	Branches	Leaves

Samples for wood density analysis	Sampling position:	Mark 'X" if sample is taken
	Wood disc at 0.0 m	
	Wood disc at 1/4 bole length	
	Wood disc at 1/2 bole length	
	Wood disc at 3/4 bole length	

Annex 03. Field data form for plot measurement of bamboo forests

Survey date:		Plot code:	
Name of survey team members:			
Administration location of plot:			
Coordinates of plot centre	Longtitude:	Latitude:	
Altitude (m)		Average slope:	
Plot area		Plot size:	
Forest types:			
Sub-plot measurement ID		**Sub-plot code:**	
		Number of clump in sub-plot	
		Average stem per clump	

ID	Bamboo name	Bamboo age	Total height (m)	DBH (cm)	Remarks
1					
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					
31					
32					
33					
34					
35					
etc					

Annex 04. Field data form for destructive measurement of bamboo biomass

Survey date

Sample plot code:

Name of survey team

Starting time

Ending time

ID of sampe bamboo	Age class	Size of sample bamboo		Fresh weight of sample bamboo by parts (kg)			Fresh weight of sample taken for analysis (kg)					
		H (m)	DBH (cm)	Stem	Branh	Foliage	Stem (0.0m)	Stem 1/4)	Stem (1/2)	Stem (3/4)	Branch	Foliage
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
….												

Annex 05. Field data form for measurement of forest floor vegetation

Survey date:		Plot code:	
Name of survey team members:			
Administration location of plot:			
Coordinates of plot centre	Longtitude:	Latitude:	
Altitude (m)		Average slope:	
Plot area		Plot size:	
Forest types:			
Dominant foor vegetation species			

A - Fresh biomass measurement

ID	Sub-sample code/name	Plot area (m^2)	Foor vegetation value		Fresh weight by vegetation components (kg)		
			Height (m)	Cover (%)	Stem	Branches	Foliage
1							
2							
3							
4							
5							

B - Sampling for dry mass analysis

ID	Sample code/name	Plot code	Fresh weight of samples		
			Stem	Branches	Foliage
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
etc					

Annex 06. Field data form for measurement of dead wood biomass

Survey date:	
Name of survey team members:	
Location of survey area	
Forest types:	

A - Measurement of standing dead wood

ID	Sample plot code	Sampling plot area (m^2)	Diameter (cm)			Tree height (m)	Length of bole (m)
			At 1.3 m	At base	At top	At top	
1							
2							
3							
4							
5							

B - Measurement of lying dead wood

ID	Transect length No. and length	Dead wood piece No.	Diameter (cm)	Density claas (use 'X' to mark where appropriate)			Hollow diameter (if any, cm)
				S	I	R	
1	1, 50 m	1					
		2					
		3					
		etc					
etc							

C - Sampling for wood density analysis

ID	Sample name	Type of wood density (S, I, R) for sampling	Number of sample taken

Notes: Density class is: S: Solid; I: Intermediate; R: Rooten

Annex 07. Field data form for measurement of litter biomass

Survey date:		Plot code:	
Name of survey team members:			
Administration location of plot:			
Coordinates of plot centre	Longtitude:	Latitude:	
Altitude (m)		Average slope:	
Plot area		Plot size:	
Forest types:			

A - Litter measurement

ID	Sub-sample code/name	Sampling plot area (m^2)	Weight of litter (kg)	
			Per plot	Per ha
1				
2				
3				
4				
5				

B - Sampling for dry mass analysis

ID	Sample code/name	Sampling plot code	Weight of sample (gram)
1			
2			
3			
4			
5			
etc			

Annex 08a. Analytical data record on oven dry mass of woody sample trees

Name of laboratory:

Date of data report:

Name of person in charge:

ID	Sample tree name	Sample part	Fresh weigh with out tare (gram)	Weight of oven dry sample with tare (gram)	Weight of tare (gram)	Ratio of oven dry weight to fresh weight
1		Bole				
		Branch				
		Foliage				
2		Bole				
		Branch				
		Foliage				
3		Bole				
		Branch				
		Foliage				
4		Bole				
		Branch				
		Foliage				
5		Bole				
		Branch				
		Foliage				
6		Bole				
		Branch				
		Foliage				
7		Bole				
		Branch				
		Foliage				
8		Bole				
		Branch				
		Foliage				
9		Bole				
		Branch				
		Foliage				
10		Bole				
		Branch				
		Foliage				
11		Bole				
		Branch				
		Foliage				
12		Bole				
		Branch				
		Foliage				
13		Bole				
		Branch				
		Foliage				
14		Bole				
		Branch				
		Foliage				
15		Bole				
		Branch				
		Foliage				
etc		Bole				
		Branch				
		Foliage				

Annex 08b. Analytical data record on oven dry mass of sample bamboos

Name of laboratory:

Date of data report:

Name of person in charge:

#	Sample bamboo ID/name	Age of bamboo	Sample part	Fresh weigh with out tare (gram)	Oven dry weight of sample with tare (gram)	Weight of tare (gram)	Ratio of oven dry weight to fresh weight
1			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
2			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
3			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
4			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
5			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
6			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
7			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
8			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
9			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
10			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
11			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				
etc			Stem (0.0 m)				
			Stem (1/4 m)				
			Stem (1/2 m)				
			Stem (3/4 m)				
			Branch				
			Foliage				

Annex 09. Analytical data record on wood density

Name of laboratory:

Date of data report:

Name of person in charge:

ID	Sample tree name	Wood disc code	Sub-sample code	Volume (cm^3)	Dry weight (gram)	WD (gram/cm^3)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
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36						
37						
38						
39						
40						
41						
42						
etc						

Annex 10. Analytical data record on soil samples

Name of laboratory:

Date of data report:

Name of person in charge:

ID	Sample plot code	Sample name	Sampling depth (cm)	Soil content (%)	Buck density (gram/cm^3)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
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36					
37					
38					
39					
40					
41					
42					
etc					

Annex 11a. Synthesis of destructive measurement data of bamboo forests

Forest type:				
Administration location of survey area:				
Coordinates at centre of sample plot:	Latitude		Logitude:	
Date of survey:				
Name of implementing organization:				
Name of person responsible for data:				

#	Sample bamboo ID/name	Age	Size of sample bamboo		Fresh AGB biomass (kg/bamboo) by parts (data measured in the field)				Remarks on sample bamboo (note any irregular charater)
			DBH (cm)	H (m)	Stem	Branch	Foliage	Total	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
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43									
44									
45									
46									
47									
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52									
53									
54									
55									
56									
57									
58									
59									
etc									

Annex 11b. Synthesis of destructive measurement data of woody forests

Forest type:				
Administration location of survey area:				
Coordinates at centre of sample plot:	Latitude		Logitude:	
Date of survey:				
Name of implementing organization:				
Name of person responsible for data:				

	Sample trees/bamboo		**Size of sample trees**		**Fresh AGB biomass (kg/tree) by parts (data measured in the field)**					**Remarks on sample trees** (irregular character , i.e height of stump; no. pf stumps if tree with butress; etc)
ID	Vietnamese name	Scientic name	DBH (cm)	H (m)	Bole	Branch	Foliage	Butress	Total	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
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etc										