

# COOKBOOK ANNEX

Research Manual Vol. 4  
Ground Truth Survey

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## **Preface**

The basic concept of REDD-plus is to provide economic incentives such as funding or credits to developing countries for REDD activities (reducing emissions from deforestation and forest degradation) and "plus" activities (reducing CO<sub>2</sub> emissions and CO<sub>2</sub> levels in the atmosphere by carbon sequestration). Thus, in order to estimate the changes in the amount of carbon stored in forests, monitoring using 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 which provide basic knowledge and techniques required for REDD-plus with the main focus on the forest carbon monitoring methods. Knowledge and techniques required for REDD-plus are compiled in units called "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 the REDD-plus activities.

As REDD-plus Cookbook focuses on basic knowledge and techniques required for REDD-plus, the experts working on the 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. Also, this manual is intended to be used as a textbook for building capacity. 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 many parts of the world.

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



# Contents

<b>1 Outline</b>	<b>1</b>
1.1 Purpose of REDD-plus Cookbook Annex	1
1.2 How to use this survey manual	1
1.3 Recipes covered by REDD-plus Cookbook	1
<b>2 Ground truth survey design —A survey method using the Bitterlich method</b>	<b>2</b>
2.1 What is the ground truth survey used for?	2
2.2 Steps to perform the ground truth survey	2
2.3 What is the Bitterlich method?	2
2.4 Preparation for the survey	2
2.5 Preparing satellite images and selecting ground truth survey points	3
<b>3 Conducting the ground truth survey</b>	<b>4</b>
3.1 Necessary survey tools	4
3.2 The survey team composition	5
3.3 Navigation to survey points	5
3.4 Choosing survey points	5
3.5 Measurements and records taken at survey points	5
3.5.1 Records of survey points	6
3.5.2 Forest condition of survey points (understanding the hierarchical structure and coverage)	7
3.5.3 Selection of the survey target trees, identification of tree species, and measurements of the DBH and tree height	7
3.5.4 Photography	8
3.5.5 Sketches	8
3.5.6 Additional Bitterlich count	9
3.5.7 Notes	9
<b>4 Processing the survey data</b>	<b>10</b>
4.1 Inputting survey data	10
4.2 Calculation of AGB for surveyed trees	10
<b>Appendix</b>	<b>12</b>
How to use the tools	12
An example of the survey note	17
<b>References</b>	<b>21</b>

## 1 Outline

### **1.1 Purpose of REDD-plus Cookbook Annex**

The “REDD-plus Cookbook,” published by the Forestry and Forest Products Research Institute in 2012, is a technical manual that simply explains the basic knowledge and techniques for REDD+ with a focus on forest carbon monitoring. This survey manual explains the survey method with a focus on the ground truth survey, which is necessary to estimate forest area using remote sensing techniques shown in the REDD-plus Cookbook.

This manual was prepared with technologists in mind, who conduct ground truth surveying in the field. We hope that it also provides useful information to students studying forestry and forest remote sensing, and organizations, such as NGOs, that are interested in REDD+.

### **1.2 How to use this survey manual**

The ground truth survey is performed to collect ground information necessary for analysis using satellite imagery, so multiple survey plots are usually set, which all must be accurately measured. In addition, the surveying is often performed by multiple teams to improve the efficiency; thus, survey methods should be confirmed ahead of time. When planning and conducting a ground truth survey, this manual should be referred to so that all surveyors understand the steps of the survey and measurement methods.

This manual explains the methods of ground truth surveying using the Bitterlich method (Chapter 2), followed by an explanation of the specific steps for an actual survey (Chapter 3). Finally, steps and methods to calculate carbon stock for each of the survey points, from measurement data collected in the field survey, are specifically explained (Chapter 4).

Please refer to TIPS as this is where we offer useful knowledge and cautionary recommendations from past experiences with ground truth survey.

### **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 sites below.

[http://redd.ffpri.affrc.go.jp/pub\\_db/publications/cookbook/index\\_en.html](http://redd.ffpri.affrc.go.jp/pub_db/publications/cookbook/index_en.html)

## 2 Ground truth survey design —A survey method using the Bitterlich method

### 2.1 What is the ground truth survey used for?

Ground truth refers to the actual information of the target on the ground and is necessary for land cover classifications using remote sensing data and for verifying classification results [Recipe-T08]. It is also necessary for estimating land area based on remote sensing [Recipe-P08], which is used to calculate changes in carbon stock with the stock change method [Recipe-P07].

### 2.2 Steps to perform the ground truth survey

The ground truth survey (also called the GT survey) is performed in the order of: survey preparation, field surveying, and then data processing.

First, preparation of the survey is necessary. Satellite images of the survey target area are prepared [Recipe-T08], and the survey candidate sites are determined. Then, the various preparations necessary for the completion of the survey are made. Once the preparation is completed, the field survey is conducted, tree measurements are performed, and so on. In addition, from the obtained field survey data, information including above-ground biomass is calculated, which will be used for the analysis for the satellite images.

In this manual, we present specific steps for ground truth surveying using the Bitterlich method as an example.

### 2.3 What is the Bitterlich method?

The Bitterlich method, also called angular count sampling or angle count sampling, is a method of measuring a forest by estimating the total basal area per unit area by counting the standing trees. The trees used for counting are determined by a predetermined angle. There is no need to set a plot for the survey, which is the reason it is sometimes called plotless sampling.

#### TIPS

Simple explanation of the Bitterlich method is on page 13.

### 2.4 Preparation for the survey

First, the pretreatment of satellite images of the target site and the selection of the ground truth survey candidate points are performed. At the same time, the ground truth survey is planned with considerations given to climate, weather conditions, traffic access, accommodations, and cost necessary for the staff and survey. To conduct the survey, permission from the landowner may be necessary. In such a case, the necessary permission by landowners must be acquired

beforehand.

## **2.5 Preparing satellite images and selecting ground truth survey points**

Pretreatment of satellite images, including the target site, is performed [Recipe-T06]. When using the object-based classification method, pretreated satellite images are used to perform the object-based classification. Statistically appropriate numbers of survey points are selected, and the candidate survey points are selected on the images [Recipe-T08].

When using object-based classification, the survey points avoid the edge of objects, so that the ground truth survey candidate points are set within a certain distance inside the object boundary (at least 2 to 3 pixels).

Position information of the candidate survey points is summarized in a list. Smart devices that are able to display spatial information (smartphone, tablets, etc.) would be useful if the position information of the candidate survey points are stored.



3 Conducting the ground truth survey

3.1 Necessary survey tools

Tools necessary for the ground truth survey are as follows (Table 1, Photograph 1).

Table 1. Tools necessary for the survey.

Product name	Number of units	Notes
GPS	1	To navigate to survey points and record positions.
Digital camera	1	To record the forest type at the survey point.
Inclinometer	1	To record the slope of the survey point.
Compass	1	To navigate to and measure the direction of survey points.
Altimeter (VertexIV)	1	To measure tree heights.
Tape measure	1-2	To measure diameters.
Markers	Several	To mark measurement positions and measured trees.
Stake as markers	1-2	To mark survey points.
Fieldnotes	1	To record survey results.
Pens/pencils	Several	To record survey results.
Bitterlich dendrometers (Ludde, Prism, etc.)	1-3	To determine survey target trees with the Bitterlich method.



Ludde



Prism



GPS



Compass and inclinometer



Altimeter (VertexIV)



Tape measure

Photograph 1. Tools necessary for a survey.

### 3.2 The survey team composition

For safety reasons, the ground truth survey should be conducted by multiple members. (Table 2). When there is a large number of people, consider breaking up the members into multiple teams.

Table 2. Roles and numbers of the survey teams

Role	Desired number	Notes
Bitterlich count	1-2	Count trees at the center of survey points. When there are multiple points, run counts concurrently.
Basal area measurement	1-2	Measure basal area of trees that are counted. This job can be performed by the same person who is in charge of the transponder for tree height measurement.
Tree height measurement	1-2	One person to take measurements using the instrument for tree measurements and one person in charge of the transponder. The person in charge of the transponder can also be the person in charge of basal area measurement.
Recording fieldnotes	1	Record measurement results, etc., in the fieldnote.
Species identification	1	This job can be shared with field basal area measurement or field note record taking.

### 3.3 Navigation to survey points

Move to the candidate survey points using maps, a compass, GPS, or smart devices.

#### TIPS

Please see page 12 for how to navigate with a compass.

### 3.4 Choosing survey points

Upon arriving at the candidate points, survey points are chosen. Select locations that represent surrounding forest conditions and set the center for a survey point where the Bitterlich count is taken is determined, and set mark.

### 3.5 Measurements and records taken at survey points

Once survey points are determined, all members conduct forest measurements and record the results. An example of the notes taken in a survey is provided in appendix \*. Detailed measurements and records are explained in the order of sample note.

### 3.5.1 Records of survey points

Ground Survey Note: Used to record information obtained from a field survey. One sheet per survey point. Here, we explain the contents per item.

General Information: All items related to the summary of the survey point.

Crew Member: Record all members of the survey team.

Date (DD/MM/YY): Record the survey date.

Plot ID: Record the ID to identify the survey point.

#### TIPS

An example of a plot ID is three letters and two numbers, and a rule should be prepared so that there are no duplicate IDs.

Province: Note the name of the Province.

District: Note the name of the District.

Time of Survey: Note the time of the survey.

Start Time: Note the start time of the survey with the 24-hour clock.

End Time: Note the end time of the survey with the 24-hour clock.

Plot Information: Describe the selected survey points.

Plot Location WGS84: Note the GPS measurements for the position of the survey point.

#### TIPS

If using a Garmin GPS, use the Waypoint Averaging function, and record the measurements for the center of the survey point.

#### TIPS

When saving measured values on the GPS, recommended point name is the Plot ID. This makes easier to reference at a later time.

Latitude: Record the latitude of the survey point in the WGS84 format.

Longitude: Record the longitude of the survey point in the WGS84 format.

Altitude: Record the altitude of the survey point in meters.

GPS Receiver: Record the name of the GPS receiver used.

Topography: Record the topography of the survey point.

Slope Direction: Examine the direction of the slope using the compass, and record it down to eight directions.

#### TIPS

If there is no slope, cross out the item.

Slope Angle: The slope is measured with an inclinometer and recorded by degrees. If there is no slope, note 0 degrees.

### 3.5.2 Forest condition of survey points (understanding the hierarchical structure and coverage)

Forest Condition: Record the state of the forest.

Crown Coverage: Crown coverage is recorded as one of five stages (0-20%, 20-40%, 40-60%, 60-80%, and 80-100%).

Total Stories: Coverage of the overall forest is evaluated and recorded.

Upper + Middle: Coverage of the upper and middle stories is evaluated and recorded.

Upper story: Coverage of the upper story, with the middle story excluded, is evaluated and recorded.

#### TIPS

Coverage is determined and evaluated by all members of the team.

Note for Disturbance: Note the information related to the disturbance of the forest. For example, comments such as “there are new/old stumps” and “there are pioneer species observed after disturbance”.

### 3.5.3 Selection of the survey target trees, identification of tree species, and measurements of the DBH and tree height

Bitterlich Note: Record items according to the Bitterlich method.

Bitterlich Method Measurement: Measurements with the Bitterlich method.

Basal Area Constant (k): Record basal area constant (k).

#### TIPS

When using a Ludde, the basal area constant is 1.

Total Count: Record the Bitterlich count.

#### TIPS

Explanation of the Bitterlich method is on page 13.

#### TIPS

Total Count is equal to the sum of the survey tree count.

Tree Measurement: For target trees of the Bitterlich method, measurement information is recorded as 1 or 0.5.

No.: Number of the tree being surveyed.

SP: Record the species name or a common name.

DBH(cm): Record the diameter at breast height.

**TIPS**

The standard height for DBH measurement is 130 cm from the ground surface.

**TIPS**

DBH is measured for all counted trees by the Bitterlich method. However, if tree trunks branch apart or are deformed due to a knot or rot at 130 cm, the diameter is measured above or below at the closest height.

**TIPS**

The measurement method for DBH is explained in detail in [\[Cookbook Annex Vol. 1\]](#).

H(m): Tree height is measured with an altimeter and results are recorded.

Count: Record the Bitterlich count (1 or 0.5).

**TIPS**

Usage of a Ludde is explained on page 13.

### 3.5.4 Photography

Photograph (filename): Take photographs of the forest at the survey point. At the center of the survey point, take photographs in all four cardinal directions and record the file name of photographs.

### 3.5.5 Sketches

Sketch of the Forests Condition: Sketch the cross section of the forest around the survey point. At this time, it would be useful to record a scale for rough tree heights and species names (abbreviations are acceptable) so that the hierarchical structure and condition of the forest floor would be clear.

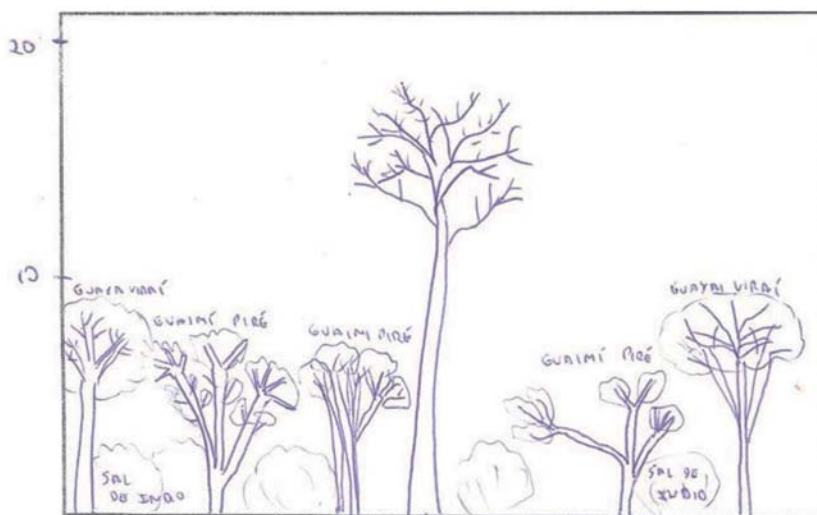


Figure 1. Example of a sketch.

### 3.5.6 Additional Bitterlich count

Additional Counts (3-5 points): At several locations around the survey point, conduct the Bitterlich count method and record the total count.

#### TIPS

To avoid duplicate tree counts, additional counts surveys should be conducted at a suitable distance from each other.

### 3.5.7 Notes

Note important items related to the target forests, such as the landowner name, contact information, name of the forest, distance from the road, and surrounding land use.

## 4 Processing the survey data

The ground truth survey data collected in Section 3 are processed, and above-ground biomass (AGB) is calculated using an allometry method. Here, let us introduce an example of a survey conducted in a tropical forest in South America.

### TIPS

Please refer to [[Cookbook Annex Vol. 1](#)] for the calculation of AGB using the allometry method.

### 4.1 Inputting survey data

Information noted under the 1) Ground Truth Survey Note and 2) Bitterlich Note is summarized in a spreadsheet used for AGB calculations. The measurement results for the surveyed trees at the survey point EGC03 are as follows.

Table 3. Information of survey trees at the survey point EGC03.

ID	No.	SP	H (m)	DBH (cm)	Count
EGC03	1	Quebracho colorado	14.8	16.9	1
EGC03	2	Algarrobillo	21.7	26.8	1
EGC03	3	Algarrobillo	8.4	10.1	1
EGC03	4	Karanday	9.1	10.6	1
EGC03	5	Algarrobillo	9.5	8.2	0.5
EGC03	6	Algarrobillo	19.1	19.9	1
EGC03	7	Quebracho colorado	15.6	19.2	1
EGC03	8	Quebracho colorado	10.9	15.3	1
EGC03	9	Kumanda	16.4	24.7	1

### 4.2 Calculation of AGB for surveyed trees

First, select an allometry equation and the parameters needed to estimate AGB.

Since the survey was conducted in a South American tropical forest, we used the general allometry equation of Chave *et al.* (2014) that is widely used in tropical areas:

$$AGB_i = 0.0673 * (\rho D_i^2 H_i)^{0.976}$$

where  $D_i$  and  $H_i$  represent DBH (cm) and tree height (m) of tree  $i$ , respectively. For wood density  $\rho$ , the default value for tropical zones (South America) is applied (0.60 g cm<sup>-3</sup>). For example, in the case of tree no.1 Quebracho Colorado:

$$\begin{aligned} AGB_{No.1} &= 0.0673 * (0.60 * (16.9)^2 * 14.8)^{0.976} \\ &= 0.0673 * (2536.2)^{0.976} = 141.4 \text{ kg} \end{aligned}$$

Next, when converting the AGB of this surveyed tree to per ha, AGB needs to be multiplied by the Bitterlich count method (1 or 0.5) and the number of trees per ha,  $N$ . The number of trees per ha for tree  $i$  ( $N_i$ ) can be calculated with:

$$N_i = \frac{4k}{\pi D_i^2}$$

Since this survey used a Ludde, and  $k = 1$ , the number of trees per ha for tree no.1 ( $N_{No.1}$ ) is:

$$N_{No.1} = (4 * 1) / (3.14 * (16.9 / 100)^2) = 44.6 / \text{ha}$$

If the count of tree  $i$  is  $C_i$ , then AGB of tree  $i$  per ha ( $AGB_{h,i}$ ) can be calculated with:

$$AGB_{h,i} = AGB_i * N_i * C_i$$

Therefore, AGB per ha for tree no.1 ( $AGB_{h,No.1}$ ) is calculated with:

$$AGB_{h,No.1} = 141.4 * 44.6 * 1 = 6306.4 \text{ kg/ha}$$

This calculation is performed for all surveyed trees, and when all AGB values are summed, the AGB of the survey point per ha is obtained (Table 4). AGB of the survey point EGC03 is ca. 51.3 t/ha.

Table 4. Summary of AGB at the survey point EGC03.

ID	No.	SP	H (m)	DBH (cm)	Count	AGB (kg)	N(ha)	AGB (kg/ha)
EGC03	1	Quebracho colorado	14.8	16.9	1	141.4	44.6	6306.4
EGC03	2	Algarrobbillo	21.7	26.8	1	505.4	17.7	8945.6
EGC03	3	Algarrobbillo	8.4	10.1	1	29.8	124.8	3719.0
EGC03	4	Karanday	9.1	10.6	1	35.4	113.3	4010.8
EGC03	5	Algarrobbillo	9.5	8.2	0.5	22.4	189.4	2121.3
EGC03	6	Algarrobbillo	19.1	19.9	1	249.5	32.2	8033.9
EGC03	7	Quebracho colorado	15.6	19.2	1	191.0	34.5	6589.5
EGC03	8	Quebracho colorado	10.9	15.3	1	86.4	54.4	4700.2
EGC03	9	Kumanda	16.4	24.7	1	327.9	20.9	6853.1
							Total	51279.8

**TIPS**

If a spreadsheet with formulas is prepared, calculations are much easier.



## Appendix

### How to use the tools

#### 1) Compass

A compass is affected by magnetism; therefore, when using a compass, objects with magnetism, such as a magnet or electronic devices (e.g., cell phones), must be kept at a distance.

- Measurement methods for the slope direction
  - (1) Face the direction of the steepest slope.
  - (2) Hold the compass in front of your body.
  - (3) When the magnetic needle and the bezel (usually red and black) match, the number outside of the bezel indicates the angle of the direction.
- Measurement method for the slope angle (only with measurement function)
  - (1) Face the direction of the steepest slope.
  - (2) Determine a position that is the height of your eyes and take a measurement using the slope function. At this time, if an item (person, stick, etc.) is used to indicate the height of your eyes, measurements would be more accurate.
- A method to walk straight in the determined direction.
  - (1) Face the direction into which you intend to walk.
  - (2) Hold the compass in front of your body.
  - (3) Match the magnetic needle and the bezel (usually red and black).
  - (4) Pick a marker at a distance in the direction in which you intend to walk (tree, branch, etc.).
  - (5) Walk towards the marker.
  - (6) Hold the compass in front of your body and face the direction in which the needle and the bezel match.
  - (7) Repeat steps (4) to (6).
- A method to guide toward the predetermined direction.
  - (1) Face the direction in which you intend to walk.
  - (2) Hold the compass in front of your body.
  - (3) Match the magnetic needle and the bezel (normally red and black).
  - (4) Pick a marker at a distance in the direction in which you intend to walk (tree, branch, etc.).
  - (5) Let the person walk forward and if he/she veers off, guide them into the right direction.
  - (6) When there is so much distance that the guide and the walker cannot confirm the direction,

stop walking.

(7) The guide joins the walker.

(8) The guide holds the compass in front of his/her body, and faces the direction in which the needle and the bezel match.

(9) Repeat steps (4) to (8).

Make sure to read the instruction manual thoroughly before use.

## 2) Ludde

A Ludde is the tool for a Bitterlich count.

### TIPS

Tools for Bitterlich count include the Bitterlich prism and Relascope, in addition to the Ludde.

• How to complete a Bitterlich count using a Ludde.

(1) Using the chain of the Ludde and holding it properly, aim the gauge toward the tree you wish to measure.

(2) If the tree is smaller than the gauge, do not count it (non-tally, Figure 2A). If the tree is larger than the gauge, record as count 1 (Figure 2B). If the gauge and the tree are exactly the same size, record as count 0.5 (Figure 2C).



A: Count = 0



B: Count = 1



C: Count = 0.5

Figure 2. Bitterlich count using a Ludde.

### TIPS

If the tree is even slightly larger than the gauge, record as count 1, and if it is even slightly smaller, do not record it.

## Explanation of the Bitterlich method

The Bitterlich method is explained in textbooks and websites about forest mensuration. Here, we introduce excerpts from “Bitterlich sampling” from AWF-WIKI.

Even trees of the same size could appear differently based on the distance to the standing tree from the observer (Figure 3).

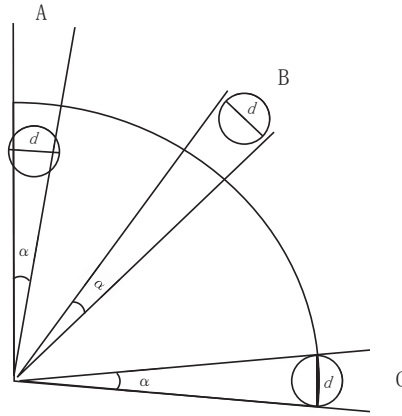


Figure 3. Relationship between the distance to the tree and the opening angle (from AWF-WIKI).

When the opening angle,  $\alpha$ , is determined, if the distance to the target tree is closer, the width of the tree appears wider (Figure 3A, count 1). If the distance is further, it appears thinner (Figure 3B, count 0). If the tree is at the right distance, the width will match the angle  $\alpha$  (Figure 3C, count 0.5).

At a given point, look around 360 degrees and compare the width of a tree viewed with the opening angle of  $\alpha$  with the width of the stem of the tree to select the tree to count. By multiplying the count total ( $N$ ) with the basal area factor ( $k$ ), determined by the opening angle  $\alpha$ , the sum of basal area per unit area ( $G$ ) is estimated.

In other words, the total basal area per unit area ( $G$ ) is expressed as:

$$G = kN$$

Basal area factor ( $k$ ) and the opening angle ( $\alpha$ ) have the following relationship:

It is known that there is relationship between the AGB and total basal area of forest stands.

$$k = 10000 * \left( \sin \frac{\alpha}{2} \right)^2$$

If there is a relationship equation for the total basal area and AGB of forest stands, the AGB of the stands can be estimated.

If measuring DBH and tree height of counted trees, the AGB can be estimated with a different way. If we look from the viewing point with the angle  $\alpha$  and assume that DBH of counted tree

$i$ , counted as 0.5, is  $d_i$ , it must be on the circumference of a circle with the radius of  $R$  from the view point. In other words, it can be assumed that there is one standing tree  $i$  with DBH  $d_i$  in the area  $\pi R^2$  of a circle with radius  $R$ . If we assume that there are standing trees with the same diameter as the standing tree  $i$  ( $d_i$ ) at the same area ratio, the number of standing trees with the same basal area per unit area (usually 1 ha) is:

$$N = \frac{10000}{\pi R^2}$$

where  $R$  is:

$$R = \frac{d_i}{2 \sin \frac{\alpha}{2}}$$

and:

$$\sin \frac{\alpha}{2} = \frac{\sqrt{k}}{100}$$

thus:

$$R = \frac{50d_i}{\sqrt{k}2}$$

therefore,  $N$  is:

$$N = \frac{4k}{\pi d_i^2}$$

if the AGB of the standing tree  $i$  (AGB <sub>$i$</sub> ) can be estimated using the measured values, such as DBH and tree height, along with the allometry equation, the AGB per unit area of AGB <sub>$i$</sub>  (AGB <sub>$h_i$</sub> ) with the same DBH  $d_i$  is:

$$AGB_{h_i} = c * AGB_i * N$$

If we assume that the standing tree  $i$  with count 1 is within the area ( $\pi R^2$ ) of a circle with a radius of  $R$ , and the area ratio is the same, the number of standing trees  $N$  with the basal area of  $d_i$  and the AGB per unit area ( $V_i$ ), are also calculated with the same equation.

If AGB per unit area (AGB <sub>$h_i$</sub> ), calculated for each standing tree counted is summed, AGB per unit area for the survey point (AGB <sub>$h$</sub> ) can be obtained:

$$AGB_h = \sum AGB_{h_i}$$



## Ground Truth Survey Note

General Information									
Crew Member									
Date(D/M/Y)	/	/					Plot ID		
Province				District					
Time of Survey 24H									
Start Time	:		End Time		:				
Plot Information									
Plot Location WGS84									
Latitude				Longitude					
Altitude				GPS Receiver					
Topography									
Slope Direction	N , NE , E , SE, S , SW , W , NW								
Slope Angle									

An example of the survey note (1/2)

Forest Condition						
Crown Coverage						
Total Stories	0-20%	20-40%	40-60%	60-80%	80-100%	80-100%
Upper+Middle	0-20%	20-40%	40-60%	60-80%	80-100%	80-100%
Upper story	0-20%	20-40%	40-60%	60-80%	80-100%	80-100%
Note for Disturbance						
Memo						

Bitterlich Method Measurement		Additional counts (3 - 5 points)
Basal Area Constant (k)		
Total Count		

Tree measurement									
No.	SP	DBH (cm)	H (m)	Count	No.	SP	DBH (cm)	H (m)	Count
1					16				
2					17				
3					18				
4					19				
5					20				
6					21				
7					22				
8					23				
9					24				
10					25				
11					26				
12					27				
13					28				
14					29				
15					30				



An example of the survey note (2/2)		
Photograph	Sketch	



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