



FOREST BIOMASS MONITORING FOR REDD+

MANUAL

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INTRODUCTION

Project Background

Forestry and Forest Products Research Institute (FFPRI) and Forest Research Institute Malaysia (FRIM) has a collaborative project on forest carbon monitoring, reporting and verification (MRV) system for a REDD+ participating country by combining the country's conditions with the international requirements, appropriate available technologies and scientific knowledge. The project is divided into three components namely remote sensing, biomass inventory and socio-economy.

Objectives of the study are:

- i. Monitoring land uses and land-use changes using remote sensing techniques,
- ii. Monitoring forest carbon stocks by ground sampling, and
- iii. Social and economic analysis of forest change.
- iv. Development of practical guidelines for forest carbon monitoring for REDD+

Systematic sampling with a sufficient number of plots and frequent updating of averaged carbon stock data is vital for an accurate estimation of CO₂ emissions from forests under pressure of land-use change and forestry activities. Tree biomass was selected as the most important carbon pool in forest carbon stock. Existing equations and factors will be used for estimating tree biomass and its carbon stock. The number of permanent sample plot (PSPs) depends on the desired level of precision, deviation of carbon stock for each stratum, etc. By moderately classifying forest types by means of satellite imagery etc. in terms of representation and interpretation of samples, a reasonably accurate estimation of carbon stock is expected. If a sufficient number of PSPs are available, highly reliable estimation is possible.

Therefore, this study will provide information of number and distribution of PSPs for reasonably accurate estimation of carbon stock. By multiplying the averaged carbon stock and forest area for its determined category, reliable forest carbon stock values can be obtained, less expensively at the sub-national or regional level. Some supplemental studies for estimating tree biomass carbon stock changes in logging also be conducted.

What is REDD+?

REDD+ (*Reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries*) is identified as one of the most effective means to reduce GHG emission in the post-Kyoto climate change negotiation. A reliable and credible system of MRV of forest carbon changes is a cornerstone of any national REDD+.

An MRV system should follow the international requirements and also be adapted to the country's specific conditions, e.g. vegetation, economy, culture, institution and/or the deforestation/forest degradation drivers. A REDD+ participating country should prepare such a forest carbon change MRV system prior to a full

implementation of REDD+ so as to promptly estimate the carbon budget and its historical trend for the reference level. A demonstration of designing a forest carbon change MRV system in a tropical forest country that takes into account the requirements and conditions would contribute not only to the country but also to the other countries by tailoring the lessons learned from the demonstration for designing their own systems.

The Importance of Measurement, Reporting and Verification (MRV) of Forest Carbon Stocks

In discussions on the framework after the first commitment period of the Kyoto Protocol in 2012 under the UNFCCC, the importance of the MRV system has been emphasized. When REDD-plus is implemented, MRV of forest carbon stocks is essential to ensure transparency. In particular, MRV must be highly accurate before economic incentives such as credits are issued.

A forest monitoring system is indispensable for accurate measurement of forest carbon stocks and their changes at the national level. The guidance for the methodology determined by COP 15 under the UNFCCC requests that developing countries build a robust and highly transparent national forest monitoring system. To estimate the balance of greenhouse gases, forest carbon stocks, and forest cover changes, a monitoring system that combines remote sensing with ground-based inventories is recommended.

Credits for REDD-plus activities will be issued based on the results of this measurement. To ensure a reliable and transparent credit system for greenhouse gas reductions, a system for reporting and verifying the measurement results is indispensable.

Manual Objectives

This manual is part of the main output from biomass inventory component of the FRIM FFPRI project mentioned above.

The manual aims to explain in detail on the process involved in determine, monitoring and reporting the biomass changes in our forest.

Part 1 of the manual deal with the standard procedures to establish the PSPs and Part 2 will describe step by step in measuring tree parameters, including diameter and height measurement and tree identification. Rules in entering the data and analysis will be discussed in Part 3. Tabulation and interpretation of the findings and report writing on the biomass stocking and changes will be covered in Part 4.

This manual is intended to help beginners understand basic topics in conducting biomass and carbon related monitoring activities.

ESTABLISHMENT OF MONITORING PLOT

PART 1

PART 1: ESTABLISHMENT OF MONITORING PLOT

1.1 Required Number of Permanent Plots and Plot Size

Determination of plot size and plot number required for the project was made based on data analysis of two different forest areas namely Pasoh Forest Reserve (FR) for lowland forest and Semangkok FR for hill forest. Data of a 50 ha and 6 ha long term ecological plot in Pasoh and Semangkok FR were used, respectively.



Several plot sizes options, i.e. 100 x 100 m, 60 x 60 m, 50 x 50 m, 40 x 50 m, 40 x 40 m and 30 x 30 m were tested. Trees ≥ 10 cm diameter at breast height (dbh) were used as baseline data. Analysis then concentrated on the number of biomass study plot required by taking into consideration of coefficient of variation and standard error for each tested plot size. Lower coefficient of variation and acceptable error limit was chosen.

Based on the analysis, the project agreed that plot size of 60 m x 60 m will be used with a total of 16 study plots required for each category identified and a total of 96 study plots required for the whole study area within Peninsular Malaysia.

1.2 Sampling Design

The purpose of using stratified sampling is to increase the estimated accuracy or to reduce the number of sampling plots needed (n). Therefore, the forest should be stratified in such a way that the variation in each stratum is as small as possible compared with the variation in the whole population. An effective means of stratification is to create a stratification matrix as suggested by Gibbs et al. The matrix should be constructed with two axes; one axis shows forest types and the other one shows the condition of the forest. However, it is important also to understand which factors, such as altitude, soil type and land-use history that relate to spatial changes in carbon stocks. (Cookbook, Pg 115).

For the purpose of Malaysia REDD+ MRV system, stratification matrix using forest type and forest condition (modified from Gibbs et al.) is suggested as shown below.

		Disturbances Category 		
		Undisturbed	Disturbed (logged ≤ 10 years)	Disturbed (logged > 10 years)
Forest type 	Lowland	16	16	16
	Hill	16	16	16
		32	32	32

Hence, for the FRIM FFPRI Project, the biomass monitoring plot consists of 96 plots distributed randomly and equally within four LANDSAT selected scenes (Figure 1). Each plot is positioned to capture two common forest types in Peninsular Malaysia, i.e. lowland and hill forest and further stratified by disturbances category (i.e. undisturbed and disturbed – logged ≤ 10 years and logged > 10 years).

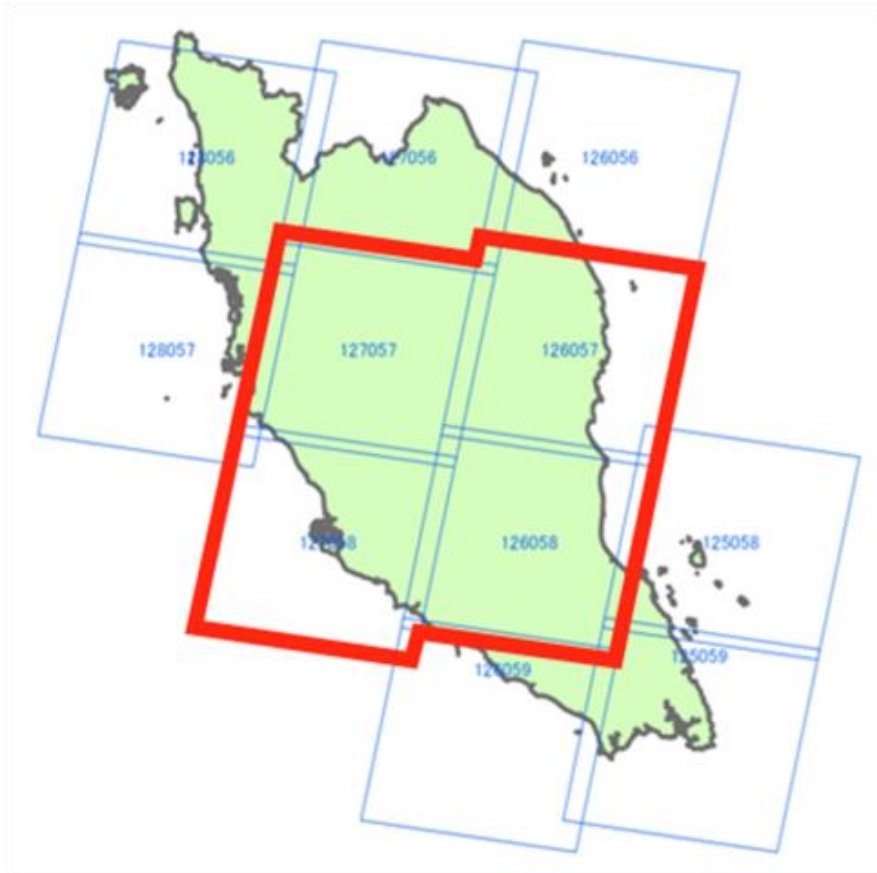


Figure 1. Project study areas was selected within four LANDSAT scene of Peninsular Malaysia

1.3 Sampling Layout

Permanent monitoring plots should be designed to enhance field measurement efficiency. Generally, permanent sample plots are circular or square. For the purpose of this project, a square plot was selected.

Thus, the monitoring plots were established as temporary sample plots, but each corners of the main plot will be marked permanently with permanent aluminium pole. Plot will be north orientated with ≥ 400 m apart from other plot and must be established 100 m from access road. In addition to that, accessibility to the forest compartment will be another major factor to be considered in laying out the plot.

Fixed-area square sampling plot of 0.36 ha (60 x 60 m) will be used to census trees. To facilitate the census, the main plot will be further divided into 10 x 10 m quadrat (Figure 2).

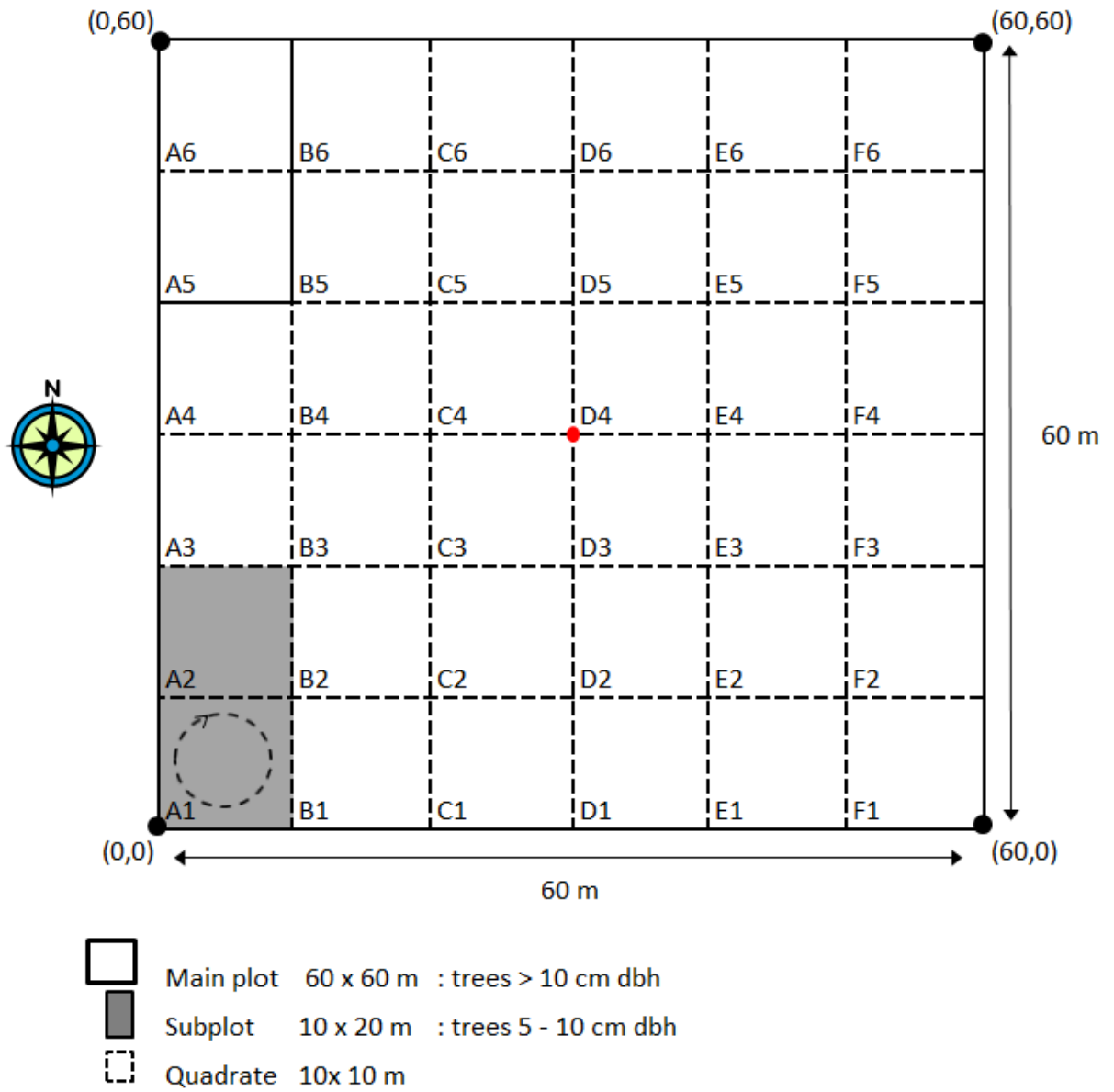
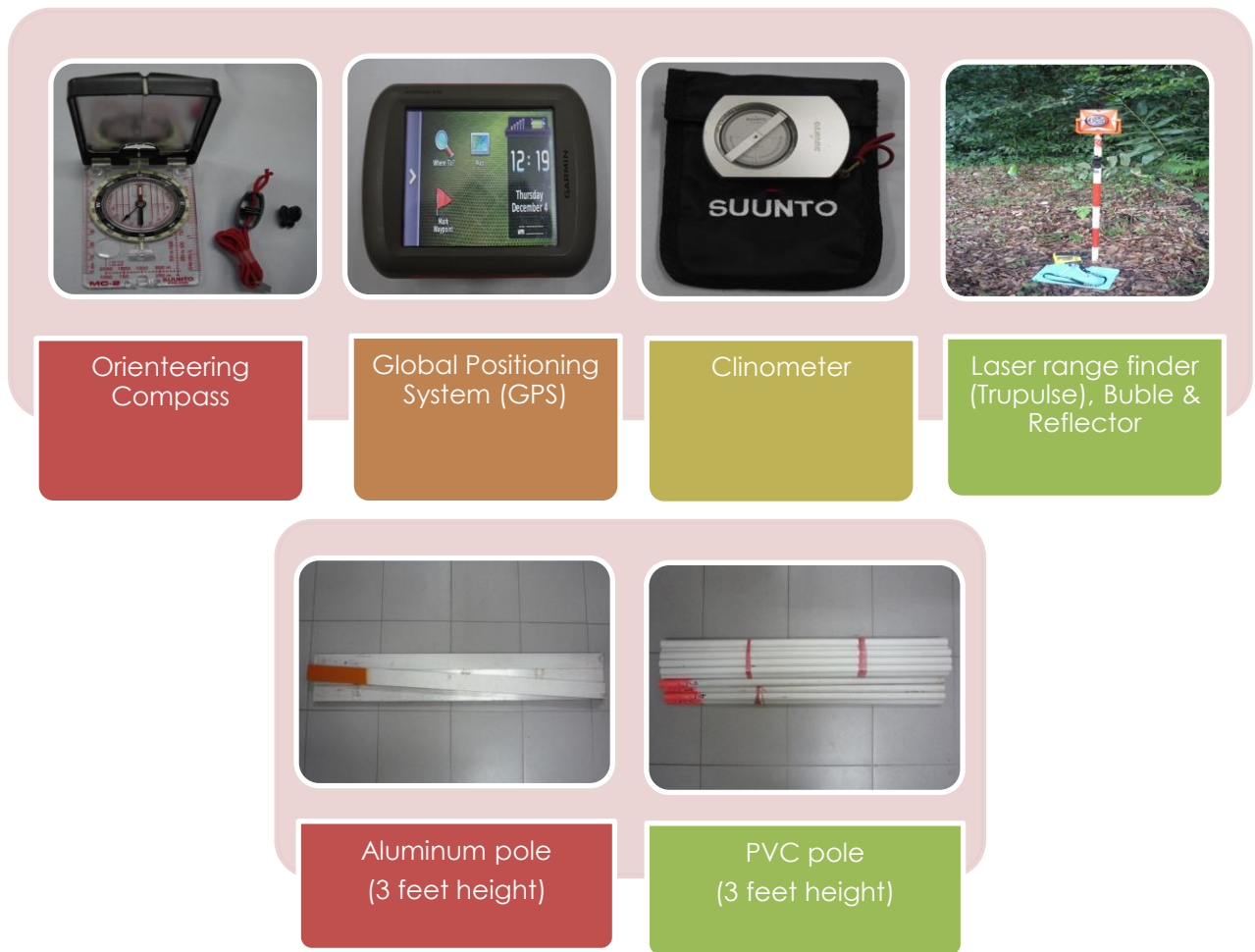


Figure 2. Sampling layout for biomass monitoring

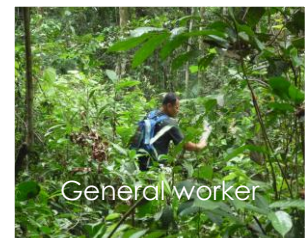
1.4 Required Equipment



1.5 Survey Team

Survey team consisting of five people per team, will include:

1. Laser range finder operator
2. Clinometer operator
3. Recorder, and
4. General worker.



1.6 Locating the First Point (0,0)

The plot location should be predetermined based on the selected criteria set by the project (or objectives). The survey team, then need to check on the ground the suitability of predetermine plot location to ensure that all criteria have been fulfilled. For FRIM FFPRI project, the most important criteria include forest type, altitude and years after logging (if any).



Figure 3. An example of ground checking by the survey team to the predetermine plot location. The entry point should be marked using GPS.



The suitable area for plot establishment should be determined within the selected plot location. Few GPS points should be taken to ensure the whole plot area is within the set criteria (altitude).



Use aluminum pole to mark the starting point (A1). Mark the point using GPS. Pole will be 3 feet at height and quadrat number should be clearly written on the pole.



The baseline of the plot (0,0 to 0,60 ; 60 m) will be laid out towards north direction.

1.7 Reference Point

Permanent plots shall be marked using materials that will last longer than project lifetime. Hence, aluminium poles will be used to mark each corners of main plot and tied to permanent benchmark such as river/stream, main road or big tree. The coordinates of each corners and their permanent bench mark will be recorded using GPS.

The GPS location alone cannot be used to locate the plot corners in the future as the error in GPS measurements is too varies and large.

- Select a permanent feature as a reference point for each corner of the main plot and mark using paint. Record the species name.

Step 1



- GPS reading should be recorded for each reference point.

Step 2



- Record bearing and distance from reference point to the selected main corner pole.

Step 3



1.8 Main Corner (0,0 to 60,0)

The corners of main plot and each quadrat will be positioned using laser range finders.



Team member ready with pvc pole and reflector.



From first point (0,0), point the laser range finder to north direction and start measure distance at every 10m.



Reflector must be hold vertically as its will be the target point for each 10 m distance measurement.



Mark the 10 m point with PVC pole and placed it on the bottom left to mark corners of each quadrate. PVC pole will be 3 feet at height and quadrate number will be clearly written on the pole.

Repeat the whole processes until plot size 60x60m completed.

During plot establishment, parameters to be recorded shall include the followings:

1. Coordinates (RSO system) of each corner of main plot (0,0 ; 0,60 ; 60,60 ; 60,0)
2. Compass bearing and slope angle from one to another corner, eg. (0,0) to (0,60)
3. Permanent benchmark (or reference point) and their coordinates will be recorded. Bearing and distance will be taken from permanent benchmark to the corner of main plot.
4. Altitude at the centre of plot (D4)
5. Photo will be captured at each of four main corners, facing towards centre of plot (D4).
6. Overall forest conditions will be recorded too.

The field form is in Annex 1.

TREES MEASUREMENT FOR BIOMASS

PART 2

PART 2: TREE MEASUREMENT FOR BIOMASS

2.1 Required Equipment



Diameter tape



Laser range finder
(Trupulse)



Tag number



Stapler gun

2.2 Survey Team

Survey team consisting of five people per team, will include:

1. Data Recorder – to record all the data. The recorder should stand in the centre of the nested plot being measured. He/she should track those measuring the trees and should try and ensure that no trees are missed.
2. Laser range finder operator – to measure the total height.
3. Dbh/tag person – to measure tree diameter and later put the tree numbered tag to the tree stem.
4. Botanist – to identify the tree species, and
5. General worker.



2.3 Diameter Measurement

In main plot (60 x 60 m), all individual trees with > 10 cm diameter at breast height (dbh) will be tagged and measured, whereas for individuals with 5 – 10 cm dbh will be tagged and measured inside the subplot (Quadrant A1 & A2) (Figure 2).



A 1.3m stick shall be prepared and used during measurement to reduced the human error.

For each tree, place the stick against the tree to indicate the point of measurement.

Placement of the stick depends on the ground slope, leaning angle of tree and tree bole shape (Figure 4).

Tree diameter will be measured using diameter tape.

If the diameter tape has a hook, push the hook into the bark of the tree slightly to secure it and pull the tape to the right. The diameter tape should always start left and be pulled right around the tree. As the diameter tape wraps around the tree and returns to the hook, the tape should be above the hook. The tape should not come around the tree below the hook. The tape should not be upside down; the numbers must be right side up.

Tree diameter should be measured to the nearest 0.1 cm (eg: 10.2 cm instead of 10 cm)



All measured individuals trees shall be tagged with a plastic numbered tag and nail to tree stem using stapler gun. Tree tag should be placed at the measurement point (1.3m).

Dbh (or diameter, d above the buttresses) of each individual tree will then be recorded in the Field Form (Annex 2).

However, in the events of unusual tree form, point of measurement should be located as follow (Figure 4).

Slope: always place stick and measure diameter on the upper slope side of tree.

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

Multi stem tree: If the tree is multi stemmed with forking below the point of measurement (eg. 1.3m), measure the diameter on each stem and tag the stems that exceed the minimum diameter for the nest. Record it as if each stem were different tree on the data sheet, but with a note that the stems make up one tree.

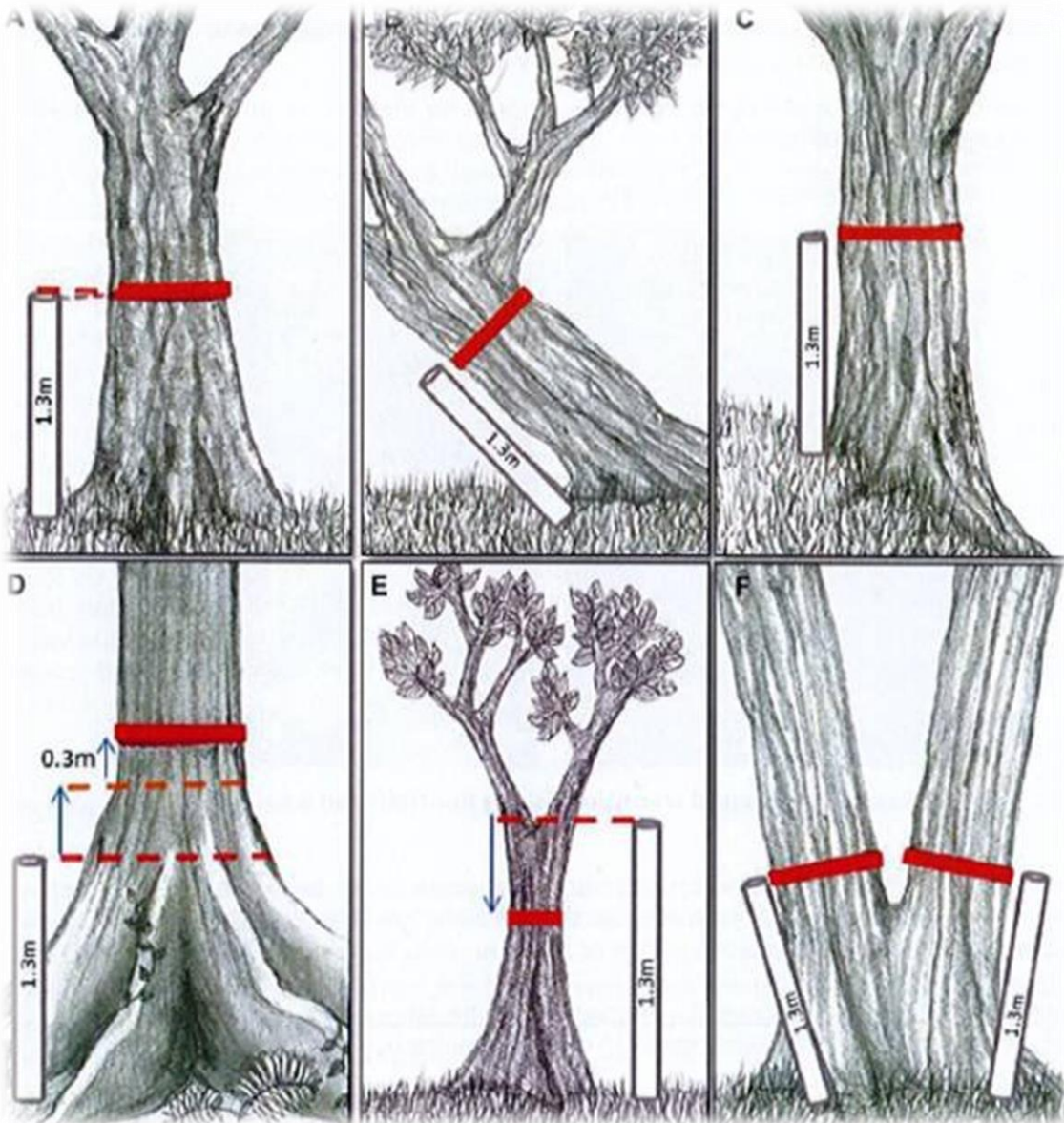


Figure 4. Point of diameter measurement

To ease the census, avoid either missed trees or double recording and minimize human errors, measurement shall be conducted quadrate by quadrate (A1 to F6) with clock-wise rotation (Figure 2).

During data collection in the field, the team member responsible for recording must repeat all measurements call by the team member conducting the measurement. This is to ensure the measurement call was acknowledged and that proper number is recorded on the data sheet. It is also the responsibility of team leader to double check to make sure that all data are correctly and completely filled. The team leader must ensure the data recorded matches with field conditions. (Winrock, 2014)

2.4 Tree Mapping

Tree location should be map in the map data sheet. The map data sheet is a large format copy of a plot with the quadrat outline. A tree was indicated on the map by a small circle with dot corresponding to the center of the stem.

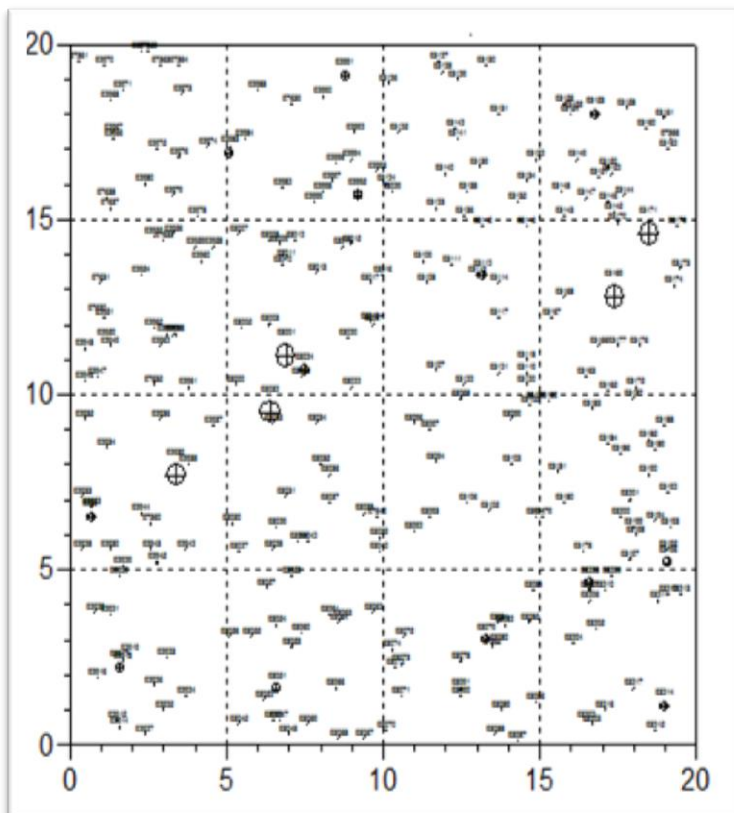


Figure 5. An example of map data sheet

2.5 Total Height Measurement

Total height is an important tree variable. It is well correlated with other important tree and stand parameters such as tree volume and the quality of site conditions. Total tree height must be measured if height has been included as a tree variable in the allometric equation/s that will be used.

Total tree height is the distance along the axis of the bole of the tree from ground to the uppermost point of the tree.

Total height will be measured using laser range finder such as trupulse.

Height will be measured from 5 individual trees per dbh class, selected randomly within six predetermined dbh class, which is:

- 1) 05.0 – 0.99 cm
- 2) 10.0 – 29.9 cm
- 3) 30.0 – 49.9 cm
- 4) 50.0 - 70 cm
- 5) 70-90 cm and
- 6) 90 cm and above

To measure height:

1. Find the best location to view the top of the tree.
2. Stand as far as possible away from the tree so that the top of the tree is less than 90 degrees above the line of sight.
3. Always stand up-slope of the tree. Standing down-slope of the tree should only take place when no other option exists.
4. Using laser range finder,
 - a) Measure distance from eye of person measuring tree to the tree. It is important to ensure that distance measured is horizontal, not along the slope.
 - b) Measure the angle in degree ($^{\circ}$) to base of the tree.
 - c) Measure the angle in degree ($^{\circ}$) to top of the canopy of the tree.
 - d) The total height measurement will be automatically calculated (based on trigonometry principle) and the measurement should be recorded in the field form (Annex 2) to the nearest 0.1 meter.





4(a). Measure the horizontal distance



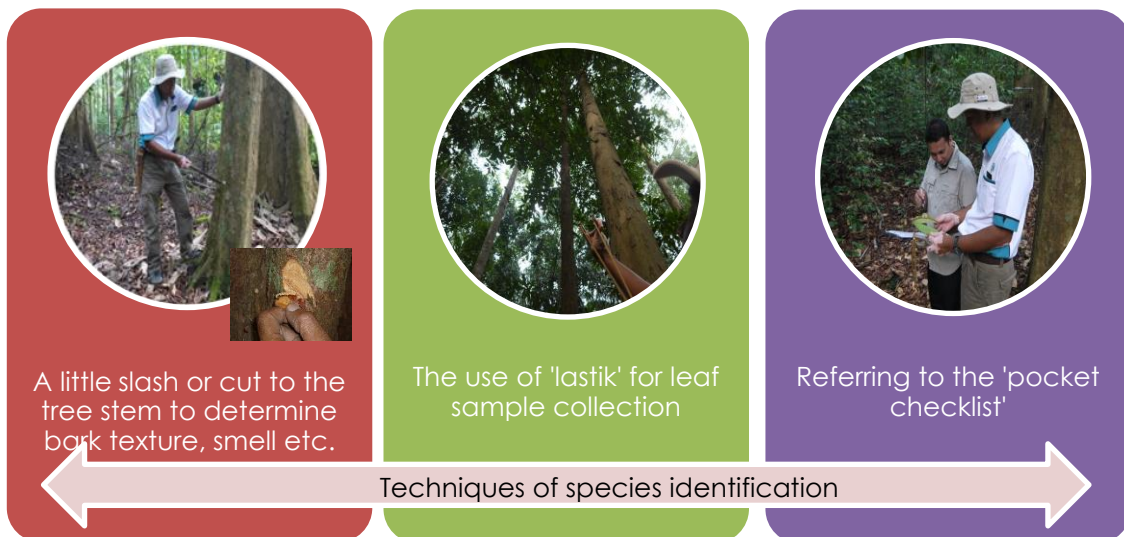
4(b). Measure the base angle



4(c). Measure the top angle

2.5 Tree Identification

Generally, vegetative characteristics of the tree will be used to determine the species. It includes tree stem, buttress, root, bark texture, canopy form, canopy colour, leaf arrangement and leaf form. Below are different techniques used in identifying species on site, including:



Species characteristics as listed in the '*Pocket Checklist of Timber Trees*' (Wyatt-Smith & Kochummen 1999) and the '*Tree Flora of Malaya*' (Whitmore 1973 & Ng 1989) shall be used as a guide. Each individual tree shall be identified up to species level (or as far as possible). The species name will be recorded in the field form (Annex 2).

Complete samples (should include leaf, fruit and flower) of any unidentified individuals will be collected. Samples will be tag with unique ID and will be recorded in the field form. Samples should be stored inside newspaper and temporary pressed until drying process. Later, the sample should be identified in Herbarium.



Figure 6. Amongst the equipment required for tree identification. Equipment include parang, lastik and small stone, binocular, paper tag and newspaper.



Figure 7. Leaf sample collection

DATA ENTRY AND ANALYSIS

PART 3

PART 3: DATA ENTRY AND ANALYSIS

The carbon stock represented by standing trees is calculated as one half the tree biomass. Biomass can be estimated from the permanent sample plot measurement data by using an allometric equation that relates biomass, including branches and leaves, of a tree to the tree's dbh or to both tree dbh and tree height.

For the purpose of this training, a template datasheet in excel worksheet format and simple interface (trial version) for calculating biomass and carbon stock had been developed.

This chapter will elaborate on how to key in the data to the datasheet, calculate the biomass stocking and table the analysis results according to specific objective (such as by study plot, category and state) which later will be use for report witting.

3.1 Data Entry

A template datasheet in excel format has been developed to be used with TBA. In order for TBA tool to run perfectly, the datasheet should follow the format as described below:

Datasheet should consist of 18 heading columns (Table 1) , start with column A. It heading columns goes with TREEID, FOR RESERVE, COMPART, CATEGORY, PLOT NO, SPP, QUADRATE, MAJ GRP and DBH (Figure 8). The first 9 columns (A – I), are compulsory and the sequence cannot be changed as it was programmed to be used for calculation later on. Columns 10 to 18 (J – R) are DBH CLASS, HEIGHT, $H=(1/DBH\text{relation})$, Stem(W_s), Branch(W_b), Leaves(W_l), Root(W_r), AGB and TOTAL BIOMASS (Figure 9). This column will be automatically fill up when the calculation run using TBA.

Excel column	Column heading	Description
A	TREEID	Tree number
B	FOR RESERVE	Name of the forest reserve
C	COMPART	Compartment name
D	CATEGORY	Forest category 1 - Hill unlogged 2 - Hill logged >10 years 3 - Hill logged < 10 years 4 - Lowland unlogged 5 - Lowland logged > 10 years 6 - Lowland logged < 10 years (Subject to changes)
E	PLOT NO	Plot number
F	SPP	Species name (up to species level or genus)
G	QUADRATE	Quadrante
H	MAJ GRP	Major group 1 – Dipterocarp species 2 – Non dipterocarp species

Excel column	Column heading	Description
I	DBH	Diameter at breast height measurement (to the nearest 0.1 m)
J	DBH CLASS	Predetermine dbh class 1. 05.0 – 0.99 cm 2. 10.0 – 29.9 cm 3. 30.0 – 49.9 cm 4. 50.0 - 70 cm 5. 70-90 cm and 6. 90 cm and above (subject to changes)
K	HEIGHT	Measured height in meter
L	H=(1/DH RELATION)	Height calculated using allometric equation develop by Kato et al. (1978) (for trees that has not been measured height) $1/H = 1/(2.0 D) + 1/61$
M	Stem (Ws)	Calculation of stem biomass using allometric equations develop by Kato et al. (1978) $W_s = 0.0313(D^2H)^{0.9733}$
N	Branch (Wb)	Calculation of branch biomass using allometric equations develop by Kato et al. (1978) $W_b = 0.136W_s^{1.070}$
O	Leaves (W _L)	Calculation of leaves biomass using allometric equations develop by Kato et al. (1978) $1/W_L = 1/[(0.124W_s)^{0.794} + 1/125]$
P	Root (Wr)	Root biomass = Below ground biomass (BGB) calculated using allometric equations developed by Niiyama et al. (2010). $W_r = 0.023 \times D^{2.59}$.
Q	AGB	Above ground biomass value, consists of stem (Ws), branch (Wb) and leaves (W _L) biomass. $AGB = W_s + W_b + W_L$
R	TOTAL BIOMASS	Total tree biomass. Sum of AGB and BGB.

Table 1. Datasheet column format

Raw data shall be key in into column A to K. The data should be as complete as possible. Wherever, there is no informations available, the column should be left blank.

Please save your excel datasheet into Excel 1997-2003 Workbook if you are using Microsoft Office 2007 and above version.

To ensure that data is entered correctly, the person entering data will recheck all of the data entered and compare it with original hard copy data sheet before entering another sheet. It is advised that field team leader either enter the data or participate in the data entry process. Team leader should have a good understanding of the study sites and can provide insightful assistance regarding potential unusual situations identified in data sheets. After all data has been entered into computer files(s), a random check shall be conducted. Sheets shall be selected randomly for re-check and compared with data entered. Ten percent of all data sheets shall be checked for consistency and accuracy in data entry. (Winrock, 2014)

1	2	3	4	5	6	7	8	9
TREEID	FOR RESERVE	COMPART	CATEGORY	PLOT NO	QUADRATE	SPP	MAJ GRP	DBH
953	Negeri Sembilan	PASOH	5	6	A1			6.1
972	Negeri Sembilan	PASOH	5	6	A2			6.7
956	Negeri Sembilan	PASOH	5	6	A1			6.9
970	Negeri Sembilan	PASOH	5	6	A2			8.1
961	Negeri Sembilan	PASOH	5	6	A1			8.7

Figure 8. Column 1 to 9 of excel datasheet

10	11	12	13	14	15	16	17	18
DBH CLASS	HEIGHT	H=1/DHrelatio	Stem (Ws)	Branch (Wb)	Leaves (Wl)	Root (Wr)	AGB	TOTAL BIOMASS
1	7.3							
1	7.4							
1	7.8							
1	8.7							
1	9.0							

Figure 9. Column 10 to 18 of excel datasheet. The column need to be blank.

3.2 Installation Guide for Tree Biomass Analysis (TBA) Tool

A simple interface using visual basic program was developed in order to calculate biomass. Data for each tree will be calculated for its above and below ground biomass which include stem, branch, leaves and root biomass. Later, tonne carbon per hectare will be calculated and be the final output.

In order to operate this program, the user should follow below instruction:

To operate TBA conveniently, user should use the high-speed computer. Suggested processor speed (CPU) is 300 Mhz and above with memory (RAM) at least 128 Mb. Higher speed of CPU and bigger RAM will reduce calculation time. TBA work on computer with any Microsoft Windows operating system and the data files format is in Microsoft Excel (*.xls).

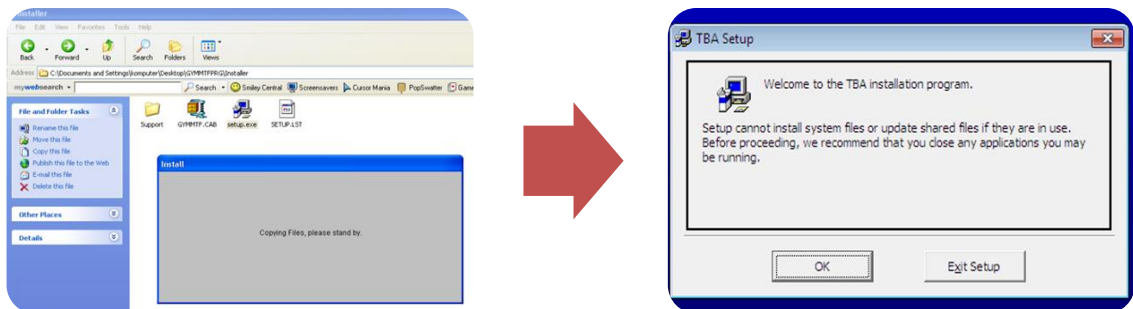
For installation:


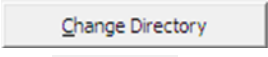
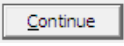
1. Place TBA installation CD into CD-Rom drive.

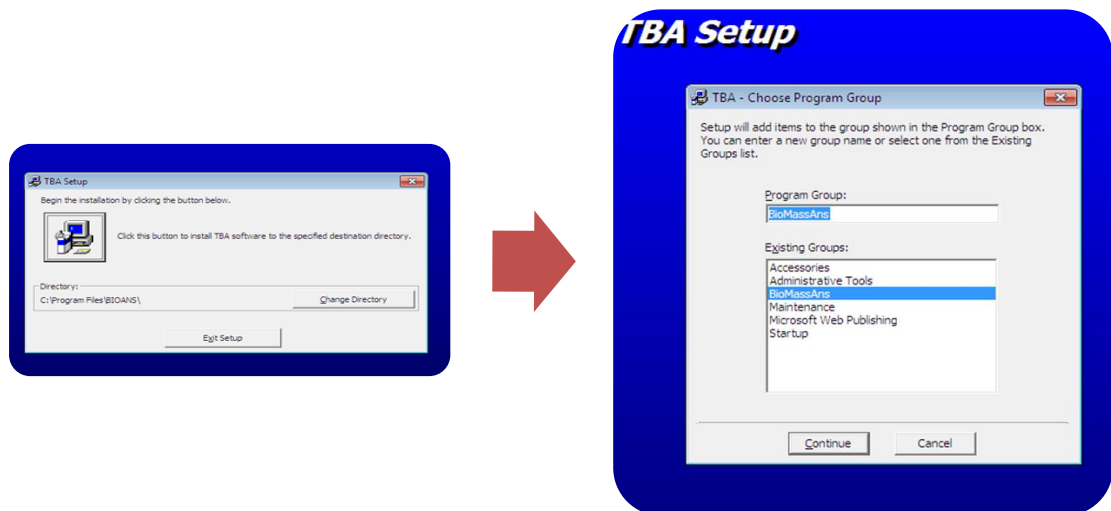


2. Click the icon **Setup.exe** to begin installation.

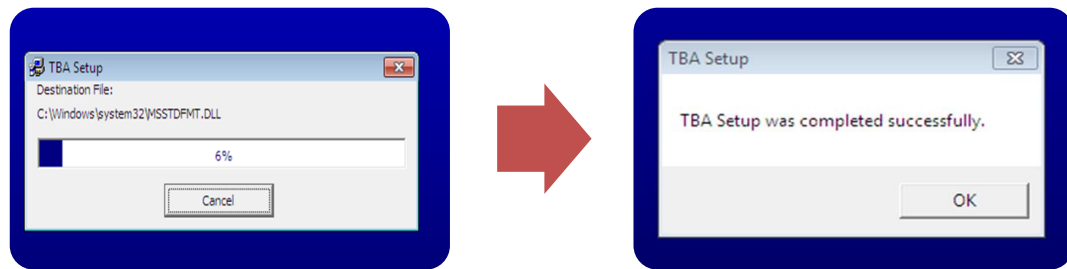
3. The message box appears *"Copying files. Please standby"*. Click OK button to resume installation.



4. To continue save the installation file in the default directory, click the  button. To change directory, click icon  and specify the destination folder. To begin installation, click .



5. Click OK, when the installation was completed.



3.3 Data Analysis

TBA was developed using Microsoft Visual Basic 6.0 that creates GUI (Graphic User Interface) for easier manipulation by user. The simple interface allows users to interact with the software without technical or mathematical method approach. Users only need to select the file using the open button in order to link the software to the datasheet.

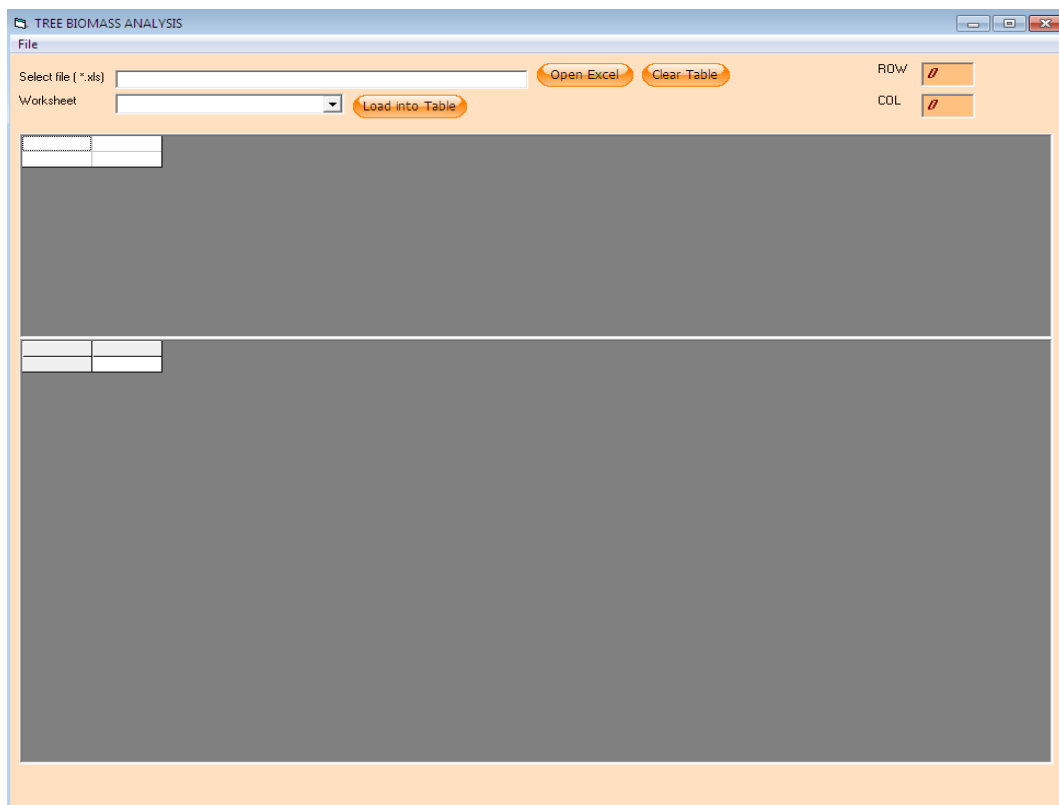
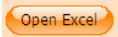
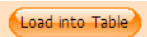
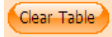
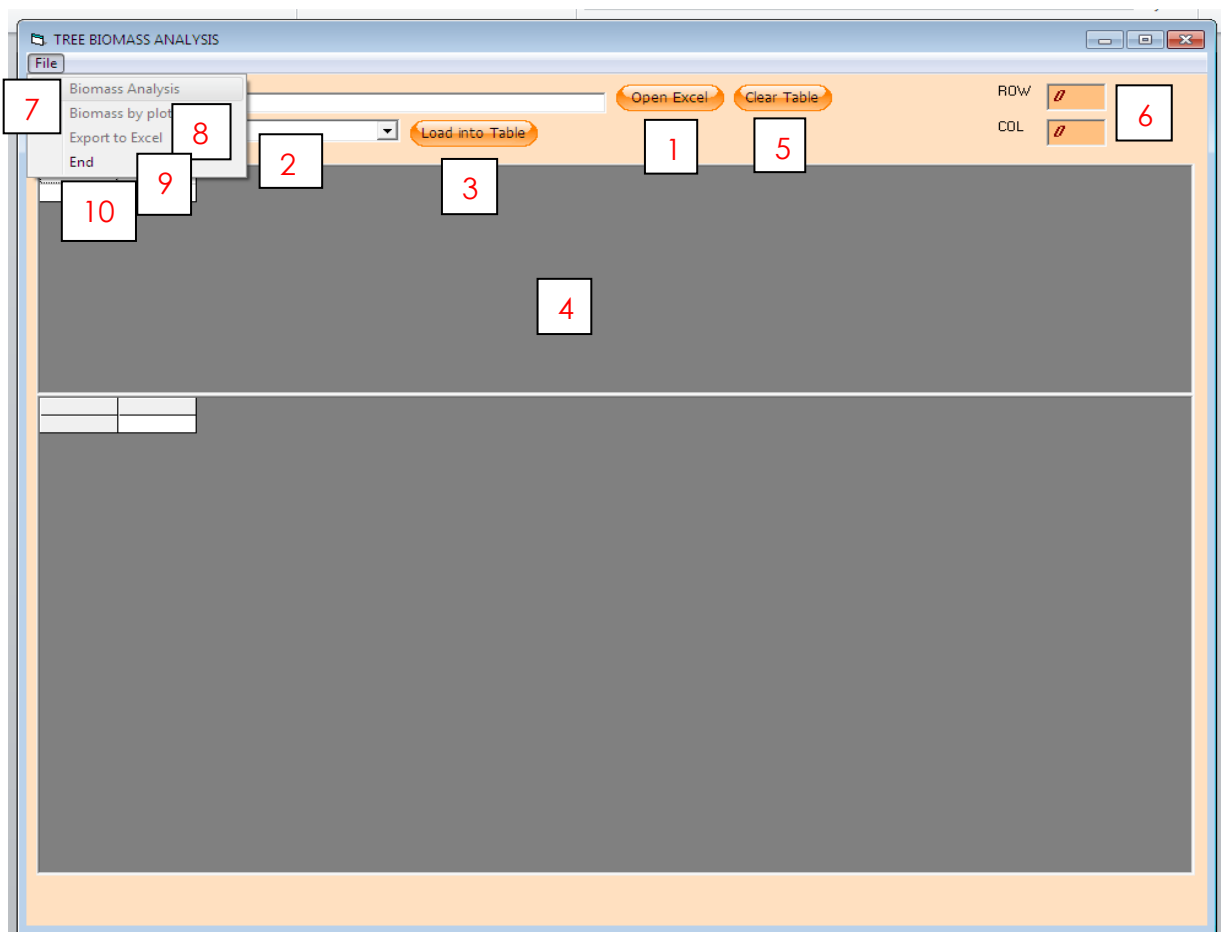


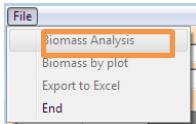
Figure 10. Graphic user interface for TBA

Below are step by step procedures to use TBA:

1. Click icon  (1) to select excel data file.
2. Select the excel datasheet to be used in the analysis (2) and click icon  (3) to export the excel datasheet in the FlexGrid (4). It should be noted that, the excel datasheet must follow the standard template as describe in Part 3 (3.1).
3. To change excel datasheet, click  (5).

4. Icon  (6) summarized the total rows and columns from the excel datasheet.

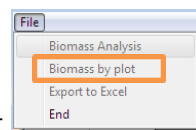


5. From the pull down menu, click  (7) to run the calculation. The result outputs will then be shown in the FlexiGrid (4)

FOR RESEF	COMPART	CATEGORY	PLOT NO	QUADRATE	SPP	MAJ GRP	DBH	DBH CLASS	HEIGHT	H-1/DHrela	Stem (W/s)	Branch (W/b)	Leaves (W/l)
Negeri Semt	PASOH	5	6 A1				6.1	1	7.3	10.17	10.11	1.62	0.79
Negeri Semt	PASOH	5	6 A2				6.7	1	7.4	10.99	13.09	2.13	0.96
Negeri Semt	PASOH	5	6 A1				6.9	1	7.8	11.25	14.18	2.32	1.03
Negeri Semt	PASOH	5	6 A2				8.1	1	8.7	12.80	21.96	3.71	1.45
Negeri Semt	PASOH	5	6 A1				8.7	1	9	13.54	26.66	4.56	1.69
Negeri Semt	PASOH	5	6 A1				10	2		15.06	38.77	6.81	2.27
Negeri Semt	PASOH	5	6 E3				10	2		15.06	38.77	6.81	2.27
Negeri Semt	PASOH	5	6 F3		HORSFIELD		10	2		15.06	38.77	6.81	2.27
Negeri Semt	PASOH	5	6 F1				10	2		15.06	38.77	6.81	2.27
Negeri Semt	PASOH	5	6 B6		XANTHOPI	2	10.1	2		15.17	39.81	7.01	2.32
Negeri Semt	PASOH	5	6 A2				10.2	2		15.29	40.89	7.21	2.37

Figure 11. Example of the TBA result outputs

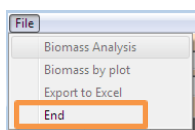
6. To summarize the result output based on plot, select



(8).

7. The result outputs should be exported to MS Excel (9) and save the result output as an excel file for further analysis (Figure 12).

8. Click End from pull down menu



(10) to exit TBA tool.

Further analysis will be run in MS Excel and based on the specific objectives.

The image shows a Microsoft Excel spreadsheet with a data table. The table has 18 columns: TREEID, FOR RESER, COMPART, CATEGORY, PLOT NO, QUADRATE SPP, MAJ GRP, DBH, DBH CLASS, HEIGHT, H=1/DHre, Stem (Ws), Branch (W), Leaves (W), Root (Wr), AGB, and TOTAL BIC. The data rows list individual trees with their respective measurements. For example, tree 953 has a DBH of 6.1, height of 7.3, and a total biomass of 15.01. The spreadsheet interface includes the ribbon (Home, Insert, Page Layout, Formulas, Data, Review, View) and the taskbar at the bottom.

TREEID	FOR RESER	COMPART	CATEGORY	PLOT NO	QUADRATE SPP	MAJ GRP	DBH	DBH CLASS	HEIGHT	H=1/DHre	Stem (Ws)	Branch (W)	Leaves (W)	Root (Wr)	AGB	TOTAL BIC	
953	Negeri Sen PASOH		5	6	A1		6.1	1	7.3	10.17	10.11	1.62	0.79	2.49	12.52	15.01	
972	Negeri Sen PASOH		5	6	A2		6.7	1	7.4	10.99	13.09	2.13	0.96	3.17	16.18	19.35	
956	Negeri Sen PASOH		5	6	A1		6.9	1	7.8	11.25	14.18	2.32	1.03	3.42	17.53	20.95	
970	Negeri Sen PASOH		5	6	A2		8.1	1	8.7	12.8	21.96	3.71	1.45	5.18	27.12	32.3	
961	Negeri Sen PASOH		5	6	A1		8.7	1	9	13.54	26.66	4.56	1.69	6.24	32.91	39.15	
959	Negeri Sen PASOH		5	6	A1		10	2		15.06	38.77	6.81	2.27	8.95	47.85	56.8	
1111	Negeri Sen PASOH		5	6	E3		10	2		15.06	38.77	6.81	2.27	8.95	47.85	56.8	
1145	Negeri Sen PASOH		5	6	F3	HORSFIELD	2	10	2		15.06	38.77	6.81	2.27	8.95	47.85	56.8
1157	Negeri Sen PASOH		5	6	F1		10	2		15.06	38.77	6.81	2.27	8.95	47.85	56.8	
1005	Negeri Sen PASOH		5	6	B6	XANTHOP	2	10.1	2		15.17	39.81	7.01	2.32	9.18	49.14	58.32
968	Negeri Sen PASOH		5	6	A2		10.2	2		15.29	40.89	7.21	2.37	9.42	50.47	59.89	
1007	Negeri Sen PASOH		5	6	B5		10.2	2		15.29	40.89	7.21	2.37	9.42	50.47	59.89	
1052	Negeri Sen PASOH		5	6	C4	DACRYODE	2	10.2	2		15.29	40.89	7.21	2.37	9.42	50.47	59.89
963	Negeri Sen PASOH		5	6	A2	PELLACALY	2	10.4	2		15.51	43.06	7.62	2.47	9.9	53.15	63.05
1036	Negeri Sen PASOH		5	6	C1		10.4	2		15.51	43.06	7.62	2.47	9.9	53.15	63.05	
1000	Negeri Sen PASOH		5	6	B6		10.5	2		15.62	44.18	7.83	2.52	10.15	54.53	64.68	
1141	Negeri Sen PASOH		5	6	F4		10.5	2		15.62	44.18	7.83	2.52	10.15	54.53	64.68	
1144	Negeri Sen PASOH		5	6	F3		10.5	2		15.62	44.18	7.83	2.52	10.15	54.53	64.68	
969	Negeri Sen PASOH		5	6	A2	SYZYGIIUM	2	10.6	2		15.73	45.31	8.05	2.57	10.41	55.93	66.34
986	Negeri Sen PASOH		5	6	A4	SYZYGIIUM	2	10.6	2		15.73	45.31	8.05	2.57	10.41	55.93	66.34
1023	Negeri Sen PASOH		5	6	B1	XANTHOP	2	10.6	2		15.73	45.31	8.05	2.57	10.41	55.93	66.34
1037	Negeri Sen PASOH		5	6	C2		10.6	2		15.73	45.31	8.05	2.57	10.41	55.93	66.34	
1047	Negeri Sen PASOH		5	6	C3		10.6	2		15.73	45.31	8.05	2.57	10.41	55.93	66.34	
960	Negeri Sen PASOH		5	6	A1	POYALTHIA	2	10.8	2		15.95	47.63	8.49	2.67	10.92	58.79	69.71
1056	Negeri Sen PASOH		5	6	C5		10.9	2		16.06	48.81	8.71	2.73	11.19	60.25	71.44	
1099	Negeri Sen PASOH		5	6	D1		10.9	2		16.06	48.81	8.71	2.73	11.19	60.25	71.44	
977	Negeri Sen PASOH		5	6	A3	PALAQIUI	2	11	2		16.17	50.02	8.95	2.78	11.45	61.75	73.2
995	Negeri Sen PASOH		5	6	A6	AGLAIAS	2	11	2		16.17	50.02	8.95	2.78	11.45	61.75	73.2
988	Negeri Sen PASOH		5	6	A4	DACRYODE	2	11.1	2		16.28	51.25	9.18	2.83	11.73	63.26	74.99
1002	Negeri Sen PASOH		5	6	B6	ORMOSIA	1	11.1	2		16.28	51.25	9.18	2.83	11.73	63.26	74.99
1032	Negeri Sen PASOH		5	6	C1		11.1	2		16.28	51.25	9.18	2.83	11.73	63.26	74.99	
955	Negeri Sen PASOH		5	6	A1		11.2	2		16.38	52.46	9.41	2.89	12	64.76	76.76	
1110	Negeri Sen PASOH		5	6	E2		11.2	2		16.38	52.46	9.41	2.89	12	64.76	76.76	
1060	Negeri Sen PASOH		5	6	C6		11.3	2		16.49	53.73	9.66	2.94	12.28	66.33	78.61	
1040	Negeri Sen PASOH		5	6	C2	POYALTHIA	2	11.4	2		16.6	55.01	9.9	3	12.56	67.91	80.47
1003	Negeri Sen PASOH		5	6	B6		11.5	2		16.7	56.28	10.15	3.05	12.85	69.48	82.33	
1096	Negeri Sen PASOH		5	6	D1		11.5	2	13.3	16.7	56.28	10.15	3.05	12.85	69.48	82.33	
1118	Negeri Sen PASOH		5	6	E3		11.5	2		16.7	56.28	10.15	3.05	12.85	69.48	82.33	
1034	Negeri Sen PASOH		5	6	C1		11.6	2		16.81	57.61	10.41	3.11	13.14	71.13	84.27	
1064	Negeri Sen PASOH		5	6	D6	PALAQIUI	2	11.6	2		16.81	57.61	10.41	3.11	13.14	71.13	84.27
1010	Negeri Sen PASOH		5	6	B4	PELLACALY	2	11.7	2		16.91	58.67	10.66	3.16	13.44	72.74	86.18

Figure 12. The result outputs in excel file

**ESTIMATION OF TREE
BIOMASS AND
CARBON STOCKS;
REPORT WRITING**

PART 4

PART 4: ESTIMATION OF TREE BIOMASS AND CARBON STOCKS; REPORT WRITING

Estimation of biomass and carbon stocking for a particular forest area should be presented in a simple and standard manner, yet effective and meaningful outcome for forest manager. Hence, this section will guide the reader on how to interpret the result gathered from Part 3 of this Manual, and produced a standard report on estimation of tree biomass and carbon stocks.

Generally, a report on estimation of tree biomass and carbon stock should contain the following informations:

- a) Area informations, including
 - i. compartment number
 - ii. forest reserve
 - iii. forest type/category, and
 - iv. plot number (for future reference)

- b) Summary result divided by total value, major species group (dipterocarp and non-dipterocarp) and predetermined diameter class of:
 - i. tree density
 - ii. basal area
 - iii. volume
 - iv. biomass (Above and below ground biomass), and
 - v. carbon

As results produced by the program, the user need to further interpret it. Different user may have different interpretation, depend on their objectives. However this manual give ordinary interpretation which usually used in the research paper.

Firstly the user need to come out with the stand table. The stand table will contain number, species, dbh, basal area and volume for each tree. Later, combination of all the data will give total tree number, basal area and volume. It also can be potray by species or species group. The stand table will guide the user how rich or poor the forests are. Its also will indirectly tell the user the level of recovery happened to the forests area due to activities done within the area.

Information from the stand table then further analyse and parameter such as biomass, i.e. stem, branch and leaves biomass, will be produced. Same as stand table, the result from this table can be seen by single species or species group either by study plot, forest category or state level. This table will allow the user to further understand how much biomass can be produce by each tree or forest area.

Finally, amount of above ground carbon for each tree, later by single species or species group either by study plot, forest category or state level, can be produced. From this table the user will know how much carbon can be fix by each tree or certain forest area. Impact of forest activities on carbon store or carbon release can be detected if we have series of PSP measurement. Forest activities can be of forest harvesting in permanent forest reserve or change of land use to another activities other than forest tree. Change of land use normally happen in stateland forest. The

below ground carbon further can be calculated by multiplying converting factor of 0.5 as indicated by IPCC.

The whole activities then can be potray into a bigger scale of at the national level. By comparing carbon stock of other forest area at the same category, the user can further judge wheather their forest is at par, below or at the upper level. The same procedure as one to compare at the national level. In general term, forests that store higher carbon are better. Forest with lower carbon content implies that such forestry activities cause carbon release.

CLOSING

Forests store large amounts of carbon and thus play a key role in the global carbon budget and possibly in mitigating climate change. Conversely, forest degradation, damage and clearance lead to carbon emissions, with global deforestation being a major contributor to the increase in atmospheric CO₂. The total carbon content of forests consists of living above and below ground biomass, dead organic matter (dead wood and litter) and soil organic matter, of which tree biomass is often the dominant component. Silviculture may influence both forest biomass and biomass production and decomposition and may lead to either the accumulation of carbon or to degradation. Therefore, historic and current forest management greatly influences the amount of carbon stored in the above ground biomass, soils, and in forest products. In this context we need to distinguish between (1) carbon storage, which is the amount of carbon stored in trees and soils, expressed as amounts in metric tonnes or Mg per hectare, and (2) carbon sequestration or release, which describes the flux of carbon either taken up or released from forests and soils, in metric tonnes or Mg per hectare per year. Both storage and flux can be expressed in units of carbon (C) or in CO₂ equivalents.

In general, there is a gradual development towards full carbon accounting, at national as well as at regional and local (project) scales, with full integration of forest inventory. Thus these manual will insight general guidelines in establishing PSPs and their potential to estimate forest carbon budgets and GHG emissions. Extending forest resource assessments from mere carbon stock assessments to the integrated assessment of disturbances as well as climate change and forest management effects will provide a comprehensive information base for the implementation of measures to maintain and enhance the mitigation potential of forests and other forest ecosystem.

ANNEX 1

ANNEX 2

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