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Enhancing Forest Carbon Stock to Reduce Emission from Deforestation and Degradation through Sustainable Forest Management (SFM) Initiatives in Indonesia

Develop Forest Carbon Standard and Carbon Accounting System for Small-scale Plantation Based on Local Experiences

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to Reduce Emission from Deforestation and Degradation
through Sustainable Forest Management (SFM) Initiatives
in Indonesia

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CONTENTS

BOXES

TABLES

FIGURES

EXECUTIVE SUMMARY

Due to the fact that plantation forest can function as potential carbon stock facility besides its wood production, information of carbon biomass produced is of important value. As a result, simple methodology like formulation of allometric equation is required to quantify accumulation of carbon biomass of specific tree plantation stand. Important information summarized from generating this methodology shall be used to promote and to enhance foreign and domestic investment for the establishment of forest tree plantations and thus to accomplish the ultimate goal of carbon sequestration in mitigation and adaptation of global climate change.

Developing forest carbon standard and carbon accounting system for small-scale plantations based on local experiences was executed by establishing sampling plot for measurements of above ground biomass, below ground biomass, total biomass, undergrwoth biomass, litter biomass and soil carbon. Destructive sampling method was used at stand at age of 1, 2, 3, 4, 6, 7, 9, 12, and 15 years old. Biomass by each organ can be estimated from the allometric relations between *DBH* and the total dry weight (*TDW*) of each organ obtained from sample trees. The equations were practically used to estimate the carbon biomass production. Soil investigation was also done covering soil bulk density at 0-100 cm depth, and soil organic carbon. An amount of carbon stored in each soil layer was calculated by multiplying carbon concentration, bulk density and thickness of each layer. The collected data were used to calculate the accumulative carbon content in the soil body.

Allometric equations of *Tectona grandis* resulted from this study are $Y= 0,054\ X^{2,579}$, $R^2 = 0,977$ (aboveground biomass); $Y= 0,006\ X^{2,702}$, $R^2= 0,890$ (belowground biomass); and $Y= 0,093\ X^{2,462}$, $R^2 = 0,971$ (total biomass). Employing these equations, the aboveground biomass, belowground biomass, and total biomass of *Tectona grandis* trees can be estimated just by measuring diameter at breast height of tree stem (trunk). These allometric equations are statistically robust and can be used to estimate tree biomass in other regions provided that the climatic zone is alike. Maximum total biomass was produced at *Tectona grandis* plantation at the age of 15 years old with plant density of 556 trees/ha, and this equivalent to carbon conservation at rate of 298,06 ton /ha CO_2. Undergrowth biomass observed in this study varies between 1,61 ton/ha to 7,22 ton/ha with average of 3,43 ton/ha. Further more, the amount of litter produced in this study varies between 1,26 ton/ha to 3,68 ton/ha with average of 2,05 ton/ha.

In most cases, soil bulk density only slightly changes with increase in soil depth. Normally soil bulk density increases with increase in soil depth, and this phenomenon is correlated with the accumulation of clay particel in lower layer of soils. The highest soil organic carbon was observed in the soil surface of 0-5 cm depth, with magnitude ranges from 1,55 % to 2,08 % across all the study sites. Cumulative soil carbon conserved from soil surface to the depth of 100 cm in *Tectona grandis* plantation ranges from 63,42 ton C/ha to 93,81 ton C/ha equivalent to 232,54 ton CO_2/ha and 343,97 ton CO_2/ha.

INTRODUCTION

It is now widely acknowledged and scientifically proven that increased emissions of Green Houses Gases (GHG's) since the mid-19th century are causing significant changes in the global climate. It is predicted that there will be increasing drought and aridity, more destructive floods and storms, and rises in sea level which will dramatically affect billions of coastal people, including the deltaic mega cities of Asia. The most significant of the GHG's is carbon dioxide which has increased in its concentration by 35% compared to the pre-industrial era, while 67% of the increase in due to the burning of fossil fuels, and tropical deforestation accounts for something between 20 and 25% of global emissions. Most of emissions from deforestation come from developing countries. Successfulness in reducing emission from deforestation will have significant impact on mitigation the global warming.

Emissions from deforestation and forest degradation are the result of a combination of the activities of people and of powerful vested and often politically driven interests aimed at harnessing forest revenues for commercial gain. About 7.3 million ha of tropical forest has degraded each year. Considering this fact, parties who signed convention on climate change and Kyoto Protocol have introduced two mechanisms that can assist developing countries to reduce the emissions from deforestation (RED) and to enhance carbon sequestration. The first mechanism known as *Reduced Emissions from Deforestation* (RED) was proposed at the UNFCCC COP 11 in Montreal in 2005, while the second known as A/R CDM (*Afforestation and reforestation Clean Development Mechanism*) under the Kyoto Protocol.

Figure 1. A 2-year teak forest of KPWN community-based plantation

Indonesia has big potential for carbon trading through A/R CDM and REDD. Nevertheless, there are a number of barriers to achieve that potential. Implementation of pilot projects on REDD and A/R CDM with the involvement of multistakeholders and community surrounding forests will increase Indonesia capacity to participate in such carbon trading. Lesson learnt from implementing pilots on both REDD and A/R CDM in more integrated way can be used for setting up long term strategies for managing forest in sustainable way with high intensity of community participation. Further more, Sustainable forest management (SFM) practice implemented by forest concession holders is believed to support the REDD program in Indonesia as such to obtain the achievement of global climate change mitigation and adaptation.

Due to the fact that plantation forest can function as potential carbon stock facility besides its wood production, information of carbon biomass produced is of important value.

As a result, simple methodology like formulation of allometric equation is required to quantify accumulation of carbon biomass of specific tree plantation stand. Important information summarized from generating this methodology shall be used to promote and to enhance foreign and domestic investment for the establishment of forest tree plantations and thus to accomplish the ultimate goal of carbon sequestration in mitigation and adaptation of global climate change.

DEVELOPMENT OF CARBON ACCOUNTING TOOL IN PLANTATION FOREST

1. To develop standard method for carbon accounting system in small-scale plantation based on local experiences
2. To determine carbon stock in teak and other tree species in small-scale plantation
3. To determine carbon stock in community forest, including certified forests in Java and Madura based on available data

HOW TO MAKE CARBON CALCULATION TOOL

Early Stage

Methodology to Develop Forest Carbon Standard and Carbon Accounting System for Small-scale Plantations Based on Local Experiences is described below:

a. Establishing a permanent sampling plot for carbon quantification (50 m X 50 m site each for 1 year, 2 year, 3 year, 4 year, 6 year, 7 year, 9 year, 12 year, and 15 year old plantation)
b. Quantification of all carbon stock on four carbon pool (above ground biomass, below ground biomass, litter, and soil on each 50 m X 50 m site). Since the amount of necromass is not significant, this pool is excluded.
c. Developing a methodology to measure above ground biomass, below ground biomass, litter, and soil.

The step by step procedure in establishment of allometric equation for each species is describes as followed :

a. Fell 32 trees (minimum)
b. Measure DBH (D), and tree height (H)
c. Weigh vegetation biomass covering stem, branch, leaf, and root (fresh weigh)
d. Bring each sample of stem, branch, leaf, and root, approximately 200 g each, and weigh their oven dry biomass in laboratory. Later was used to calculate total dry weigh of each component
e. Operate allometry equation $Y = a X^{b}$ (coefficient a, b)
   Y = total dry biomass = stem + root + branch + leaf dry weigh (kg)
   X = diameter at breast height (cm)
f. Determine carbon content of each sample using NC Analyzer. Next, determine the carbon content ratio of stem, branch, leaf, and root
g. Developing local allometric equations suggested to estimate total carbon biomass of plantation.

Tree Biomass Measurement

1. Felling samples tree

One to six trees were selected for sampling that would represent the whole plot. The DBH of the selected trees must, therefore, range from small to large DBH according to DBH distribution data collected in the field.

a. Chain saw was applied for felling the sample tree. The tree was felled at 0,3 m from the ground. The undercut from the felled tree was set aside for weighing as the weight of which was included in the total weight of the felled trunk
b. The remaining stump was cut off at the ground level that would make the log of 0,3 m in length for weighing. The weight was included in the total weight of the felled trunk
c. All the boughs were cleared off the felled trunk and the stump and collected for weighing
d. The height of the felled tree was measured before the trunk was cut in to logs
e. The tree trunk was cut in to logs for convenience of weighing. It is advisable to mark the felled trunk with cutting positions before hand at the positions indicating, for example, 1,3m, 3,3m, 5,3m, and so on from the ground ("1,3m" was marked at 1m from the cut bottom as the tree was felled at 0,3m from the ground). It is also advisable to mark the position of each log on its surface to avoid errors in recording data. For example, to the log corresponding to the part of the trunk 0,3m to 1,3m from the ground mark "0,3-1,3", and the next log corresponding to 1,3m to 3,3m mark "1,3-3,3" and so on.

Note: Each sample tree must be numbered and the logs cut out of it must bear the same number. The length of a log can be varied from one tree to another depending on the size of the tree

f. When cutting, the trunk must be cross-cut the marked position so that the diameter of the bottom end of each log can be measured accurately
g. Each log was weighed and noted in the field note. Use of various spring scales according to the weight is advisable.

   Tools: A saw or chain saw, chalks, tape measures, and various spring balances.

2. Measuring fresh weight of each organ of a sample tree

a. All the boughs were cleared off of all the small branches (twigs and leaves). The cleared boughs and the small branches were collected onto a separate vinyl sheet
b. The small branches then were stripped off of all the leaves. The leaves and the twigs were collected separately on the vinyl sheets for weighing
c. The cleared boughs were weighed, and noted in the field note. It is advisable to wrap the boughs in a vinyl sheet or bundle them with a rope for weighing by spring scale. The tare such as the vinyl sheet or the rope must be weighed and note in the field note as well
d. The twigs were weighed. It is advisable to weigh them in appropriate vinyl bags or wrapped up in a vinyl sheet. The tare such as the bags or the sheet must be weighed and note in the field note as in the above
e. Lastly, all the leaves were weighed, and noted in the field note. The leaves shall be weighted in appropriate bags or wrapped up in a sheet. The tare must be weighed and note in the field note

3. Collecting samples for dry weight estimate

Dry weight estimated, that is required to work out the volume of carbon estimate of biomass, can be made by sample.

Sample for dry weight estimate was collected from the sample tree used for fresh weight measurement in the above 2. The sample of the trunk, boughs, twigs, leaves, and roots were collected. It is advisable to collect each of them in to separate paper bags for drying and weighing. The sample tree number and the organ name must be indicated on each bag. The sample collected in the bags was weighed immediately for the fresh weight and was noted in the field note. The weight of the tare was weighed and noted in the field note as well. It is strongly suggested that a balance with high accuracy such as an electronic balance be used.

a. Trunk

   A disk of 2,0 cm to 4,0 cm thickness was cut out of each log marked with "0,3-1,3", "1,3-3,3" and so on indicating its position of felled trunk. The disk with the bark was put into a paper bag with the sample tree number and the log position clearly indicated.

b. Boughs

Sample was selected from boughs of various diameter and cut into 10 cm pieces in length. The cut pieces were put into a paper bag with the sample tree number clearly indicated. The desirable weight of a sample is around 0,5kg to 1,0kg.

c. Twigs

Sample was cut in to 10 cm pieces in length and put into a paper bag. The desirable weight of a sample is around 0,3kg to 0,5kg.

d. Leaves

The leaves were put into a paper bag. The desirable weight of a sample is around 0,3kg to 0,5kg.

e. Roots

The roots were put into a paper bag. The desirable weight of a sample is around 0,3kg to 0,5kg.

Tools: Small saw, pruning shears, ground sheets in vinyl, large and small paper bag, small plastic bags, spring scales, an electronic balance.

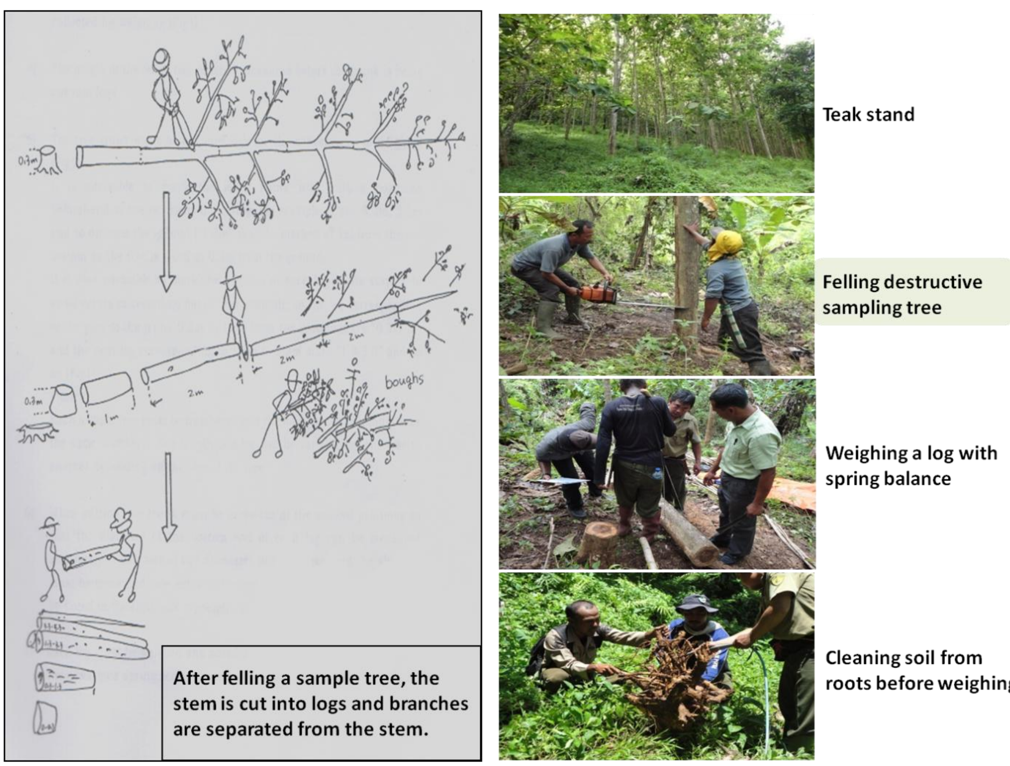


Figure 2. Procedures to measure tree bio-mass

4. Drying sample

The sample must be dried in circulating oven. The sample of the trunks (the disk of the above item 3-a), sample of the boughs of the above item 3-b, and sample of the roots with diameter ≥ 2 cm were dried in a circulating oven at the temperature kept at 80 to 90 degrees centigrade for 4 days (96 hrs). The sample of twigs, leaves, and small roots were dried for two days (48hrs). The dry weight of the sample was weighed and noted in the field note, and then calculate the moisture contents of the each organ.

Estimating Total Dry Weight of Each Sample Tree

Total dry weight (TDW) of each organ of sample tree was calculated from its total fresh weight (TFW), the fresh weight of its organ sample (SFW) and its dry weight (SDW).

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

$$TDW_{trunk} = \frac{SDW_{trunk}}{SFW_{trunk}} \text{ X } TFW_{trunk}$$

$$TDW_{boughs} = \frac{SDW_{boughs}}{SFW_{boughs}} \text{ X } TFW_{boughs}$$

$$TDW_{twigs} = \frac{SDW_{twigs}}{SFW_{twigs}} \text{ X } TFW_{twigs}$$

$$TDW_{leaves} = \frac{SDW_{leaves}}{SFW_{leaves}} \text{ X } TFW_{leaves}$$

$$TDW_{roots} = \frac{SDW_{roots}}{SFW_{roots}} \text{ X } TFW_{roots}$$

Figure 3. An old teak stand, a promising C-stock at Perum Perhutani (Ciamis, West Java)

Making Allometric Equation for Estimating Tree Biomass

Biomass by each organ in the site can be estimated from the allometric relations between *DBH* and the total dry weight (*TDW*) of each organ obtained from sample trees. Allometric relation is expressed in the following equations;

$$TDW = a \, . \, (DBH)^b \, ; \quad Y = a \, . \, (X)^b$$

Or

$$\ln TDW = \ln a + b \, . \, \ln (DBH)$$

where,

> ***a*** and ***b*** are coefficients. The coefficients can be applied to estimating biomass of other sites of the same species near the test site.
> *TDW* of each organ of every standing tree in the site can be estimated, using the equations and *DBH* distribution data of the site.

Biomass per unit area is calculated as follows:

$$BM = \frac{sumTDW}{AREA}$$

where,

> $_{Sum}$ ***TDW*** : the sum of the total dry weight of every standing tree in the target site (total dry matter)
>
> ***AREA*** : the area of the target site (ha=10000m^2)
>
> ***BM*** : the biomass of the target site (t dry matter/ha)
>
> In converting the dry matter to carbon unit, 0,5 is generally used as a conversion coefficient.

Soil Sampling Procedures for Soil Carbon Stock Estimation

Soil samples were collected from 1 , 2 , 3 year old teak plantation (representing Ciampea site), 4 year old teak plantation (representing Parung site), and 9 year old teak plantation (representing Ciamis site). From each representing site, soil samples were collected from 0-100 cm deep. Stages of soil sampling are as follows:

1. Place a measuring frame or a bicycle tire on the ground and collect all the litters in it
2. Make a hole near the place where collecting the litters for collecting soil samples
3. Bury the soil sampling rings of known volume in the ground where collecting the litters
4. Dig the ground in 5 cm horizontally
5. Bury the soil sampling rings in the new ground 5 cm deep
6. Repeat the procedures 4 and 5 until 1 meter depth
7. Dig the soil sampling ring one by one carefully
8. Cut the excessive soil out of the soil sampling ring with the knife
9. Take the soil out from the ring and put together in to plastic bag to make a composition sample for each layer/horizon.

Figure 4. Soil samples for carbon estimation

Figure 5. Undergrowth and litter bio-mass measurement

Soil Analysis and Calculation of Soil Carbon Storage

1. Bulk density (BD) was measured using a 98,125 cm^3 core cylinder for sampling. The sampling was performed with four replications for each soil layer, and the four cylinder samples taken from each soil layer were mixed together to prepare one composite sample for each layer
2. Total carbon content was determined by the dry-combustion method using a N-C analyzer (Sumigraph NC-900, Sumitomo Chemicals)
3. An amount of carbon stored in each soil layer was calculated by multiplying carbon concentration, bulk density and thickness of each layer. The amount of carbon storage down to ascertain soil depth was worked out by summing up the storage in all soil layers included.

Figure 6. Young teak stands mixed with agricultural crops

ALLOMETRIC EQUATIONS of *Tectona grandis*

Allometric equations of *Tectona grandis* resulted from this study is summarized in Table 1 and three curves are shown in Box 1. Employing these equations, aboveground biomass, belowground biomass, and total biomass of *Tectona grandis* trees can be estimated just by measuring diameter at breast height of tree stem (trunk). These allometric equations is statistically robust and can be used to estimate tree biomass in other regions provided that the climatic zone is alike.

Table 1. Parameters of allometric equations to estimate aboveground biomasas, belowground biomass and total biomass, $Y= a\ x^{b}$

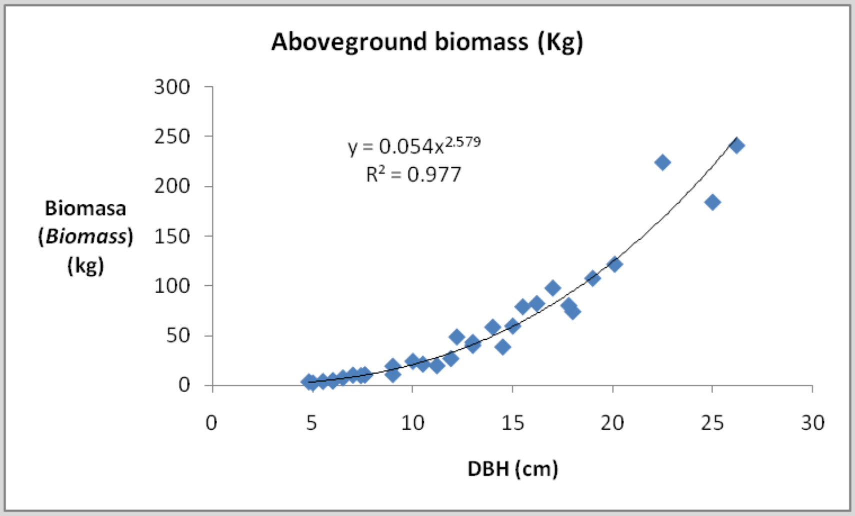
Biomass	***Independent variable (X)***	***Constant***		***R-square***
		a	**b**	
Above ground	DBH (cm)	0,054	2,579	0,977
Below ground	DBH (cm)	0,006	2,702	0,890
Total	DBH (cm)	0,093	2,462	0,971

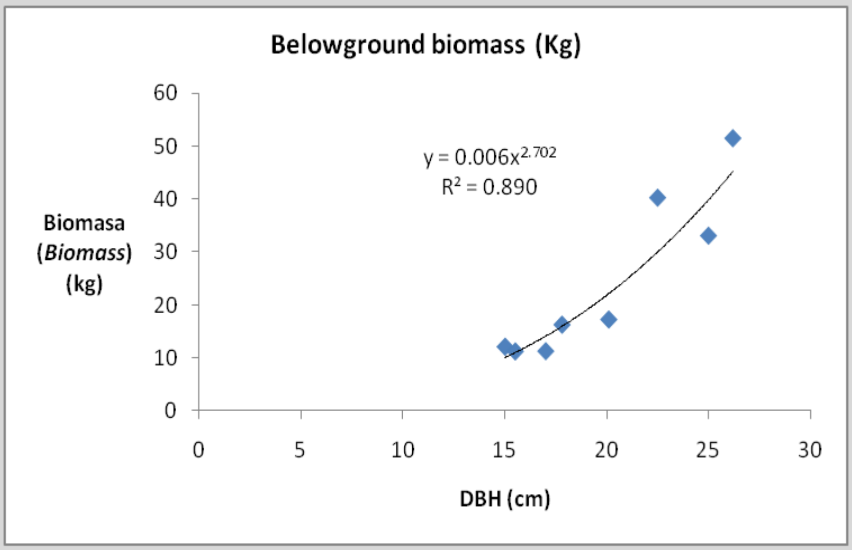
Allometry is an effective method for accurately estimating biomass of trees. However, the labor and expense of construction and validating the necessary equations limit the application of the allometric approach in biomass sampling (MacDicken, 1997). Allometry represents relationships between/among growth of different part of plants. For example, if the relationship between diameter of stem at breast height and total biomass has been established, it becomes easier to estimate total biomass of the forest. Just measuring diameter of stem at breast height of each tree is enough to estimate the amount of biomass and carbon in that forest.

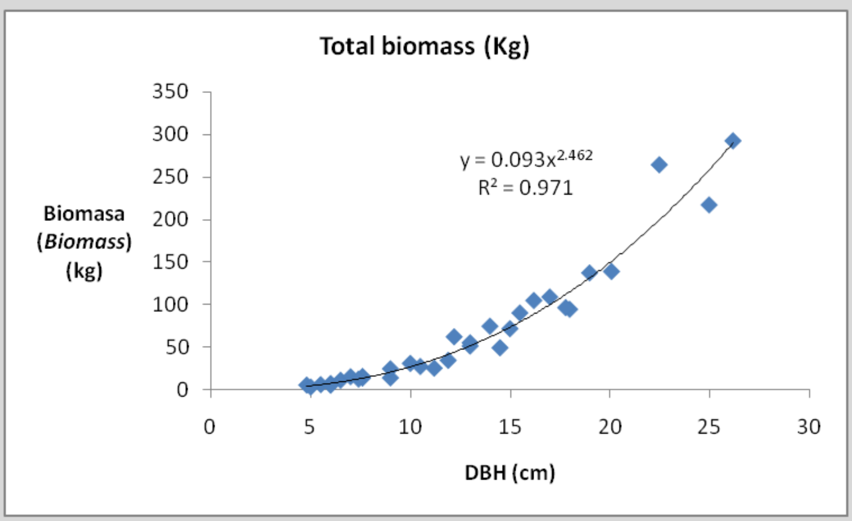
Allometric equations of *Tectona grandis* obtained from this study is good to be operated, however, the use of the equations should consider the fact that the equations were constructed by utilizing diameter at breast height (DBH) ranged from 4,8 cm to 22,6 cm. The allometric equations produced are $Y= 0{,}054\ X^{2{,}579}$, $R^2 = 0{,}977$ (aboveground biomass); $Y= 0{,}006\ X^{2{,}702}$, $R^2= 0{,}890$ (belowground biomass); and $Y= 0{,}093\ X^{2{,}462}$, $R^2 = 0{,}971$ (total biomass). Raw data of field observation can be seen in Appendix 1. Note that biomass estimation by using diameter of stem at breast height (DBH) outside this diameter interval value should be avoided to maintain the accuracy of estimation value.

Based on *Tectona grandis* allometric equation resulted from this study, estimation of aboveground biomass value (kg) per tree with DBH ranging from 4,8 cm to 28,3 cm is presented in Box 2. In addition to this *Tectona grandis* allometric, allometric equation of several important plantation forest tree species is presented in Box 3. A description of the growing site similarity may need to be considered, including soil and climate factors, in order to operate allometric equation in other growing site.

Box 1. Allometric equation for aboveground, belowground, and total biomass of T. grandis plantation at Ciampea, Parung and Ciamis, West Java: DBH as independent variabel







Box 2. Aboveground biomass estimated value of *T. grandis* based on DBH measurement

DBH (cm)	Aboveground biomass (kg)	DBH (cm)	Aboveground biomass (kg)	DBH (cm)	Aboveground biomass (kg)	DBH (cm)	Aboveground biomass (kg)	DBH (cm)	Aboveground biomass (kg)
4,8	3,09	9,5	17,94	14,2	50,60	18,9	105,78	23,6	187,56
4,9	3,25	9,6	18,43	14,3	51,52	19,0	107,23	23,7	189,61
5,0	3.43	9,7	18,93	14,4	52,46	19,1	108,69	23,8	191,68
5,1	3,61	9,8	19,44	14,5	53,40	19,2	110,16	23,9	193,77
5,2	3,79	9,9	19,96	14,6	54,35	19,3	111,65	24,0	195,87
5,3	3,98	10,0	20,48	14,7	55,32	19,4	113,14	24,1	197,98
5,4	4,18	10,1	21,01	14,8	56,30	19,5	114,66	24,2	200,10
5,5	4,38	10,2	21,56	14,9	57,29	19,6	116,18	24,3	202,24
5,6	4,60	10,3	22,11	15,0	58,28	19,7	117,71	24,4	204,40
5,7	4,81	10,4	22,66	15,1	59,29	19,8	119,26	24,5	206,56
5,8	5,03	10,5	23,23	15,2	60,31	19,9	120,82	24,6	208,74
5,9	5,25	10,6	23,80	15,3	61,34	20,0	122,39	24,7	210,94
6,0	5,49	10,7	24,39	15,4	62,37	20,1	123,98	24,8	213,15
6,1	5,72	10,8	24,98	15,5	63,42	20,2	125,57	24,9	215,37
6,2	5,97	10,9	25,58	15,6	64,49	20,3	127,18	25,0	217,61
6,3	6,22	11,0	26,19	15,7	65,56	20,4	128,80	25,1	219,86
6,4	6,48	11,1	26,81	15,8	66,64	20,5	130,43	25,2	222,13
6,5	6,74	11,2	27,43	15,9	67,73	20,6	132,07	25,3	224,41
6,6	7,01	11,3	28,07	16,0	68,84	20,7	133,74	25,4	226,70
6,7	7,30	11,4	28,71	16,1	69,95	20,8	135,41	25,6	231,34
6,8	7,57	11,5	29,37	16,2	71,08	20,9	137,10	25,7	233,67
6,9	7,87	11,6	30,03	16,3	72,21	21,0	138,80	25,8	236,03
7,0	8,16	11,7	30,71	16,4	73,36	21,1	140,51	25,9	238,39
7,1	8,47	11,8	31,38	16,5	74,52	21,2	142,24	26,0	240,77
7,2	8,78	11,9	32,08	16,6	75,69	21,3	143,97	26,1	243,17
7,3	9,10	12,0	32,78	16,7	76,87	21,4	145,72	26,2	245,58
7,4	9,42	12,1	33,49	16,8	78,07	21,5	147,49	26,3	248,00
7,5	9,75	12,2	34,21	16,9	79,27	21,6	149,26	26,4	250,44
7,6	10,09	12,3	34,93	17,0	80,49	21,7	151,05	26,5	252,90
7,7	10,43	12,4	35,67	17,1	81,71	21,8	152,85	26,6	255,37
7,8	10,79	12,5	36,42	17,2	82,95	21,9	147,49	26,7	257,85
7,9	11,15	12,6	37,17	17,3	84,20	22,0	156,50	26,8	260,35
8,0	11,52	12,7	37,94	17,4	85,46	22,1	158,33	26,9	262,86
8,1	11,90	12,8	38,72	17,5	86,73	22,2	160,19	27,0	265,39
8,2	12,28	12,9	39,50	17,6	88,02	22,3	162,06	27,1	267,93
8,3	12,67	13,0	40,30	17,7	89,31	22,4	163,94	27,2	270,49
8,4	13,07	13,1	41,10	17,8	90,62	22,5	165,83	27,3	273,06
8,5	13,47	13,2	41,91	17,9	91,94	22,6	167,74	27,4	275,64
8,6	13,88	13,3	42,74	18,0	93,27	22,7	169,66	27,5	278,25
8,7	14,30	13,4	43,57	18,1	94,61	22,8	171,60	27,6	280,87
8,8	14,73	13,5	44,41	18,2	95,97	22,9	173,54	27,7	283,50
8,9	15,17	13,6	45,27	18,3	97,33	23,0	175,51	27,8	286,14
9,0	15,61	13,7	46,13	18,4	98,71	23,1	177,48	27,9	288,81
9,1	16,06	13,8	47,00	18,5	100,10	23,2	179,47	28,0	291,48
9,2	16,51	13,9	47,87	18,6	101,50	23,3	162,06	28,1	294,18
9,3	16,99	14,0	48,78	18,7	102,91	23,4	183,49	28,2	296,88
9,4	17,46	14,1	49,69	18,8	104,34	23,5	185,51	28,3	299,61

Box 3. Allometric equation of several plantation forest tree species

No.	Tree species	Allometric (Y)	Location
1.	*A. mangium*	$Y = 0.12\ (DBH)^{2.28}$	Maribaya, Bogor
2.	*P. merkusii*	$Y = 0.1\ (DBH)^{2.29}$	Cianten, Bogor
3.	*S. leprosula*	$Y = 0.15\ (DBH)^{2.3}$	Ngasuh. Bogor
4.	*P. falcataria*	$Y = 0.1479\ (DBH)^{2.2989}$	Sukabumi
5.	*P. falcataria*	$Y = 0.2831\ (DBH)^{2.063}$	Kediri
6.	*Avicennia marina*	$Y = 0.2901(DBH)^{2.2605}$	Ciasem, Subang
7.	*Agathis loranthifolia*	$Y = 0.4725\ (DBH)^{2.0112}$	Baturaden
8.	*Aleurites moluccana*	$Y = 0{,}064(DBH)^{2{,}4753}$	Kutacane, Aceh Tenggara
9.	*Rhizophora mucronata*	$Y = 0{,}1366(DBH)^{2{,}4377}$	Ciasem, Purwakarta

Proportion of aboveground biomass (trunk, boughs, twigs, and leaves) to belowground biomass (roots) so called top root ratio is also presented in Table 2. This critical information illustrates the biomass distribution within one whole tree. It is of interest to note that root biomass measurement in the field, in fact, was proven to be somewhat exhausted. In the mean time, in general, available biomass data easier to measure is aboveground biomass. This is to say that availability of top root ratio value of a given tree species will be important in predicting the belowground biomass value whenever only aboveground biomass data is available. As a result, contribution of root biomass in terms of carbon conservation can be easily estimated. This study indicates that top root ratio of *Tectona grandis* plantation, in most cases ranged from 2,10 to 5,56 (see Table 2). Top root ratio value of 7,06 and 8,70 are considered as outliers indicating sub-optimum growth of *Tectona grandis* observed in the case of 7 year old plantation bearing lower diameter as compared to that of 6 year old plantation, and in the case of 9 year old plantation bearing lower diameter as compared to that of 7 year old plantation in Ciamis. Table 3 shows that, in general, top root ratio of *Tectona grandis* plantation increases gradually with increases in age (2,10 to 5,56).

This fact indicates that *Tectona grandis* plantation at age from one year to nine years produced biomass during growth and development process in which most of the mass was allocated at trunk, boughs, twigs, and leaves (aboveground). Furthere more, at age from 12 years to 15 years the top root ratio of biomass tended to decrease and this indicating the relatively higher root growth intensity than the growth of aboveground part which undergoes flat fashion. This phenomenon implies that biomass production at late growth stage was allocated to the root at the expense of aboveground part of a tree (Siregar, 2007).

Table 2. DBH, total height, aboveground biomass , root dry weight, and top root ratio of *T. grandis* plantaion at Ciampea, Parung and Ciamis

DBH (cm)	Total height (m)	Aboveground biomass (Kg)	Root dry weight (Kg)	Top-root ratio	Plantation density (tress /ha)	Remarks (Location, age)
4,8	4,55	3,89	1.85	2,10	1000	Ciampea, 1 Years
5,5	4,67	4,274	***2.03***	-	1000	Ciampea, 1 Years
6	5,2	5,122	***2.44***	-	1000	Ciampea, 1 Years
6,5	6,3	7,766	***3.70***	-	1000	Ciampea, 1 Years
7	7,15	10,56	***5.03***	-	1000	Ciampea, 1 Years
7,6	8,6	10,781	***5.13***	-	1000	Ciampea, 1 Years
5	4,85	2,643	***0.74***	-	1000	Ciampea, 2 Years
6	6,4	4,639	***1.29***	-	1000	Ciampea, 2 Years
7,6	8,25	10,886	***3.03***	-	1000	Ciampea, 2 Years
9	8,45	11,14	3.10	3,59	1000	Ciampea, 2 Years
10,5	9,07	21,595	***6.01***	-	1000	Ciampea, 2 Years
13	9,56	40,354	***11.23***	-	1000	Ciampea, 2 Years
11,2	9,8	20,012	5.53	3,62	1000	Ciampea, 3 Years
11,9	7,71	27,218	7.49	3,63	1000	Ciampea, 3 Years
9	8,11	19,521	***5.37***	-	1000	Ciampea, 3 Years
7,4	7,91	10,05	***2.77***	-	1000	Ciampea, 3 Years
14,5	7,08	38,872	***10.70***	-	1000	Ciampea, 3 Years
18	12,35	74,274	***20.44***	-	1000	Ciampea, 3 Years
10	9,6	24,443	***6,73***	-	1000	Parung, 4 Years
12,2	11,67	48,944	***13,48***	-	1000	Parung, 4 Years
13	12,9	43,42	***11,96***	-	1000	Parung, 4 Years
14	13,56	58,684	***16,17***	-	1000	Parung, 4 Years
16,2	13,25	82,354	***22,69***	-	1000	Parung, 4 Years
19	9,3	107,742	***29,68***	-	1000	Parung, 4 Years
15	15,2	59,853	***12.12***	-	1111	Ciamis, 6 Years
17,8	14,16	80,425	16.28	4,94	1111	Ciamis, 6 Years
15,5	15,1	79,212	11.22	7,06	1111	Ciamis, 7 Years
20,1	17,3	121,873	***17.26***	-	1111	Ciamis, 7 Years
17	13,07	97,961	11.27	8,70	833	Ciamis, 9 Years
25	9,7	184,192	***33.11***	-	556	Ciamis, 12 Years
22,5	19,25	224,097	40.29	5,56	556	Ciamis, 12 Years
26,2	19,55	240,971	51.53	4,67	556	Ciamis, 15 Years

***Italic number is estimated value**

Table 3. Average of aboveground, below ground, total biomass, top root ratio, gross biomass and litter biomass of each stand age in *T. grandis* at Ciampea, Parung and Ciamis, West Java

	Stand age (Year)								
	1	**2**	**3**	**4**	**6**	**7**	**9**	**12**	**15**
Stand density (N/ha)	1000	1000	1000	1000	1111	1111	833	556	556
Aboveground biomass									
Average									
kg/tree	7,07	15,21	31,65	60,93	70,14	100,54	97,96	204,14	240,90
ton/ha	7,07	15,21	31,65	60,93	77,92	111,69	81,60	113,50	133,94
Carbon content (ton/ha)	3,54	7,61	15,83	30,47	38,96	55,85	40,80	56,75	66,97
Belowground biomass									
Average									
kg/tree	3,36	4,23	8,72	16,79	14,2	14,24	11,27	36,7	51,53
ton/ha	3,36	4,23	8,72	16,79	15,78	15,82	9,39	20,40	28,65
Carbon content (ton/ha)	1,68	2,12	4,36	8,40	7,89	7,91	4,70	10,20	14,33
Total biomass									
Average									
kg/tree	10,43	19,44	40,37	77,72	84,34	114,78	109,23	240,84	292,43
ton/ha	10,43	19,44	40,37	77,72	93,7	127,51	90,99	133,9	162,59
Carbon content (ton/ha)	5,22	9,73	20,19	38,87	46,85	63,76	45,5	66,95	81,30
Average of top root ratio	2,10	3,58	3,63	3,63	4,94	7,06	8,70	5,56	4,67
Undergrowth biomass									
Average									
ton/ha	7,22	4,72	3,74	3,11	2,29	1,61	1,98	2,83	3,38
Carbon content (ton/ha)	3,61	2,36	1,87	1,55	1,14	0,80	0,99	1,41	1,69
Litter biomass									
Average									
ton/ha	1,26	1,30	1,81	3,68	1,36	1,51	3,48	2,11	1,99
Carbon content (ton/ha)	0,63	0,65	0,90	1,84	0,68	0,75	1,74	1,05	0,99

Total biomass (aboveground and belowground) produced at one year old *Tectona grandis* (stand density 1000 trees/ha) is 10,43 ton/ha, while at 2 year old plantation (stand density 1000 trees/ha) is 19,44 ton/ha, 3 year old plantation (stand density 1000 trees/ha) is 40,37 ton/ha, 4 year old plantation (stand density 1000 trees/ha) is 77,72 ton/ha, 6 year old plantation (stand density 1111 trees/ha) is 93,7 ton/ha, 7 year old plantation (stand density 1111 trees/ha) is 127,51 ton/ha, 9 year old plantation (stand density 833 trees/ha) is 90,99 ton/ha, 12 year old plantation (stand density 556 trees/ha) is 133,9 ton/ha, and 15 year old plantation (stand density 556 trees/ha) is 162,59 ton/ha. This finding shows that maximum total biomass occurred at *Tectona grandis* plantation at the age of 15 years old with plant density of 556 trees/ha, and this equivalent to carbon conservation at rate of 298,06 ton /ha CO_2 (assuming that carbon content is 50 % of dry tree biomass (Brown, 1997)).

Undergrowth biomass observed in *Tectona grandis* plantation at the age of 1, 2, 3, 4, 6, 7, 9, 12, and 15 varies between 1,61 ton/ha to 7,22 ton/ha with average of 3,43 ton/ha. Further more, the amount of litter produced in *Tectona grandis* plantation varies between 1,26 ton/ha to 3,68 ton/ha with average of 2,05 ton/ha. Approximately 50% of litter biomass production consists of elemental carbon, and this organic carbon will be decomposed over time, and in turn will enrich the soil organic carbon or soil organic matter.

Case study of aboveground biomass estimates based on secondary data of community plantation forest in Madura (BPKH Wilayah XI Jawa-Madura, 2009) is summarized in Box 4. In the case of *Tectona grandis* plantation, distribution of diameter at breast height ranges from 6,05 cm to 50,00 cm; while in the case of *Acacia mangium* plantation, distribution of diameter at brest height ranges from 1,00 cm to 63,00 cm; and in the case of *Paraserianthes falcataria* plantation, distribution of diameter at brest height ranges from 21,00 cm to 47,00 cm. This observation indicates that the highest aboveground biomass production occurred in the fast growing *P. falcataria* plantation with magnitude of 207,49 ton/ha equivalent to 380,41 ton/ha CO_2 conservation.

Box 4. Aboveground biomass estimated value for *T. grandis, A. mangium,* and *P. falcataria* at Bangkalan regency/ Madura. (using allometric equations: *T. grandis,* $Y= 0,054\ DBH^{2,579}$, *A. mangium,* $Y= 0,12\ DBH^{2,28}$, *P. falcatia,* $Y= 0,2831\ DBH^{2,063}$)

	Tree species		
	T. grandis	***A. mangium***	***P. falcataria***
Stand density assumption (N/ha)	556	556	556
Average aboveground biomass			
kg/tree	317,280	234,865	373,188
ton/ha	176,40	130,60	207,49
Carbon content (ton/ha)	88,20	65,30	103,75

SOIL CARBON CONTENT

Results of soil carbon and bulk density analisis at 0-100 cm depth in *Tectona grandis* at Ciampea, Parung, and Ciamis is presented in Box 5. Data presented in Box 5 shows that soil organic carbon decreases with increase in soil depth. The amount of soil organic material encountered at the surface layer, is affected by soil texture, vegetation, water content or soil aeration, and temperature. Generally, soil organic matter content correlated positively with clay particles and negatively correlated with sand particles, and decreases with increasing soil depth (Baize, 1993). In most cases, soil bulk density only slightly changes with increase in soil depth. Normally soil bulk density increases with increase in soil depth, and this phenomenon is correlated with the accumulation of clay particel in lower layer of soils.

The highest soil organic carbon was observed in the soil surface of 0-5 cm depth, with magnitude ranges from 1,55 % to 2,08 % across all the study sites. The same results were also reported by Siregar *et al.* (2003) and Siringo-ringo *et al.* (2003) working on *Orthic Acrisol, Orthic Ferrasol,* dan *Dystric Nitosol*.

Soil and soil organic matter function in the global carbon cycle has been an object of wide array of research for many years, and it was reported that soil consreved carbon 2,1 time as much as that conserved in atmosphere, and conserved carbon 2,7 time as much as that conserved in vegetation globally (Metting *et al.,* 1999). Observation made from this study indicates that cumulative soil carbon conserved from soil surface to the depth of 100 cm ranges from 63,42 ton C/ha to 93,81 ton C/ha equivalent to 232,54 ton CO2/ha and 343,97 ton CO2/ha.

Several important findings summarized from the activities of developing forest carbon accounting standard for small plantation based on local experience are shown in Box 6.

Figure 7. A planted *Acacia mangium* stand, huge C-stock in tropical forests

Box 5. Soil carbon content and bulk density at 0-100 cm depth of *T. grandis* plantation

Location	Depth (cm)	C org (%)	Bulk density (g/cm3)	Carbon Stock (ton/ha)	Cummulative carbon stock	
					Depth (cm)	(ton/Ha)
CIAMPEA	0-5	2,08	0,876	9,11	0-5	9,11
	5-10	2,04	0,848	8,65	10	17,76
	10-20	1,51	0,925	13,97	20	31,73
	20-30	0,96	0,943	9,05	20-30	40,78
	30-50	0,83	0,968	16,07	30-50	56,85
	50-70	0,58	0,983	11,40	50-70	68,25
	70-100	0,36	1,007	10,88	70-100	79,13
CIAMPEA	0-5	2,07	0,955	9,88	0-5	9,88
	5-10	1,74	0,917	7,98	10	17,86
	10-20	1,28	0,902	11,56	20	29,42
	20-30	1,07	0,815	8,72	20-30	38,14
	30-50	0,82	0,925	15,17	30-50	53,31
	50-70	0,58	0,912	10,58	50-70	63,89
	70-100	0,48	0,936	13,47	70-100	77,36
CIAMPEA	0-5	1,65	0,983	8,11	0-5	8,11
	5-10	1,48	0,920	6,81	10	14,92
	10-20	1,20	0,955	11,46	20	26,38
	20-30	0,87	0,930	8,10	20-30	34,48
	30-50	0,64	0,894	11,44	30-50	45,92
	50-70	0,49	0,859	8,42	50-70	54,34
	70-100	0,41	0,876	10,77	70-100	65,11
PARUNG	0-5	1,55	1,009	7,82	0-5	7,82
	5-10	1,12	0,910	5,10	10	12,92
	10-20	1,01	1,085	10,96	20	23,88
	20-30	0,55	1,185	6,52	20-30	30,40
	30-50	0,44	1,399	12,31	30-50	42,71
	50-70	0,32	1,529	9,79	50-70	52,50
	70-100	0,30	1,213	10,92	70-100	63,42
CIAMIS	0-5	1,75	1,197	10,47	0-5	10,47
	5-10	1,42	1,103	7,83	10	18,30
	10-20	1,17	1,162	13,60	20	31,90
	20-30	1,09	0,986	10,75	20-30	42,65
	30-50	0,85	1,001	17,02	30-50	59,67
	50-70	0,80	0,887	14,19	50-70	73,86
	70-100	0,65	1,023	19,95	70-100	93,81

Box 6 . Some conclusions derived from this field study are:

1. The allometric equations for *Tectona grandis* are $Y= 0{,}054\ X^{2{,}579}$, $R^2 = 0{,}977$ (aboveground biomass); $Y= 0{,}006\ X^{2{,}702}$, $R^2= 0{,}890$ (belowground biomass); and $Y= 0{,}093\ X^{2{,}462}$, $R^2 = 0{,}971$ (total biomass).
2. Aboveground biomass estimated value of *T. grandis* based on DBH measurement presented in Table 3 can be employed for practical use.
3. Maximum total biomass occurred at *Tectona grandis* plantation at the age of 15 years old with plant density of 556 trees/ha, and this equivalent to carbon conservation at rate of 298,06 ton /ha CO_2.
4. Cumulative soil carbon conserved from soil surface to the depth of 100 cm in *Tectona grandis* plantation ranges from 63,42 ton C/ha to 93,81 ton C/ha equivalent to 232,54 ton CO_2/ha and 343,97 ton CO_2/ha.

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Appendix 1. Individual tree registers of the measured variable of the 32 trees sampled in the present study

Site	Age (Year)	Plantation density (tress /ha)	dbh (cm)	Total height (m)	Stem dry weight (gr)	Branch dry weight (gr)	Twigs dry weight (gr)	Foliage dry weight (gr)	Root dry weight (gr)
Ciampea	1	1000	4,8	4,55	3304,74	38,1818	-	547,368	1851,97
	1	1000	5,5	4,67	3434,02	142,202	-	698,148	-
	1	1000	6	5,2	4002,8	219,556	-	900	-
	1	1000	6,5	6,3	6924,69	145,679	-	695,96	-
	1	1000	7	7,15	8777,52	399,259	-	1382,38	-
	1	1000	7,6	8,6	10038,5	-	-	742,857	-
	2	1000	5	4,85	2116,03	37,8378	-	489,56	-
	2	1000	6	6,4	3717,37	100,079	-	821,229	-
	2	1000	7,6	8,25	7825,03	1470,51	-	1590,91	-
	2	1000	9	8,45	6965,24	2335,88	-	1838,51	3100
	2	1000	10,5	9,07	16122,1	3518,89	-	1953,9	-
	2	1000	13	9,56	23308,4	10304,1	-	6741,94	-
	3	1000	11,2	9,8	14511,6	3704,08	-	1796,79	5528,8
	3	1000	11,9	7,71	15146,8	7368,51	-	4702,38	7489,84
	3	1000	9	8,11	14526,6	3510,86	-	1483,24	-
	3	1000	7,4	7,91	6695,67	2812,5	-	541,667	-
	3	1000	14,5	7,08	20846,9	13167,3	-	4858,04	-
	3	1000	18	12,35	46707,4	19105,3	-	8461,36	-
Parung	4	1000	10	9,6	14178,3	5991,35	1441,38	2832,34	-
	4	1000	12,2	11,67	26866,9	14696,9	2686,21	4693,92	-
	4	1000	13	12,9	29577,9	8403,6	2083,33	3354,84	-
	4	1000	14	13,56	35005	16935,2	1653,33	5090,91	-
	4	1000	16,2	13,25	48111,6	17437	7510,59	9294,89	-
	4	1000	19	9,3	61551	25764,3	8385,03	12042	-
Ciamis	6	1111	15	15,2	46449,3	6421,33	2611,11	4371,43	-
	6	1111	17,8	14,16	47874,1	17278,5	8793,6	6479,29	16279,6
	7	1111	15,5	15,1	62636,5	9395,12	1921,98	5258,54	11218,5
	7	1111	20,1	17,3	85730,8	24598,9	6098,16	5445,65	-
	9	833	17	13,07	78621,6	15328,8	2222,22	1788,39	11265,7
	12	556	25	9,7	134385	25449,5	21290,6	3067,52	-
	12	556	22,5	19,25	156319	32666,7	24614	10497,9	40287,4
	15	556	26,2	19,55	177654	22828,6	28381	12107,5	51527,3

Field Documentation in Ciamis

Figure 8. Six year old teak stand in KPH

Figure 9. Measurement of trunk diameter

Figure 10. Weighing a log with spring balance

Figure 11. Felling destructive sampling tree

Figure 12. Cleaning soil from roots before

Figure 13. Stripping and collecting leaves

Field Documentation in Ciampea

Figure 14. Three year old teak stand in Ciampea

Figure 15. Weighing a log with spring balance

Figure 16. Stripping and collecting leaves

Figure 17. Cleaning soil from roots before weighing

Figure 18. Plot setting for undergrowth and litter bio-mass measurements

Figure 19. Collecting soil samples for soil carbon content and bulk density analysis

Field Documentation in Parung

Figure 20. Four year old teak stand in Parung

Figure 21. Bunch of teak leaves sample

Figure 22. Weighing twigs and teak boughs

Figure 23. Setting a plot for undergrowth and litter bio-mass measurements

Develop Forest Carbon Standard and Carbon Accounting System for Small-scale Plantation Based on Local Experiences

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MINISTRY of FORESTRY

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Enhancing Forest Carbon Stock to Reduce Emission from Deforestation and Degradation through Sustainable Forest Management (SFM) Initiatives in Indonesia

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