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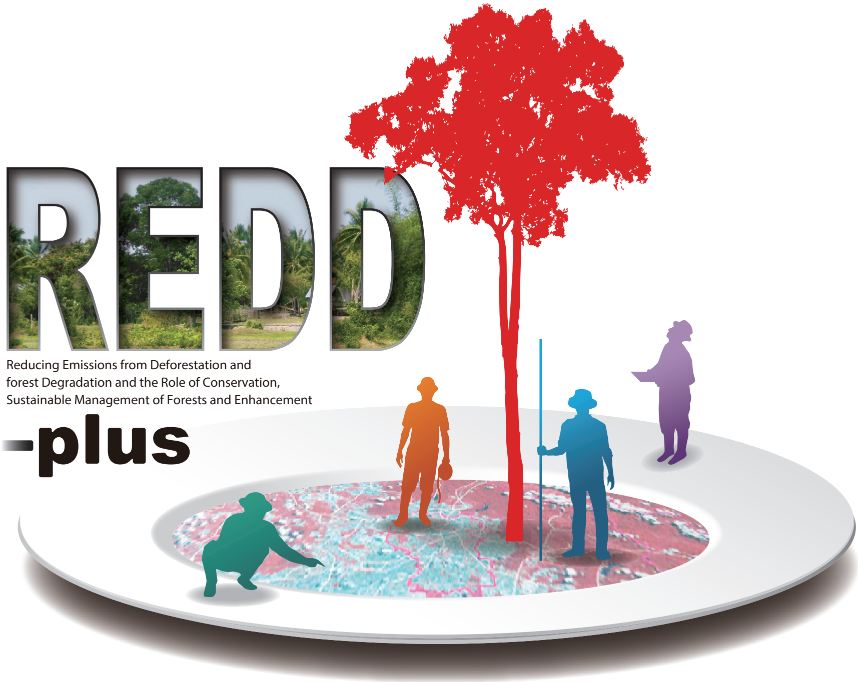

COOKBOOK ANNEX

Research Manual Vol. 2
Destructive Sampling for Tree Biomass

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Research achievement of the 4th mid-term plan 2 (Forest Management Technology-2)

Preface

The basic concept of REDD-plus is to provide economic incentives such as funding and credits to developing countries for REDD activities (reducing emissions from deforestation and forest degradation) and “plus” activities (reducing CO_2 emissions and CO_2 levels in the atmosphere by carbon sequestration). Thus, in order to estimate the changes in the amount of carbon stored in forests, monitoring using a scientific approach is essential.

The REDD Research and Development Center, Forestry and Forest Products Research Institute, compiled “REDD-plus Cookbook” in 2012, an easy-to-understand technical manual that provides basic knowledge and techniques required for REDD-plus, with the primary focus on forest carbon monitoring methods. Knowledge and techniques required for REDD-plus are compiled in units termed as “Recipe” in this REDD-plus Cookbook. This REDD-plus Cookbook is intended for the policy makers working for the introduction of REDD-plus and the practitioners and experts working on REDD-plus activities.

As REDD-plus Cookbook focuses on basic knowledge and techniques required for REDD-plus, the experts working on REDD-plus activities will need further detailed information in the field. Thus, we compiled “REDD-plus Cookbook Annex” to provide the experts with more detailed and practical information in each “Recipe”. In this manual, specific measuring methods are explained. In addition, this manual is intended to be used as a textbook for capacity building. In order to have a better technological understanding on these topics, it is recommended to read this manual in conjunction with REDD-plus Cookbook.

We hope this manual will contribute to the promotion of REDD-plus in several parts of the world.

September, 2016

The REDD Research and Development Center
Forestry and Forest Products Research Institute

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1 Outline

1.1 Purpose of REDD-plus Cookbook Annex

REDD-plus Cookbook compiled in 2012 is an easy-to-understand technical manual that provides basic knowledge and techniques required for REDD-plus, with the primary focus on forest carbon monitoring methods. REDD-plus Cookbook explains the estimation method of forest carbon stocks, while this manual explains, inter alia, inventory methods focusing on the ground-based inventory needed to develop equations for estimating carbon stocks per unit area.

This manual is intended for experts who will actually collect data on forest carbon stocks. We hope this manual will also be useful for students studying forestry and forest ecology, NGOs interested in REDD-plus, and people concerned in this field.

1.2 How to use this manual

The destructive sampling should be carefully planned, taking the risk of accident caused by the use of an excavation machine and a chainsaw into consideration. It is advisable to have an overview of the survey process in advance from this manual when planning the destructive sampling.

In this manual, Chapter 2 explains the number of staff and tools required for the survey and then explains the specific survey procedure, and Chapter 3 introduces a check sheet useful in the field.

Please see TIPS as for the points to consider in the field.

1.3 Recipes covered by REDD-plus Cookbook

Recipes covered by REDD-plus Cookbook are shown in [ ]. Please refer to REDD-plus Cookbook.

REDD-plus Cookbook can be downloaded from the Website mentioned below.

http://redd.ffpri.affrc.go.jp/index_en.html

2 What is destructive sampling

2.1 Purpose of destructive sampling

An important key for REDD+ is an accurate estimation of forest carbon stocks in the target country. Carbon stocks in trees account for a large percentage of the forest carbon stocks in most cases; therefore, it is necessary to know its amount. The methods for determining tree biomass vary **[*Recipe-P10, P11*]**, but, in most cases, estimation equations using allometry are used **[*Recipe-T14*]**. In order to develop a better allometry equation, accurate biomass data of a large number of trees, including trees with a large DBH, are essential. As biomass data of the forest in question are available in the published data or previous studies, it is encouraged to actively utilize them. However, when very few data are available or the data lack accuracy, tree biomass data need to be collected. For this, destructive sampling covered in this manual must be carried out.

2.2 Measurement procedure

2.2.1 Staff and tools

Here, the staff and tools required for the measurement are explained.

1) Number of staff required for destructive sampling (Table 1)

When carrying out the destructive sampling, the risk of accident caused by the use of a chainsaw or an excavation machine should be taken into account. For safety reasons, it is desirable that more than one staff who has an overview of the entire project be involved in the survey. In addition, the measurement should be carefully planned to prevent an accident. In addition, in order to ensure safety during the survey, it is important to make a plan that includes much time to spare (Tight schedule is not recommended.).

Table 1 Number of staff required for destructive sampling

Role	Desired number of staff
Staff who have an overview of the entire project	At least 2 staff
Excavation machine operator(s)	As required
Chainsaw operator(s)	As required
Assistant staff	5-6 staff

2) Tools required for selecting the felling trees

Select sample trees for destructive sampling. Tools shown in Table 2 and Photo 1 must be prepared to record the size of sample trees (diameter, tree height, etc.) before felling down.

In the field, first, measure the girth at breast height (GBH) using a steel measuring tape and then record in a tally sheet. Then, convert the GBH into diameter at breast height (DBH).

Table 2 Tools required for selecting sample trees

Tool	Number	Remarks
Digital camera	1-2	For recording the size of sample trees before felling down
Tally sheet	2 sets	For data entry and as back-up
Clipboards	2	For data entry and as buck-up
Writing tools	2 sets	For data entry and as back-up
Steel measuring tape, 10 m (Max. 10 m; min. unit 0.1 cm)	3	To measure girth at breast height and crown width
Measuring equipment for tree height (e.g., Vertex)	1 set	
Marking tape	2 rolls	To mark the selected trees

(1) Tally sheet and drawing board

(2) Steel measuring tape (10 m)

(3) Equipment for measuring tree height (Vertex)

(4) Marking tapes

Photo 1 Tools required for selecting the felling trees

TIPS A measuring tape that has different units on both sides such as a diameter tape measure should not be used because it may result in confusion of girth with diameter.

3) Felling, digging, and dividing the felling trees

Tools required for felling down above-ground biomass, digging out below-ground biomass, and separating them to measure the weight of the sample trees are shown in Table 3 and Photo 2.

Table 3 Tools required for felling, digging, and separating sample trees

Tool	Number	Remarks
Excavation machine	1	For digging the below-ground biomass, preparing a mound for collecting roots
Chainsaw	1	For felling and cross-cutting
Hand saw	5	For cutting thin stems and branches
Hoe and/or shovel	2-3	For digging out roots
Tape measure, 50 m (Max. 50 m; min. unit 0.1 cm)	3	For measuring stem length and cross-cutting position
Marking chalk*	20	Including spare
Pruner	3	For cutting thin stems and branches
Work glove	as required	For all staff
First-aid kit		For first-aid treatment

(1) Excavation machine

(2) Chainaw

(3) Hand saw

(4) Tape measure

(5) Marking chalk

(6) Pruner

Photo 2 Tools required for cutting, digging, and dividing the felled trees

TIPS Thick and red chalks are desirable, as they are hard to break and conspicuous, although it depends on the color of the bark.

4) Measuring weight of sample trees in the field (Table 4 and Photo 3)

Measuring the weight of sample trees is the most important work in the survey. Power supply is often unavailable in the field. With this in mind, tools that run on batteries or a spring balance that does not require a power source should be prepared.

Table 4 Tools required for weighing samples

Tool	Number	Remarks
Tarpaulin ◦Large (e.g.,5.4 m × 5.4 m) ◦Small (e.g.,1.8 m × 1.8 m)	 1–2 sheets 4–5 sheets	For separating tree components and for using as tare
Rope ◦Sling (e.g., diameter 25 mm, length 1.5 or 3 m) ◦Plastic rope (thick, 300 m)	 2 2 rolls	For bundling
Plastic bag (thick type) ◦Large (e.g., 600 × 900 mm) ◦Small (e.g., 300 × 500 mm)	 50 sheets 50 sheets	Tare
Felt pen	10	Including spare
Paper bag	100	Tare
Stapler	2	
Staple	2 boxes	
Weighing equipment ◦Spring balance Max 300 kg (min unit 1 kg) Max 50 kg (min unit 500 g) Max 30 kg (min unit 500 g) Max 10 kg (min unit 100 g) Max 5 kg (min unit 50 g) Max 2 kg (min unit 20 g) Max 1 kg (min unit 10 g) ◦Electric spring balance (max 50 kg; min unit 5g)	 1 1 1 1 1 1 1 1	 For weighing stems and roots For weighing small organs For weighing small organs For weighing small organs For weighing small organs For weighing small organs For weighing small organs For weighing branches and leaves
Spare battery	As required	For an electric spring balance
Bowl balance (max 2 kg)	1	
Bar for hanging balance	1	See Photo 11

(1) Tarpaulin

(2) Sling

(3) Paper bag

(4) Spring balance (300 kg)

(5) Electric spring balance (50 kg)

(6) Spring balance (30 kg–1 kg)

Photo 3 Tools required for weighing tree samples

It should be noted that tarpaulin and plastic bags vary in weight, size, and material. During the measurement, staff would be busy working at the study site. Therefore, data should be recorded in a simple way to avoid the omission of recording. For example, fewer types of tares are better to be used. It is desirable to weigh tares before weighing samples.

TIPS Deteriorated spring balance is often a source of error in measurement. It is necessary to check the condition of the spring balance before using it.

TIPS It is advisable to collect the subsamples in a paper bag to bring them back, as they can be placed directly into the drying oven.

5) Measuring weight in laboratory

Carbon stocks used for REDD+ are estimated from dry weight. For this purpose, fresh weight (containing water) measured in the destructive sampling must be converted into dry weight. The ratio of the fresh and dry weight of samples collected at the study site is used to convert fresh weight into dry weight. Thus, samples collected in the destructive sampling are dried in a drying oven in the laboratory for measuring their dry weight. Tools required for measuring the dry weight are shown in Table 5 and Photo 4.

Table 5 Tools required for weighing samples

Tool	Number	Remarks
Drying oven (forced-convection type)	1	For drying sample
Electrical balance (max 3000 g; min unit 0.1 g)	1	For weighing dry sample

(1) Drying oven (forced-convection type)

(2) Electrical balance

Photo 4 Equipment required for drying and measuring samples

TIPS Do not place too much volume of samples in the drying oven to avoid increasing the temperature in the oven or causing a fire.

2.2.2 Survey procedure

Here, the survey procedure of destructive sampling is explained. The destructive sampling is divided into three phases.

Phase 1 Preparation for survey

1) Information collection at the study site

(1) Collection and sorting of information gathered at the study site (e.g., administrative district, universal transverse Mercator (UTM), elevation, and forest type)

(2) Determination of species composition and tree size distribution

Examine the forest type, tree species composition, and tree size distribution at the study site based on published articles or tree inventory data, and then determine the forest type to be selected for destructive sampling.

Phase 2 Field work

1) Selection of trees to be felled

(1) Selecting trees to be felled

Sample trees in the field should be selected from dominant species in suitable size based on DBH (DBH and H, if possible), ranging from the largest size to the smallest and DBH ≈ 5 cm. In particular, since the data of the largest size of sample trees have a significant impact on the accuracy of allometric equations, it is desirable to select more than one tree.

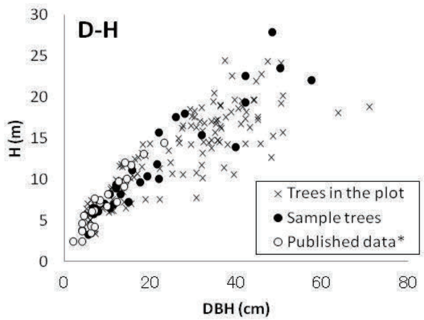


Figure 1 Relationship between DBH and H

The total number of sample trees needed to develop an allometric equation is at least 20–30. The larger the number of individual trees, the more accurate allometric equations can be developed. Destructive sampling is costly and time consuming, but staff will improve their skills in the course of the survey. Therefore, at first, select a slightly larger amount of sample trees and then adjust the number of trees in the course of the survey, taking account of the cost and time.

Figure 1 shows an example of selecting trees for biomass measurement. The standard size and size diversity in the selected forest type obtained based on the published and inventory data must be taken into account when selecting sample trees. If such data are not available, a field survey to determine the tree inventory should be carried out before selecting sample trees.

TIPS Avoid field work on a rainy day and windy day, as branches might fall down due to strong winds.

TIPS In the field, work zone safety and heavy machine transportability are very important factors in selecting sample trees.

(2) Measurement of crown width

Crown width should be measured before felling, because the crown will be broken by the impact of felling. Measure major axis and its orthogonal-oriented diameter.

(3) Marking ground level on stump with chalk

A boundary line is chalk-marked on the stump as the ground level is difficult to identify after felling.

2) Dividing above-ground biomass (AGB) into three components and measurement of fresh weight in each component

(1) Felling down of sample trees

A chainsaw operator should always be alert and aware of potential dangers, while other staff should stay in a safe place.

Photo 5 Measurement of stump height

Photo 6 Marking on main stump

(2) Measurement of stump height (Photo 5)

Based on the ground-level height, measure the height of the felling point and record it.

(3) Marking on main stem (Photo 6)

When the stem is divided, the taller and larger stem will be the main stem. Mark the height of 1.3 m from the ground level and at 2 m intervals from there until the top of the stem using a 50-m measuring tape and chalk. A stem larger than 2 m in length might be heavier than the capacity of the balance (the weighing capacity of 300 kg will be used in this manual). The length of the stem may change depending on the capacity of the balance. In some cases, the stem length measured along the stem is greater than the tree height.

Photo 7 Measurement of stem girth at marking points

Photo 8 Separation of branch from main stem

(4) Measurement of stem girth (Photo 7)

Measure the girth of the stem at the marking points. Measure the point where the lowest living branch is derived from the main stem and its girth and height have to be recorded. After the field work is completed, calculate the diameter of each tree using the girth of the stem (diameter = girth/π).

(5) Separation of stems and branches (Photo 8)

Separate all branches from the stem, sparing the leaves on the branches, using a chainsaw. Separate the stems and branches to avoid confusing thin stems with branches.

Photo 9 Separation of leaves from branches

Photo 10 Measurement of weight of fresh leaves

(6) Separation of branches and leaves (Photo 9)

Separate leaves from branches on a tarpaulin. Sorting them on the tarpaulin is advisable, as leaves and twigs scattered on the tarpaulin can be easily collected by folding the tarpaulin.

(7) Measurement of fresh weight of leaves and branches (Photos 10–12)

Measure the fresh weights of leaves (FW_{lf}) and branches (FW_{br}) using a spring balance or a bowl balance. Record these weights (FW_{lf} and FW_{br}) and the type of tare used.

TIPS Leaves should be measured before measuring branches as leaves dry faster than branches.

Photo 11 Measurement of fresh weight of branches

Photo 12 Leaves and branches after measuring fresh weight

(8) Collection of subsamples

Leaf and branch subsamples should be randomly taken from the weighed leaves and branches, respectively. Record the weight of each subsample and the type of tare used. Place each subsample in a plastic bag labeled with the tree number and components (leaf or branch). Keep the subsamples in the shade.

(9) Separation of stem (Photo 13)

Cut the stem at each marked point (1.3-m height and 2-m intervals) using a chainsaw. After separating the stem, write the tree number and height of the cutting point on the base of each log immediately.

Photo 13 Separation of stem

Photo 14 Measurement of weight of fresh logs using an excavation machine

Photo 15 Measurement of weight of fresh logs by hand

(10) Measurement of weight of fresh logs (Photos 14 and 15)

Weigh fresh logs (stems) using an excavation machine, spring balance (max. 300 kg), and sling. If the log's weight is greater than the capacity of the scale, cut the log into small pieces and weigh each one and record the weights and the tare value. Thin stems and short stems can be weighed by hand.

(11) Collection of stem subsamples (disk samples) for measuring weight (Photo 16)

Collect disk samples (5-cm thick) from the logs at regular intervals. Mark the tree number and the height of each point (e.g., H 1.3 m, H 3.3 m, etc.) on each disk sample.

Weigh each disk sample, and record the fresh weights (FW_{st}) individually. If a tare is used, record the type of tare used.

Photo 16 Disk samples

4) Separation of below-ground biomass (BGB) and measurement of fresh weight (Photo 17)

(1) Digging up of roots (Photo 17)

To expose the underground part of the stump, excavate around it using an excavation machine. Excavation work is dangerous; therefore, keep safe distance from the radius of the working range of the excavator's arm. This should be informed to all staff before the work starts.

TIPS Small sample trees can be pushed down after digging around the stumps using an excavator.


Photo 17 Digging with an excavator


Photo 18 Cleaning of stump

(2) Clean the stump using hoe, etc. (Photo 18)

Place the dug-out stump on a safe place to remove soil. Soil should be removed thoroughly; otherwise, roots heavier than actual weight will be measured.

(3) Measurement of stem girth at ground level (Photo 19)

Stem girth is measured using a steel measuring tape and recorded.

(4) Separation of stump at the ground level (Photo 20)

A stump is separated at the ground level into two parts using a chainsaw. The above-ground stump comprises the stem from 0 m to the felling point; the below-ground stump and roots are defined as below-ground biomass. Determine and record the fresh weight of the samples and the type of tare used.


Photo 19 Checking stem girth at the ground level


Photo 20 Separation of above-ground stump and below-ground stump

(5) Pick up large-sized roots of the sample tree from excavated area (Photos 21 and 22).

Dig up soil around the stump of the felled tree to collect roots left in the ground. In general, most of the roots are in the crown projection area. When the crown projection area of the sample tree and that of adjacent tree overlap each other, determine the digging area according to the size of the stem diameter of both trees. A primary root may grow deep into the ground depending on soil conditions. Collect roots from the dug-up soil. When roots of other trees are mixed in the dug-up soil, remove them, judging from the root bark and other factors. Carefully remove soil from the roots and place them on the tarpaulin.


Photo 21 Picked-up large-sized roots


Photo 22 Cleaned root sample

TIPS Larger size of tarpaulin is useful when determining and recording fresh weight.

(6) Creation of mound (Photo 23)

In the field survey, some roots are left uncollected even when carefully picked up. In particular, a large amount of roots are often left uncollected in trees with large DBH. Therefore, the accurate value of below-ground biomass is complemented by estimating the amount of uncollected roots. Make a mound with soil around the roots to estimate the amount of uncollected roots. In order to estimate the root volume, first mix uniformly soil around the removed root using an excavator and then take out the soil from the pit to make a mound. Next, level the mound surface to make the measurement of the soil volume easier.

Photo 23 Creation of mound

Photo 24 Measurement of mound

(7) Calculation of mound volume (Photo 24)

Measure the areas of the upper and bottom sides and the height of the mound to determine the volume of the mound. This procedure is necessary when estimating the root weight in the entire mount from the root weight in the sample plot.

Measuring positions for determining the areas of the upper and bottom vary, depending on the shape of the mound.

i) Elliptical; long and short span
ii) Trapezoid; long side, short side, and the height of trapezoid
iii) Rectangle; two sides

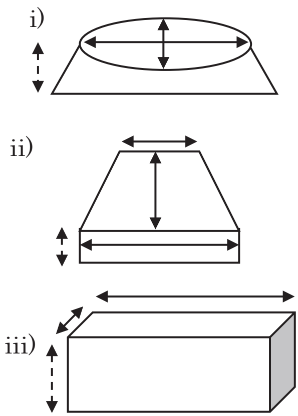


Figure 2 Measuring point of area calculation (solid lines) and mound height (dashed lines)

(8) Collection of roots from mound (Photo 25)

Collecting all the roots in the mound requires a huge labor; therefore, the amount of roots in the mound is estimated by collecting a part of roots in the mound and the mound volume. First, create several sample plots (1 m × 1 m) on the mound depending on the size of the mound and then measure the height of sample plots. In a large mound, increase the number of sample plots. Measure the height of the sample plot and record it.

(9) Collection of roots from sample plot (Photo 26)

Carefully collect roots, including fine roots, from the soil in the sample plot. Do not collect roots of other trees or herbs. Determine the fresh weight of the roots in the sample plot (FW_{mr}). Record the FW_{mr} and the type of tare used.

Photo 25 Creation of sample plot

Photo 26 Collection of roots from sample plot

(10) Collection and weight measurement of below-ground subsample

Below-ground subsample is composed of large roots, below-ground stump, and root sample collected from the mound. Select a subsample considering the weight balance of the components, and then record the subsample's fresh weight and the type of tare used.

Phase 3 Laboratiry work

1) Drying of samples (Photo 27)

(1) Immediately bring the collected subsamples to the laboratory to dry

Photo 27 Sample storage

If a drying oven (forced-convection type) is not available, the subsamples should be air-dried. To prevent the subsamples from rotting during air-drying, the room for drying the subsamples should be well ventilated.

Measure the weight of the heaviest subsamples at intervals during the air-drying process. When the weight of the samples no longer changes, measure all the weights of air-dried subsamples and record the tares used for them.

(2) Oven-drying in laboratory

If an appropriate oven is available, oven-dry subsamples for more than 3 days at an air temperature of 70–90°C. Measure the weight of each oven-dried subsample and record them.

When transporting the subsamples to other countries, prepare the necessary documents for exporting and importing these items in accordance with laws and regulations of the exporting and importing countries.

- When sending or transporting samples to other countries, thoroughly remove soil, insects, fungi, etc. from the samples before packing them. Root samples, in particular, should be washed carefully with water. Place the samples in clean packing cases/ bags to avoid contamination.

- Fully air-dried plant samples are allowed to bring into Japan without a permit. However, sample plant name, component (stem or root or leaf), the purpose of use, etc. are asked at the import quarantine inspection. It is advisable to prepare for it in advance.

2.3 Example of data calculation

Calculate the entire biomass of the individual tree (dry weight) using the data recorded in the tally sheet and the weight of the sample dried in the laboratory. Then, convert the dry weight into carbon.

2.3.1 Conversion to dry weight of individual tree

Convert the fresh weight of each component into dry weight using the ratio of fresh and dry weight of samples.

Biomass of component (kg)
= (fresh weight of component) × (dry weight of subsample) / (fresh weight of subsample)

Below-ground biomass consists of collected below-ground biomass (a portion of stump below the ground and roots collected from dug-up soil) and estimated uncollected below-ground biomass (which is converted from roots collected in the sampling plot on the mound). The method of estimating uncollected below-ground biomass is explained in the next paragraph.

The weight of subsamples is determined by subtracting the tare weight from the fresh and dry weight of subsamples recorded in the tally sheet.

Calculation example:

Calculate the dry/fresh weight of each component based on the weight of subsamples.

Stems → 4.74 ÷ 7.655 = 0.619
Branches → 1.568 ÷ 2.555 = 0.614
Leaves → 0.398 ÷ 1.205 = 0.330
Below-ground biomass → 1.78 ÷ 2.555 = 0.697

Calculate each component biomass.

Stem biomass = 2823.750 × 0.619 = 1747.9
Branch biomass = 520.300 × 0.614 = 319.5
Leaf biomass = 78.640 × 0.330 = 26.0
Below-ground biomass = (42.750 + 61.291) × 0.697 = 560.417

*Tare weight (kg)

Sling 1.0 m, 0.9; Sling 1.5 m, 1.35; Tarpaulin (S), 0.5; Tarpaulin (L), 4.5; Plastic bag (L), 0.09; Plastic bag (S), 0.045; Paper bag, 0.02; Rope, Less than 0.01

2.3.2 Below-ground biomass estimated from uncollected samples

First, calculate the volume of the mound, and then estimate the root biomass left in the entire mound by multiplying the root biomass collected from the sample plot by the ratio of soil volume of the sample plot to that of the mound.

Calculation example:

Volume in elliptic cylindrical-shaped mound soil (m^3)

= (Area of the ellipse, m^2) × (Height of the mound, m)

= (9.0 m^2) × (0.517 m) = 4.653 m^3

Here, two sample plots are created in one mound.

Weight of fresh roots in the entire mound (kg)

= (Weight of fresh roots collected from the sample plot, kg) × (Volume of mound soil, m^3/Volume of sample plot soil, m^3)

= (6.581 kg + 7.031 kg) × (4.653 m^3 ÷ [0.517 m^3 + 0.517 m^3]) = 61.291 kg

2.3.3 Conversion from biomass to carbon

Convert to carbon by multiplying each biomass by 0.47 (2006 IPCC Guidelines for National Greenhouse Gas Inventories).

3 Appendix

Here is a check sheet that is used to ensure that destructive sampling is carried out without skipping any procedure in the field.

3.1 Check list

	Yes	No	
1.	□	□	All size data (tree height, stem girth, crown width, etc.) are recorded in the tally sheet. (If not, write the reason in the remarks.)
2.	□	□	All fresh weights and type of tares used are recorded in the tally sheet.
3.	□	□	Tare weights are measured separately by types.
4.	□	□	Documents for exporting samples are prepared.
5.	□	□	Samples are fully air-dried.
6.	□	□	Soil, insects, mold, and other components are not attached on the samples.
7.	□	□	Soil is washed down from the roots.
8.	□	□	Sample packing cases/bags are clean.
9.	□	□	The amount of sample volume (a total weight including the weight of packing boxes, number of packing boxes, etc.) is consistent with the amount that is allowed to export.
10.	□	□	Samples are species that are allowed to bring into the importing country.

3.2 Flow chart

[Flow chart of field works]

Part 1 Tree selection and measurement before felling

1. Tree selection
   - Selection from dominant species
   - Selecting suitable size
2. Measurement of DBH (if possible, DBH and H) of selected sampling trees
3. Measurement of crown width
4. Chalk-marking of ground level on stumps

Part 2 Fresh weight measurement of above-ground biomass (stem, branches, and leaves)

1. Cut tree with a chainsaw
2. Measure the height of felling point
3. Mark the height points on the stem
   - Mark at the point of 1.3 m from the ground level
   - Mark every 2 m from a point of 1.3-m height to the top of the stem
4. Measure the height of the lowest living branch
5. Measurement of stem girth at the marking points
   Measure girth at the height of the lowest living branch
6. Remove all branches from the stem using a chainsaw
7. Divide the leaves from the branches on a tarpaulin
8. Weigh fresh leaves and branches
9. Pick leaf and branch subsamples
   Weigh each subsample
10. Separate the main stem
    - Cut at the marked position using a chainsaw
11. Weigh fresh logs
12. Pick stem subsamples (disk samples) and weigh them

Part 3 Fresh weight measurement for below-ground biomass (stump and roots)

Excavate around a stump using an excavation machine
• Keep a safe distance from the excavation as working with an excavation machine is dangerous

↓

Clean the stump using a hoe

↓

Measure the stem girth at ground level

↓

Divide the stump at the point of above- and below-ground level using a chainsaw

↓

Weigh samples of the upper and lower ground-level parts
• Upper ground-level parts comprise stems and are defined as above-ground biomass (AGB)
•Lower ground-level parts comprise roots and are defined as below-ground biomass (BGB)

↓

Excavate the root network & pick large-sized roots

↓

Clean the roots and determine their fresh weights

↓

Mound the dug up soil using an excavation machine

↓

Measure the mound size (area and height)

↓

Make a sampling plot (1 m × 1 m) on the mound
• Measure the height of the sampling plot

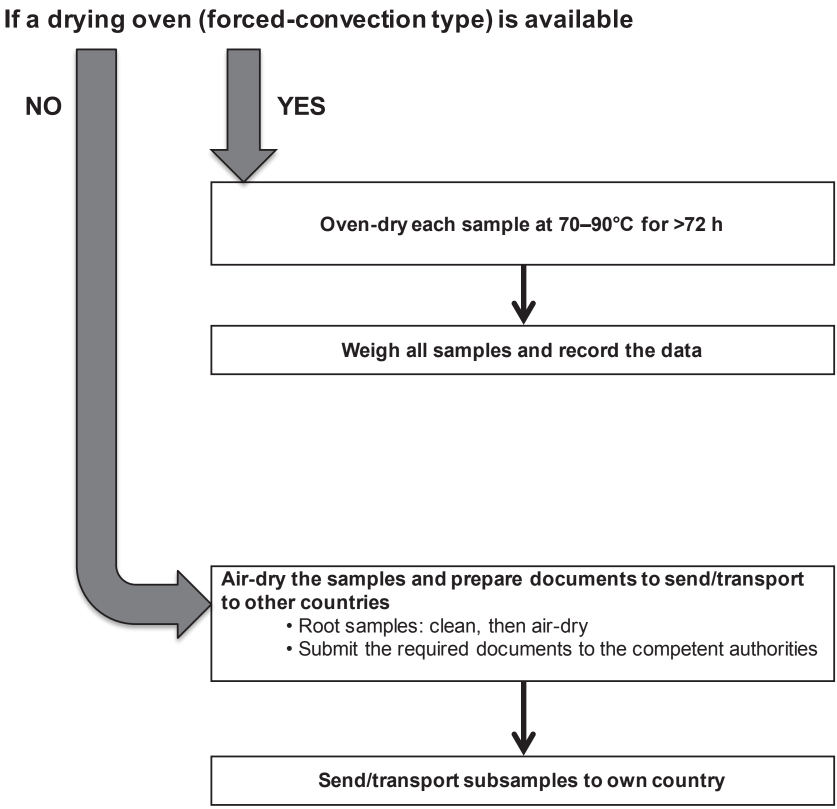
↓

Carefully collect the root samples from the sampling plot and weigh them

↓

Collect the below-ground subsamples and weigh them
• A below-ground subsample comprises roots, below-ground stump, and roots collected from the sampling plot

[Flow chart of laboratory works (drying process)]



3.3 Entry example of field note

The data obtained by destructive sampling are recorded in the common data entry sheet. This will help find incomplete data in measurement in the field or omissions in entry.

3.3.1 Example of AGB data entry

Example	Tree No. 3		page 1/2
調査年月日 date	22-Dec-2010	樹高H (m) Tree height	22.6
Speacies	*Terminalia tomentosa*	胸高幹周GBH (cm) Girth breast height	131.9
調査地 Location name	*Kratie tower site*	伐採位置の高さHcut(m) Height of cut height	0.57
計測者 Surveyor	Monda	生枝下高H_{LB}(m) Height of the lowest living branch	15.5
		生枝下幹周(cm) Girth of the lowest living branch	70.8
		樹冠幅 (m) Crown width	9.3

		No.	Base side sampling Height(m) 下端高さ	Base side **Girth(cm)** 下端周囲長	Fresh weight with tare(kg)	Remarks	Tare
Aboveground Biomass	**Stem**	0	0	157.0	157		sling(1m+1.5m)
		1	0.3	151.7	240		sling(1m+1.5m)
		2	1.3	144.0	379		sling(1m+1.5m) ×2
		3	3.3	143.0	384		sling(1m+1.5m)×2
		4	5.3	133.0	345		sling(1m+1.5m)×2
		5	7.3	118.0	266		sling(1m+1.5m)
		6	9.3	110.0	240		sling(1m+1.5m)
		7	11.3	99.0	231		sling(1m+1.5m)
		8	13.3	98.5	171		sling(1m+1.5m)
		9	15.3	94.1	156		sling(1m+1.5m)
		10	17.3	76.5	119		sling(1m+1.5m)
	Large size branches	1			55		rope
		2			39		rope
		3			33		rope
		4			18		rope
		5					
	Small branches	1			49		tarpaulin(L)
		2			21.5		tarpaulin(S)
		3			44.5		rope
		4			41		rope
		5			41.3		rope
		6			42		rope
		7			44.5		rope
		8			41.5		rope
		9			35.5		rope
		10			19.5		rope
	Leaves	1			3.9		plastic bag(L)
		2			3.8		plastic bag(L)
		3			1.8		plastic bag(L)
		4			2.3		plastic bag(L)
		5			5.3		plastic bag(L)
		6			4.5		plastic bag(L)
		7			5.8		plastic bag(L)
		8			5		plastic bag(L)
		9			6.6		plastic bag(L)
		10			3.6		plastic bag(L)

		22-Dec-2010		5-Jan-2011	6-Feb-2011	
Subsample		Fresh weight with tare(kg)	Tare	Air-dry weight (kg)	Oven-dry weight (kg)	Tare
Stem	H 1.3	7.65	plastic bag(S)	5.55		
	H 9.3	7.7	plastic bag(S)	5.84	4.76	paper bag
	H 17.3	4.5	-	3.29		
	H 25.3	0.2	-	0.0128		
Large size Branches		incl. small size branches				
Small size Branches		2.6	plastic bag(S)	1.93	1.5879	paper bag
Leaves		1.25	plastic bag(S)	0.47	0.4177	paper bag

3.3.1 Example of AGB data entry (continued)

Tree No. 3 page 2/2

調査年月日 date	22-Dec-2010	樹高H (m) Tree height	22.6
Speacies	*Terminalia tomentosa*	胸高幹周GBH (cm) Girth breast height	131.9
調査地 Location name	*Kratie tower site*	伐採位置の高さHcut(m) Height of cut height	0.57
計測者 Surveyor	Monda	生枝下高H_{LB}(m) Height of the lowest living branch	15.5
		生枝下幹周(cm) Girth of the lowest living branch	70.8
		樹冠幅 (m) Crown width	9.3

		No.	Base side sampling Height(m) 下端高さ	Base side **Girth(cm)** 下端周囲長	Fresh weight with tare(kg)	Remarks	Tare
Aboveground Biomass	**Stem**	0	19.3	56.0	89		sling(1.5m)
		1	21.3	41.0	51		sling(1m)
		2	23.3	24.0	21.5		rope
		3	25.3	7.8	8	incl. tip of stem	rope
		4	27.3				
		5					
		6					
		7					
		8					
		9					
		10					
	Large size branches	1					
		2					
		3					
		4					
		5					
	Small branches	1					
		2					
		3					
		4					
		5					
		6					
		7					
		8					
		9					
		10					
	Leaves	1			3.8		plastic bag(L)
		2			3.9		plastic bag(L)
		3			2.7		plastic bag(L)
		4			2.4		plastic bag(L)
		5			5.9		plastic bag(L)
		6			7.45		plastic bag(L)
		7			5		plastic bag(L)
		8			1.6		plastic bag(L)
		9			5		plastic bag(L)
		10					

Subsample	Fresh weight with tare(kg)	Tare	Air-dry weight (kg)	Oven-dry weight (kg)	Tare
Stem					
Large size Branches					
Small size Branches					
Leaves					

3.3.2 Example of BGB data entry

Example **Tree No. 7** page 1/1

調査年月日 date	19-Nov-2011	地際幹周G_0(cm) Girth of ground level(height=0m)	188
Speacies	*Shorea siamensis*	計測者 Surveyor	Monda

		No.	Fresh weight with tare(kg)	Remarks	Tare
Belowground biomass	**Stump and large roots**	1	183	stump	sling(1m+1.5m)
		2	144	root	sling(1m+1.5m)
		3	114	root	sling(1m+1.5m)
		4	181	root	sling(1m+1.5m)
		5	132	root	sling(1m+1.5m)
		6			
		7			
		8			
		9			
		10			
	Mound roots	1	16.3		tarpaulin(S)
		2	11.50		tarpaulin(S)
		3			

Mound roots

Area	Shape	Side length or diameter(m)
Mound1	elliptical	3.7 × 3.1
Mound2		
Mound3		

Height		Height of the mound(cm)
Mound1	elliptical	50, 55, 50
Mound2		
Mound3		

Subsample	19-Nov-2011 Fresh weight with tare(kg)	19-Nov-2011 Tare	12-Feb-2011 Air-dry weight (kg)	9-Mar-2011 Oven-dry weight (kg)	9-Mar-2011 Tare
Roots and stump	2.6	plastic bag(S)	2.2	1.8	paper bag

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