TEPIAN Vol. 4 No. 2 (June 2023) p-ISSN 2721-5350 e-ISSN 2721-5369
doi.org/10.51967/tepian.v4i1.2542

Utilizing Geographic Information Systems to Estimate Biomass and Carbon Based on Slope in Secondary Dryland Forests in The Forest Area of Mulawarman University

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Submitted: 2023-05-31; Accepted: 2023-06-20; Published: 2023-06-25

***Abstract*—** Calculation of standing biomass is usually carried out using linear and non-linear regression equation models based on the type of plant or tree resulting from field measurements. The aim of this study was to estimate the estimation of biomass and carbon based on the slope of the secondary forest in the KHDTK educational forest of Mulawarman University. Mulawarman University Educational Forest. Data collection to calculate biomass and carbon stocks obtained by direct measurements in the field and utilizing the Geographic Information System. The results of the highest biomass estimation at the sapling level are on a slope of 25-45% with an average value of 12.599 tons/ha; at the pile level with a slope of 25-45% the average value is 28.412 tons/ha; at the tree level with a slope of 8-15% the average value is 155.024 tons/ha; and in a litter with a slope of 25-45% the average value is 38.12 tons/ha. The greatest potential carbon yield is at the sapling level with a slope of 25-45% with an average value of 6.300 tons/ha; at the pile level with a slope of 25-45% the average value is 14.206 tons/ha; at the tree level with a slope of 8-15% the average value is 77.512 tons/ha; and in litter with a slope of 25-45% the average value is 17.86 tons/ha.

***Keywords*—** Biomass, Carbon, Mapping, Geographic Information Systems, Slope

I. INTRODUCTION

Forest management has now developed from forest ecosystem management to ecosystem-based forest management. Forests create ecosystem conditions that can provide environmental services for the ecosystem around them. The decline in forest function is a threat to the ecosystem. One of the causes of the decline in forest function is deforestation. Deforestation is a change in land cover conditions from the Forest (forested) land cover class to the Non-Forest (non-forested) land cover class (Hidup K.L., 2021). The impact of deforestation that is very clear to date is the occurrence of social and environmental disasters such as floods, landslides, and long dry spells which are also related to the issue of global warming (Syah, 2017). Deforestation and forest degradation are one of the main causes of climate change and contribute 15% to global warming pollution worldwide. Trees store a lot of carbon, about 50% of their biomass weight (Boucher, et al., 2011), so if deforestation and forest degradation occur, they will release high CO2 gas into the atmosphere. Forest degradation that occurs in Indonesia encourages the development of issues as a significant contributor to carbon emissions. On the other hand, forests are still positioned as a resource for economic development which is feared will accelerate the rate of forest degradation which will increase greenhouse gas emissions from the forestry sector. Nonetheless, the awareness to maintain and improve the quality and quantity of forests continues to increase.

Climate change mitigation efforts in Indonesia require data from Greenhouse Gas (GHG) inventory activities that monitor emission reductions. Most of the emissions come from increasing carbon which is not offset by increased carbon sequestration (Kardika et al., 2021). Emission reductions can be calculated by calculating forest carbon stocks. Carbon stocks are stored carbon content either on the soil surface as plant biomass, dead plant residues (necromas), or in the soil as soil organic matter (Kaufman and Donato, 2012). Forests are useful as carbon dioxide (CO2) absorbers and oxygen (O2) producers (Sumargo et al., 2011). This is what gives rise to the relationship between carbon content (carbon pool) and forest biomass. The increase in the amount of carbon stored in this carbon pool represents the amount of carbon absorbed from the atmosphere (Al-Reza, et al, 2014).

Biomass is the mass of vegetation that is still alive, namely tree crowns, undergrowth or weeds, and annual plants (Hairiah et al., 2011). There are 2 forest carbon inventories (carbon pools) that are considered, namely (1) aboveground biomass (AGB) which includes tree biomass, understorey biomass, necromass, understorey, and (2) underground (biomass) which includes root biomass and soil organic matter (Hairiah et al., 2011). Dead organic matter consists of dead wood and litter, while soil organic carbon includes carbon in mineral soils and organic matter including peat.

Calculation of standing biomass is usually carried out using linear and non-linear regression equation models based on the type of plant or tree resulting from measurements in the field (Albers, et al. 2019; Mukuralinda et al. 2020; Trautenmüller, et al. 2021; Islam et al. al. 2021). Although there are many types of AGB estimation, based on species composition, tree height, basal area, and vegetation structure, the most widely used to calculate AGB is stem diameter data at breast height (Kamara and Said, 2022). Based on this linear regression equation, the biomass calculation will be used later. This data is important to use to calculate the carbon in Samarinda City, especially in the Mulawarman University educational forest. Mulawarman University educational forest consists of secondary dry forest land cover areas and other use areas which are one of the forests with an important role in reducing carbon emissions. Biomass and carbon data are collected based on slope. Large and small biomass values, depending on the growth of vegetation. The growth of forest stands is influenced by the slope of the land (Drupadi et al., 2021). The growth of vegetation that grows on flat slopes (8%) has better growth than vegetation that grows on slopes of 28% and 35% (Khairani, 2019). In addition, the thickness of the litter based on the slope also produces different levels of thickness (Suryanto and Wawan, 2017).

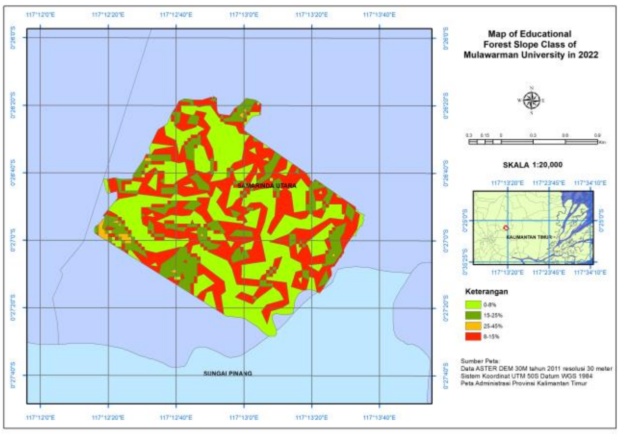
Based on the problems above, this research was conducted to estimate biomass and carbon in secondary dryland forests in the educational forest of Mulawarman University. The aim of this study was to utilize a Geographic Information System to estimate the potential of biomass and carbon based on the slope of the secondary dryland forest in the educational forest of Mulawarman University.

II. RESEARCH METHODS

This research was conducted in a secondary dryland forest area in the Educational Forest of Mulawarman University, for 4 months. The tools and materials used are phiband, rope, tape measure, GPS (Globbal Positioning System), plastic bags, machetes, permanent markers, scales, ovens, balances, clinometers, measuring sticks, personal computers (PC)/Laptops that have GIS Software (Geographic Information System) in the form of ArcGIS 10.3.

The data used consists of primary and secondary data. Primary data was obtained from the calculation of saplings, piles, trees, and litter. The sapling data is the 2 - 10 cm diameter of the sapling, the sapling height, and the number of saplings. while the pile data is piling diameter 10 - 20 cm, pile height, and number of piles. Tree data are diameter at breast height (dbh = diameter at breast height), tree height (h) and number of trees. Litter data is wet weight data taken from each sample plot. Secondary data is in the form of the general condition of the research location, including a map of the location of the Special Purpose Forest Area of Mulawarman University, ASTER DEM 30M data for 2011 with a resolution of 30 meters (for slope maps), and a map of land cover for University of Mulawarman Education Forest.

Data collection to calculate biomass and carbon stocks obtained by direct measurements in the field. Field data collection was carried out at locations that had been determined when making the slope class map (Picture 1) and the land cover map (Picture 2) at the research location. Classification of the slope of the stand location is carried out according to the classification stipulated in the Decree of the Minister of Agriculture Number 837/Kpts/Um/11/1980 concerning Criteria and Procedures for Designating Protected Forests. The slope class table is presented in Table 1:

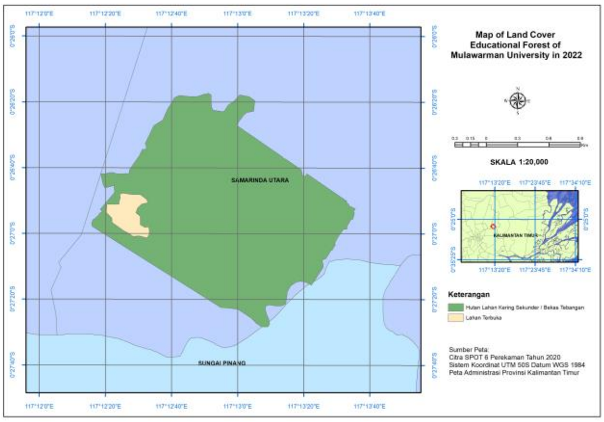


Picture.1. Map of Educational Forest Slope Class of Mulawarman University in 2022

Table 1. Educational Forest Slope Class Classification of Mulawarman University

Slope Class	Slope	Class
I	0 - 8%	Flat
II	8 - 15%	Sloping
III	15 - 25%	Rather Steep
IV	25 - 45%	Steep
V	> 45%	Very Steep

Source: Decree of the Minister of Agriculture No 837/Kpts/Um/11/1980



Picture.2. Map of Land Cover Educational Forest of Mulawarman University in 2022

Picture 2 shows that there are 2 types of land cover in the Mulawarman University Educational Forest, namely secondary dryland forest and open land. The area of land cover in the Mulawarman University Educational Forest is presented in Table 2.

Table 2. Classification of Land Cover Types of Mulawarman University Educational Forest

No	Types of Land Cover	Wide (Ha)
1.	Secondary Dryland Forest	299,5
2.	Open Field	10,03
	Total Land Cover Area	309,53

Placement of plots based on the type of slope in the study site. For each type of slope (0-8%, 8-15%; 15-25%, and 25-45%) 2 sample plots were made each and only focused on land cover with secondary dryland forest types, so there was a total of 8 sample plots. Determination of plot points was carried out based on purposive sampling, namely choosing the closest location by considering the accessibility of each slope in the research location. The steps for measuring aboveground biomass begin with making a main rectangular plot measuring 20 m × 20 m north-south for measuring trees and sub-plots for measuring sapling, pole, and litter biomass. In detail, the size of the main plot and its sub-plots are presented in Table 3.

Calculation of sapling, pole, and tree biomass uses the secondary dryland forest allometric equation, proposed by Basuki et al, 2009, the formulas are as (1):

$$AGB = \exp(-0{,}744 + 2{,}188 \ln(D) + 0{,}832 \ln(WD)) \quad (1)$$

Where (1):
AGB : Above-ground biomass (tons/ha)
D : Tree diameter (cm)
WD : Wood Density (gr/cm3)

Calculation of carbon stakes, poles and trees, using the equation from Brown (1997), , the formulas is as (2):

$$C = 0.5\ B \quad (2)$$

Where (2):
C : Carbon content (tons/ha)
B : Biomass (tons/ha)

Table 3. Types of Data Collected and Measured in the Field

No	Component Biomass	Method	Size Plot	Which data type collected
1.	Tree	Non-destructive (without doing damage)	5 m x 5 m 10 m x 10 m 20 m x 20 m	Species name, diameter (dbh), total height, number of trees wood density (density of wood),
2.	Litter	Destructive (do damage)	2 m x 2 m	Gross weight total , weight wet example, dry weight sub example

Calculation of litter biomass using the same method. The litter that was calculated for the total wet weight was the litter taken from the 2 m x 2 m sub-plot (SNI, 2011). Then the wet weight of the sample was taken as much as 300 grams per plot (SNI, 2011). Each litter sample was placed in an aluminum container for drying using an oven at 75^{o}C for ± 24 hours (SNI, 2011) in the conservation laboratory of the Samarinda State Agricultural Polytechnic. After baking, weighing is carried out to determine the dry weight of the litter (SNI, 2011). The calculation of the total dry weight (BK), which is also known as litter biomass in units of grams, is then converted to tons per hectare, the formula refers to Hairiah et al. (2011), the formula is as (3):

$$BK\ total = \frac{BK\ example}{BB\ example} \times BB\ Total \quad (3)$$

Where (3):
BB : Wet weight (g)
BK : Dry weight (g)

Litter carbon content is expressed in kilograms which are then converted to tons per hectare. The calculation of litter carbon (4) refers to the calculation of carbon from dead organic matter (litter, dead wood and dead trees) in the 2011 SNI, the formula is as:

$$C_m = Bo \times \%\ Corganik \quad (4)$$

Where (4):

Cm : Carbon content of dead organic matter (kg)

Bo : Total biomass/organic matter (kg)

%C organic : The percentage value of carbon content, is 0.47 or using the percentage value of carbon obtained from laboratory measurements

III. RESULT AND DISCUSSION

A. *Estimation of Above Ground Biomass*

Table 4. Stake-Level Biomass

No	Slope	Stake Type	AGB (ton/ha)
1	0-8% (Plot 1)	Kapur (*Dryobalanops aromatica*)	1.105
2		Kapur (*Dryobalanops aromatica*)	0.754
3		Meranti merah (*Shorea parvifolia)*	0.682
4		Meranti merah (*Shorea parvifolia*)	0.840
Total Stake Biomass on Slope 0-8% Plot 1 (ton/ha)			3.381
1	0-8% (Plot 2)	Tengkawang (*Shorea macrophylla)*	2.723
2		*Jabon (Anthocephalus cadamba*)	0.639
3		Jabon (*Anthocephalus cadamba*)	0.835
Total Stake Biomass on Slope 0-8% Plot 2 (ton/ha)			4.196
Average Stake Biomass on a Slope of 0-8% (ton/ha)			3.788
1	8-15% (Plot 1)	Tengkawang (*Shorea macrophylla*)	3.046
2		Tengkawang (*Shorea macrophylla*)	2.419
3		Tengkawang (*Shorea macrophylla*)	1.089
4		Tengkawang (*Shorea macrophylla*)	1.396
Total Stake Biomass on Slope 8-15% Plot 1 (ton/ha)			7.951
1	18-15% (Plot 2)	Mahang *(Macaranga gigantea)*	0.701
2		Mahang *(Macaranga gigantea)*	1.529
3		Kapur (*Dryobalanops aromatica*)	1.105
4		Kapur (*Dryobalanops aromatica*)	2.762
Total Stake Biomass on Slope 8-15% Plot 2 (ton/ha)			6.097
Average Stake Biomass on a Slope of 8-15% (ton/ha)			5.356
1	15-25% (Plot 1)	Mahang *(Macaranga gigantea)*	0.757
2		Mahang *(Macaranga gigantea)*	1.367
3		Kerantungan (Durio oxleyanus)	2.210
4		Mahang *(Macaranga gigantea)*	3.193
Total Stake Biomass on Slope 15-25% Plot 1 (ton/ha)			7.527
1	15-25% (Plot 2)	Pasak Bumi (*Eurycoma longifolia)*	1.285
2		Tengkawang (*Shorea macrophylla*)	0.824
3		Tengkawang (*Shorea macrophylla*)	2.135
Total Stake Biomass on Slope 15-25% Plot 2 (ton/ha)			4.244
Average Stake Biomass on a Slope of 15-25% (ton/ha)			5.886
1	25-45% (Plot 1)	Tengkawang (*Shorea macrophylla*)	11.704
2		Tengkawang *(Shorea macrophylla)*	1.396
3		Tengkawang *(Shorea macrophylla*)	2.419
Total Stake Biomass on Slope 25-45% Plot 1 (ton/ha)			15.519
1	25-45% (Plot 2)	Gaharu (*Aquilaria malaccensis*)	0.612
2		Meranti merah (*Shorea parvifolia*)	3.827
3		Meranti merah (*Shorea parvifolia*)	2.620
4		Meranti merah (*Shorea parvifolia*)	2.620
Total Stake Biomass on Slope 25-45% Plot 2 (ton/ha)			9.678
Average Stake Biomass on a Slope of 25-45% (ton/ha)			12.599

Information : AGB = Above Ground Biomass

Table 5. Pole Grade Biomass

No	Slope	Pole Type	AGB (ton/ha)
1	0-8% (Plot 1)	Trambesi (*Albizia saman*)	8.931
2		Ulin (*Eusideroxylon zwageri)*	17.022
Total Pole Biomass on Slope 0-8% Plot 1 (ton/ha)			25.953
1	0-8% (Plot 2)	Meranti Merah *(Shorea parvifolia)*	8.283
2		Meranti Merah (*Shorea parvifolia*)	16.127
Total Pole Biomass on Slope 0-8% Plot 2 (ton/ha)			24.410
Average Pole Biomass on Slope 0-8% (ton/ha)			25.182
1	8-15% (Plot 1)	Tengkawang (*Shorea macrophylla)*	5.655
Total Pole Biomass on Slope 8-15% Plot 1 (ton/ha)			5.655
1	8-15% (Plot 2)	Tengkawang (*Shorea macrophylla)*	5.905
2		Tengkawang *(Shorea macrophyll*)	8.894
3		Tengkawang (Shorea macrophylla)	5.655
Total Pole Biomass on Slope 8-15% Plot 2 (ton/ha)			20.454
Average Pile Biomass on Slope 8-15%			13,054

Kardika, A. J., Istanto, J., Sufiana , K., Murniyati , A., Kamarati , K. F. A., & Rudito. (2023). Utilizing Geographic Information Systems to Estimate Biomass and Carbon Based on Slope in Secondary Dryland Forests in the Forest Area of Mulawarman University. TEPIAN, 4(2).

No	Slope	Pole Type	AGB (ton/ha)
(ton/ha)			
1	15-25% (Plot 1)	Tengkawang *(Shorea macrophylla)*	11.807
2		Tengkawang *(Shorea macrophylla*)	9.053
Total Pole Biomass on Slope 15-25% Plot 1 (ton/ha)			20.860
1	15-25% (Plot 2)	Tengkawang *(Shorea macrophylla)*	11.260
2		Tengkawang *(Shorea macrophylla*)	8.122
3		Tengkawang (Shorea macrophylla)	11.260
Total Pole Biomass on Slope 15-25% Plot 2 (ton/ha)			30.643
Average Pile Biomass on Slope 15-25% (ton/ha)			25.752
1	25-45% (Plot 1)	Tengkawang *(Shorea macrophylla)*	5.655
2		Tengkawang (Shorea macrophylla)	16.915
Total Pole Biomass on Slope 25-45% Plot 1 (ton/ha)			22.569
1	25-45% (Plot 2)	Mahang (*Macaranga gigantea)*	11.431
2		Kapur (*Dryobalanops aromatica)*	22.823
Total Pole Biomass on Slope 25-45% Plot 2 (ton/ha)			34.254
Average Pole Biomass on Slope 25-45% (ton/ha)			28.412

Information : AGB = Above Ground Biomass

Table 6. Tree-Level Biomass

No	Slope	Tree Type	AGB (ton/ha)
1	0-8% (Plot 1)	Jabon (*Anthocephalus cadamba*)	6.330
2		Jabon (*Anthocephalus cadamba*)	5.255
3		Jabon (*Anthocephalus cadamba*)	8.528
4		Mahang (*Macaranga gigantea*)	5.598
5		Kapur (*Dryobalanops aromatica*)	11.308
6		Kapur (Dryobalanops aromatica)	8.702
7		Keruing (*Dipterocarpus hasseltti*)	10.956
8		Kerantungan (*Durio oxleyanus*)	13.930
Total Slope Tree Biomass 0-8% Plot 1 (ton/ha)			70.607
1	0-8% (Plot 2)	Matoa *(Pometia pinnata*)	12.560
2		Mahang (*Macaranga gigantea*)	17.264
3		Mahang (*Macaranga gigantea*)	9.356
4		Ulin (*Eusideroxylon zwageri*)	8.996
Total Slope Tree Biomass 0-8% Plot 2			48.176

No	Slope	Tree Type	AGB (ton/ha)
(ton/ha)			
Average Tree Biomass on Slope 0-8% (ton/ha)			59.392
1	8-15% (Plot 1)	Trambesi (*Albizia saman*)	10.576
2		Trambesi (*Albizia saman*)	8.291
3		Tengkawang *(Shorea macrophylla*)	10.961
Total Slope Tree Biomass 8-15% Plot 1 (ton/ha)			29.828
1	8-15% (Plot 2)	Kokang (*Lepisanthes amoena*)	6.473
2		Kokang (*Lepisanthes amoena*)	8.104
3		Gmelina (*Gmelina arborea*)	22.454
4		Gamelina (*Gmelina arborea*)	15.972
5		Beringin (*Ficus sp*)	198.260
6		Gamelina (*Gmelina arborea*)	28.957
Total Slope Tree Biomass 8-15% Plot 2 (ton/ha)			280.220
Average Tree Biomass on Slope 8-15% (ton/ha)			155.024
1	15-25% (Plot 1)	Rambai (*Baccaurea motleyana*)	19.470
2		Rambai (*Baccaurea motleyana*)	17.181
3		Mahang (*Macaranga gigantea*)	15.639
4		Mahang (*Macaranga* gigantea)	9.356
5		Mahang (*Macaranga gigantea*)	3.234
6		Mahang (*Macaranga gigantea*)	12.426
7		Mahang (*Macaranga gigantea*)	9.044
Total Slope Tree Biomass 15-25% Plot 1 (ton/ha)			86.351
1	15-25% (Plot 2)	Ulin (*Eusideroxylon zwageri*)	120.646
2		Keruing (*Dipterocarpus hasseltti*)	15.188
3		Tengkawang (*Shorea macrophylla*)	7.935
Total Slope Tree Biomass 15-25% Plot 2 (ton/ha)			143.770

No	Slope	Tree Type	AGB (ton/ha)
Average Tree Biomass on Slope 15-25% (ton/ha)			115.060
1	25-45% (Plot 1)	Meranti merah *(Shorea parvifolia*)	67.493
2		Meranti merah (*Shorea parvifolia*)	53.149
3		Mahang (*Macaranga gigantea*)	11.703
Total Slope Tree Biomass 25-45% Plot 1 (ton/ha)			132.344
1	25-45% (Plot 2)	Mahang (*Macaranga gigantea*)	8.437
2		Mahang (Macaranga *gigantea*)	11.703
3		Gaharu (*Aqualaria malaccensis*)	8.402
4		Matoa (*Pometia pinnata*)	10.196
Total Slope Tree Biomass 25-45% Plot 2 (ton/ha)			38.739
Average Tree Biomass on Slope 25-45% (ton/ha)			85.541

Information : AGB = Above Ground Biomass

Table 7. Litter Biomass

No Plot	Slope	BK Total (g)	BK Total (ton/ha)
1	0-8%	467.7	18.71
2		72.8	2.91
Total Litter Biomass on a Slope of 0-8%			21.62
1	8-15%	240.24	9.61
2		425.3	17.01
Total Litter Biomass on a Slope of 8-15%			26.62
1	15-25%	406.4	16.26
2		288.2	11.53
Total Litter Biomass on a Slope of 15-25%			27.78
1	25-45%	441	17.64
2		512	20.48
Total Litter Biomass on a Slope of 25-45%			38.12

Information : BK Total = Total Dry Weight (Litter Biomass)

Forest Area with Special Purpose (KHDTK) Mulawarman University Educational Forest has an area of 309.53 ha and there are 2 types of land cover, namely Secondary Dryland Forest and Open Land. KHDTK Mulawarman University Educational Forest has 4 types of slopes, namely slopes of 0-8%, 8-15%, 15-25%, and 25-45%.

Based on the observations presented in Table 4, the highest average sapling biomass was found on a 25-45% slope of 12.599 tons/ha, while the lowest average sapling level biomass was found on a 0-8% slope of 3.788 tons/ha. The results of the observations are presented in Table 5, the highest average pile level biomass was found on the 25-45% slope of 28.412 tons/ha, while the lowest average pile level biomass was found on the 8-15% slope of 13.054 tons/ha. The results of the observations are presented in Table 6, the highest average tree-level biomass was found on an 8-15% slope of 155.024 tons/ha, while the lowest average tree-level biomass was found on a 0-8% slope of 59.392 tons/ha. The results of the observations are presented in Table 7, the highest average litter biomass was observed on a 25-45% slope of 38.12 tons/ha, while the lowest average biomass was on a 0-8% slope of 21.62 tons/ha.

The results of the analysis showed that the diameter of the saplings, tree poles, influenced the biomass content, the number of types of stands on each slope contributed to the biomass content at the study site, whereas in litter biomass the total wet weight had an effect on the biomass content. The potential of forest biomass can be identified through inventory data, using either the volume-to-biomass conversion factor or an allometric equation that relates tree dimensions (diameter and height) to their biomass (Tiryana, 2005). This study uses an allometric equation with parameters of diameter and wood density for the calculation of biomass. This is consistent with other research, namely the use of allometric equations that have been developed by (Ketterings et al., 2001) using the parameters of diameter and density of wood species in calculating its biomass.

B. Estimation of Carbon Uptake

Table 8. Stake Grade Carbon

No	Slope	Stake Type	C (ton/ha)
1	0-8% (Plot 1)	Kapur (*Dryobalanops aromatica*)	0.5525
2		Kapur (*Dryobalanops aromatica*)	0.377
3		Meranti merah (*Shorea parvifolia)*	0.341
4		Meranti merah (*Shorea parvifolia*)	0.420
Total Stake Carbon on Slope 0-8% Plot 1 (ton/ha)			1.691
1	0-8% (Plot 2)	Tengkawang (*Shorea macrophylla)*	1.3615
2		*Jabon (Anthocephalus cadamba*)	0.3195
3		Jabon (*Anthocephalus cadamba*)	0.4175
Total Stake Carbon on Slope 0-8% Plot 2 (ton/ha)			2.0985
Average Stake Carbon on a Slope of 0-8% (ton/ha)			1.895
1	8-15% (Plot 1)	Tengkawang (*Shorea macrophylla*)	1.523
2		Tengkawang (*Shorea macrophylla*)	1.2095
3		Tengkawang (*Shorea macrophylla*)	0.545
4		Tengkawang (*Shorea macrophylla*)	0.698
Total Stake Carbon on Slope 8-15% Plot 1 (ton/ha)			3.975
1	18-15% (Plot 2)	Mahang *(Macaranga gigantea)*	0.351
2		Mahang *(Macaranga gigantea)*	0.765

No	Slope	Stake Type	C (ton/ha)
3		Kapur (*Dryobalanops aromatica*)	0.5525
4		Kapur (*Dryobalanops aromatica*)	1.381
Total Stake Carbon on Slope 8-15% Plot 2 (ton/ha)			3.049
Average Stake Carbon on a Slope of 8-15% (ton/ha)			3.512
1	15-25% (Plot 1)	Mahang *(Macaranga gigantea)*	0.378
2		Mahang *(Macaranga gigantea)*	0.683
3		Kerantungan (Durio oxleyanus)	1.105
4		Mahang *(Macaranga gigantea)*	1.597
Total Stake Carbon on Slope 15-25% Plot 1 (ton/ha)			3.764
1	15-25% (Plot 2)	Pasak Bumi (*Eurycoma longifolia)*	0.643
2		Tengkawang (*Shorea macrophylla*)	0.412
3		Tengkawang (*Shorea macrophylla*)	1.0675
Total Stake Carbon on Slope 15-25% Plot 2 (ton/ha)			2.122
Average Stake Carbon on a Slope of 15-25% (ton/ha)			2.943
1	25-45% (Plot 1)	Tengkawang (*Shorea macrophylla*)	5.852
2		Tengkawang *(Shorea macrophylla)*	0.698
3		Tengkawang *(Shorea macrophylla*)	1.2095
Total Stake Carbon on Slope 25-45% Plot 1 (ton/ha)			7.7595
1	25-45% (Plot 2)	Gaharu (*Aquilaria malaccensis*)	0.306
2		Meranti merah (*Shorea parvifolia*)	1.914
3		Meranti merah (*Shorea parvifolia*)	1.310
4		Meranti merah (*Shorea parvifolia*)	1.310
Total Stake Carbon on Slope 25-45% Plot 2 (ton/ha)			4.840
Average Stake Carbon on a Slope of 25-45% (ton/ha)			6.300

Information : C = Carbon Content

Table 9. Pole Grade Carbon

No	Slope	Pole Type	C (ton/ha)
1	0-8% (Plot 1)	Trambesi (*Albizia saman*)	4.466
2		Ulin (*Eusideroxylon zwageri)*	8.511
Total Pole Carbon on Slope 0-8% Plot 1 (ton/ha)			12.977
1	0-8% (Plot 2)	Meranti Merah *(Shorea parvifolia)*	4.142
2		Meranti Merah (*Shorea parvifolia*)	8.064
Total Pole Carbon on Slope 0-8% Plot 2 (ton/ha)			12.205
Average Pole Carbon on Slope 0-8% (ton/ha)			12.591
1	8-15% (Plot 1)	Tengkawang (*Shorea macrophylla)*	2.828
Total Pole Carbon on Slope 8-15% Plot 1 (ton/ha)			2.828
1	8-15% (Plot 2)	Tengkawang (*Shorea macrophylla)*	2.953
2		Tengkawang *(Shorea macrophyll)*	4.447
3		Tengkawang (Shorea macrophylla)	2.828
Total Pole Carbon on Slope 8-15% Plot 2 (ton/ha)			10.227
Average Pole Biomass on Slope 8-15% (ton/ha)			6.527
1	15-25% (Plot 1)	Tengkawang *(Shorea macrophylla)*	5.904
2		Tengkawang *(Shorea macrophylla*)	4.527
Total Pole Carbon on Slope 15-25% Plot 1 (ton/ha)			10.430
1	15-25% (Plot 2)	Tengkawang *(Shorea macrophylla)*	5.630
2		Tengkawang *(Shorea macrophylla*)	4.061
3		Tengkawang (Shorea macrophylla)	5.630
Total Pole Carbon on Slope 15-25% Plot 2 (ton/ha)			15.321
Average Pole Carbon on Slope 15-25% (ton/ha)			12.876
1	25-45% (Plot 1)	Tengkawang *(Shorea macrophylla)*	2.828
2		Tengkawang (Shorea macrophylla)	8.458
Total Pole Carbon on Slope 25-45% Plot 1 (ton/ha)			11.285
1	25-45% (Plot 2)	Mahang (*Macaranga gigantea)*	5.716
2		Kapur (*Dryobalanops aromatica)*	11.412
Total Pole Carbon on Slope 25-45% Plot 2 (ton/ha)			17.127
Average Pole Carbon on Slope 25-45% (ton/ha)			14.206

Information : C = Carbon Content

Table 10. Tree Grade Carbon

No	Slope	Tree Type	C (ton/ha)
1	0-8% (Plot 1)	Jabon (*Anthocephalus cadamba*)	3.165
2		Jabon (*Anthocephalus cadamba*)	2.628
3		Jabon (*Anthocephalus cadamba*)	4.264
4		Mahang (*Macaranga gigantea*)	2.799
5		Kapur (*Dryobalanops aromatica*)	5.69
6		Kapur (Dryobalanops aromatica)	4.351
7		Keruing (*Dipterocarpus*	5.478

No	Slope	Tree Type	C (ton/ha)
		hasseltti)	
8		Kerantungan (*Durio oxleyanus*)	6.965
Total Slope Tree Carbon 0-8% Plot 1 (ton/ha)			35.340
1	0-8% (Plot 2)	Matoa *(Pometia pinnata*)	6.28
2		Mahang (*Macaranga gigantea*)	8.632
3		Mahang (*Macaranga gigantea*)	4.678
4		Ulin (*Eusideroxylon zwageri*)	4.498
Total Slope Tree Carbon 0-8% Plot 2 (ton/ha)			24.088
Average Tree Carbon on Slope 0-8% (ton/ha)			29.714
1	8-15% (Plot 1)	Trambesi (*Albizia saman*)	5.288
2		Trambesi (*Albizia saman*)	4.146
3		Tengkawang *(Shorea macrophylla*)	5.4805
Total Slope Tree Carbon 8-15% Plot 1 (ton/ha)			14.914
1	8-15% (Plot 2)	Kokang (*Lepisanthes amoena*)	3.237
2		Kokang (*Lepisanthes amoena*)	4.052
3		Gmelina (*Gmelina arborea*)	11.227
4		Gamelina (*Gmelina arborea*)	7.986
5		Beringin (*Ficus sp*)	99.130
6		Gamelina (*Gmelina arborea*)	14.478
Total Slope Tree Carbon 8-15% Plot 2 (ton/ha)			140.11
Average Tree Carbon on Slope 8-15% (ton/ha)			77.512
1	15-25% (Plot 1)	Rambai (*Baccaurea motleyana*)	9.735
2		Rambai (*Baccaurea motleyana*)	8.5905
3		Mahang (*Macaranga gigantea*)	7.8195
4		Mahang (*Macaranga* gigantea)	4.678
5		Mahang (*Macaranga gigantea*)	1.617
6		Mahang (*Macaranga gigantea*)	6.213
7		Mahang (*Macaranga gigantea*)	4.522
Total Slope Tree Carbon 15-25% Plot 1 (ton/ha)			43.175
1	15-25% (Plot 2)	Ulin (*Eusideroxylon zwageri*)	60.323
2		Keruing (*Dipterocarpus hasseltti*)	7.594
3		Tengkawang (*Shorea macrophylla*)	3.9675
Total Slope Tree Carbon 15-25% Plot 2 (ton/ha)			71.885
Average Tree Carbon on Slope 15-25% (ton/ha)			57.530
1	25-45% (Plot 1)	Meranti merah *(Shorea parvifolia*)	33.747
2		Meranti merah (*Shorea parvifolia*)	26.57
3		Mahang (*Macaranga gigantea*)	5.8515
Total Slope Tree Carbon 25-45% Plot 1 (ton/ha)			66.173
1	25-45% (Plot 2)	Mahang (*Macaranga gigantea*)	4.187
2		Mahang (Macaranga *gigantea*)	5.8515
3		Gaharu (*Aqualaria malaccensis*)	4.201
4		Matoa (*Pometia pinnata*)	5.098
Total Slope Tree Carbon 25-45% Plot 2 (ton/ha)			19.337
Average Tree Carbon on Slope 25-45% (ton/ha)			42.755

Information : C = Carbon Content

Table 11. Litter Carbon

No	Slope	C_m (Kg)	C_m (Ton/Ha)
1	0-8%	0.22	8.65
2		0.03	1.32
Total Litter Carbon on Slope 0-8%		0.25	9.96
1	8-15%	0.11	4.51
2		0.20	7.90
Total Litter Carbon on Slope 8-15%		0.31	12.41
1	15-25%	0.19	7.52
2		0.13	5.26
Total Litter Carbon on Slope 15-25%		0.32	12.78
1	25-45%	0.21	8.27
2		0.24	9.59
Total Litter Carbon on Slope 25-45%		0.45	17.86

Information : C_m : Dead organic carbon content

Based on the measurement results of above-surface carbon storage presented in Table 8, the highest average stake level carbon storage was on the 25-45% slope of 6,300 tons/ha, while the lowest average carbon storage was on the 0-8 slope of 1,895 tons/ha. The measurement results are presented in Table 9, the highest average pile level carbon storage was on a slope of 14,206 tons/ha, while the lowest average carbon storage was on an 8-15% slope of 6,527 tons/ha. The measurement results are presented in Table 10, the highest average carbon storage at tree level was on an 8-15% slope of 77.512 tons/ha, while the lowest average carbon storage was on a 0-8% slope of 29.714 tons/ha. Based on the measurement results presented in Table 11, the highest average litter carbon was on the 25-45% slope of 17.86 tons/ha, while the lowest average litter carbon was on the 0-8% slope of 10.15 tons/ha.

The value of biomass is directly proportional to the value of carbon because each addition of biomass content will be followed by addition of carbon content. Carbon is an important component of plant biomass. The main storage place for carbon is in tree biomass (including the upper part which includes stems, branches, twigs, leaves, flowers, and fruit, the lower part which includes roots), dead organic matter (necromass), litter, soil, and those stored in the form of wood products. (Kumar and Nair, 2011).

Estimation of carbon dioxide absorption potential is obtained from the conversion of biomass estimation, as it is known from research results that on average every 1 ton of biomass stores 0.5 tons of carbon, and every 1 ton of carbon stored in trees is produced through absorption of 3.67 tons of carbon dioxide (IPPC 2006). The largest proportion of carbon storage on land is generally found in trees or stands (Hairiah and Rahayu 2007). Carbon storage is strongly influenced by biomass, therefore anything such as diameter, biomass, and density that causes an increase or decrease in potential biomass will also affect carbon storage.

IV. Conclusion

The average potential of biomass stored in secondary dryland forests in KHDTK educational forests at Mulawarman University based on the sapling level sequentially at the slope of 0-8%, 8-15%, 15-25%, and 25-45% is 3,788 tons/ ha, 5,356 tons/ha, 5,886 tons/ha, and 12,599 tons/ha. Average pile level biomass sequentially on slopes of 0-8%, 8-15%, 15-25%, and 25-45% were 25,182 tons/ha, 13,054 tons/ha, 25,752 tons/ha, and 28,412 tons/ha Ha. Average tree biomass sequentially on slopes of 0-8%, 8-15%, 15-25%, and 25-45% were 29,714 tons/ha, 77,512 tons/ha, 57,530 tons/ha, and 42,755 tons/ha. The average litter biomass sequentially on the slopes of 0-8%, 8-15%, 15-25%, and 25-45% is 21.62 tons/ha, 26.62 tons/ha 27.78 tons/ha, 38.12 tons/ha.

The average carbon storage in the secondary dryland forest area in the KHDTK educational forest at Mulawarman University based on the sapling level at the slope of 0-8%, 8-15%, 15-25%, and 25-45% is 1,895 tons/ha, 3,512 tons/ha, 2,943 tons/ha, and 6,300 tons/ha. The average pile-level carbon storage on slopes of 0-8%, 8-15%, 15-25%, and 25-45% is 12,977 tons/ha, 6,527 tons/ha, 12,876 tons/ha, and 14,206 tons/ha. The average tree carbon storage on slopes of 0-8%, 8-15%, 15-25%, and 25-45% is 29,714 tons/ha, 77,512 tonnes/ha, 57,530 tons/ha, and 42,755 tons/ha. The average litter carbon storage on slopes of 0-8%, 8-15%, 15-25%, and 25-45% is 10.15 tons/ha, 12.60 tons/ha, 13.16 tons/ha, and 17.86 tons/ha.

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