http://dx.doi.org/10.22161/ijeab/3.1.29 *ISSN: 2456-1878*

Estimated carbon stored on some landscape forests in South East Sulawesi

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Abstract*—Carbon stored in several forest landscapes in Southeast Sulawesi such as the Jati stand on the People's Forest, Pine stands in Protected Forest, Mangrove Forest vegetation, Natural vegetation of urban forest, and Campus Forest show the weight of carbon stored per hectare different from one vegetation to another. The objective of this research is to know the biomass and the amount of carbon stored up (levels of the tree, pole, stakes), the lower plants, litter and nekromassa in various forest landscape in Southeast Sulawesi. Biomass is obtained through the use of allometric equations (plants on the surface), and measures the wet weight and dry weight (bottom plants, woody necromassa and non-woody). Furthermore, the estimated amount of carbon stored. The results showed Pinus stand (Pinus mercusii) carbon stored 65,992 tons ha^{-1}, stand Teak (Tectona grandis) 36.213 tons ha^{-1}, Mangrove vegetation (Bruguiera gymnorrhiza, Lumnitzera racemosa, Rhizophora sp, Sonneratia alba, and Avicennia alba) 68.12 tons ha^{-1}, natural vegetation Forest City 50.01 tons ha^{-1}, natural vegetation Forest Campus 98.18 tons ha^{-1}. The availability of carbon estimation information in various forest landscapes can be used as supporting data for REDD + programs aimed at addressing climate issues.*

***Keywords*— Biomass, Carbon estimation, Forest landscape, Vegetation.**

I. INTRODUCTION

Forest landscape is a description of land cover both within forest area and outside forest area in the form of forest and non forest. This can be described in terms of the area of land cover. Area of land cover in and outside the forest area of Southeast Sulawesi Province 3,638,000,7 Ha. Where land cover area in forest area is 1,943,000,8 Ha and not forest area 1,694,000,9 Ha [1].

REDD + activities are one of the mitigation or mitigation measures caused by climate change in the forestry sector by reducing emissions from deforestation, degradation and conservation, SFM and increased carbon stocks.

[2], [3], [4] that, there are 5 carbon sources to be measured through field measurements; above ground biomass, below ground biomass, dead wood, litter, and soil. While the source of carbon to 6 that is harvested wood products (harvested wood products) has not been taken into account. Carbon needs to be measured because basically carbon stock is the amount of carbon stored in vegetation, other biomass in the soil.Efforts to reduce GHG concentrations in the atmosphere (emissions) is to reduce the release of CO_2 into the air. Therefore, the amount of CO_2 in the air must be controlled by increasing the amount of CO_2 uptake by the plants as much as possible and suppressing the emission release as low as possible. [2]Thus maintaining the integrity of natural forests, planting trees on agricultural lands and protecting peatlands is essential to reduce excessive amounts of CO_2 in the air.

II. MATERIALS AND METHODS

2.1 Materials

The results of the research took place in the teak plantation forest (*Tectona grandis* Lf)) in North Buton District, Mangrove Forest in Latompa village, Maligano sub-district, Muna district, Pinus stands (*Pinus mercusii*) in Nanga-Nanga Protection Forest Kendari City, Natural Forest Vegetation in Kecamatan Baruga Kendari City, and natural vegetation Forest Campus in District Baruga Kendari City.

2.2 Methods

This research method using Desk Study approach by summarizing the results of existing carbon estimation research that took place in 2012 until 2015, and also collects materials and other information from literature related to climate issues. The results are then studied in the form of qualitative and quantitative descriptive.

III. STATISTICAL ANALYSIS

Biomass calculations use some allometric equations (Table 1), and estimates of carbon stored in several forest landscapes in Southeast Sulawesi use the equation ie C = BK (ton / ha) x 0.46 [2]

http://dx.doi.org/10.22161/ijeab/3.1.29 *ISSN: 2456-1878*

Calculations Biomass used in the results of research, can be seen in Table 1 below:

Table.1: Biomass Calculation Methods of several forest landscapes in Southeast Sulawesi

Forest Landscape	Type of Vegetation	Biomass Calculation			
		Top plants (allometric equations)	Lower plants	Nekromassa	
				Woody	Not woody
Protected forest	Pine stands (*Pinus merkusii*)	$Y=0{,}0936 \int D^{2{,}432}$ [5]	$BK=(BK_{sc}/BB_{sc}) \times BB_{tot}$ [6]	$Y=\pi.\int.H.D^2/40$ [6]	$BK=(BK_{sc}/BB_{sc}) \times BB_{tot}$ [6]
Forest City	Natural vegetation	Tree branched: [5] $Y=0{,}11 \int D^{2{,}62}$ Not Branching:[6] $Y=\pi.\int.H.D^2/40$ Pillars and Stakes:[7] $Y=10^{0{,}535+\log 10(BA)}$	$BK=(BK_{sc}/BB_{sc}) \times BB_{tot}$ [6]	$Y=\pi.\int.H.D^2/40$ [6]	$BK=(BK_{sc}/BB_{sc}) \times BB_{tot}$ [6]
Campus Forest	Natural vegetation	Tree branched:[5] $Y=0{,}11 \int D^{2{,}62}$ Not Branching: [6] $Y=\pi.\int.H.D^2/40$ Pillars and Stakes:[7] $Y=10^{-0{,}535+\log 10(BA)}$	$BK=(BK_{sc}/BB_{sc}) \times BB_{tot}$ [6]	$Y=\pi.\int.H.D^2/40$ [6]	$BK=(BK_{sc}/BB_{sc}) \times BB_{tot}$ [6]
Forest People	Teak Plant (Tectona grandis Lf)	[8]$Y=0{,}08842D^{2{,}6014}$	-	-	-
Mangrove forest	Standby Mangrove	Trunk: [9] $Y=0{,}079211DBH^{2{,}470895}$ Branch:[9] $Y=0{,}481575x1{,}24628^{DBH}$ Leaf: [9] $Y=0{,}171711x1{,}96367^{DBH}$	-	-	-

IV. RESULTS AND DISCUSSION

4.1 Pine stands in Protected Forest

The Protected Forest has an area of 307.54 ha. [10] Study on Pine stands (*Pinus mercusii*) in Nanga-Nanga Protected Forest, from 5 point sampling plots can be explained that the number of individual Pinus (*Pinus mercusii*) averages 1045 individuals ha^{-1}, and diameter averages 21 cm. Mean of biomassa on Pine Plant Various Levels of vegetation 159.286 ton ha^{-1} and carbon deposit 65.992 ton ha^{-1}.

4.2 Natural Vegetation in City Forest

[11] Forest City Baruga is one of the city forest in Kendari City is established with an area of 3 ha with natural environmental conditions so that the management must be able to meet one of the ecological functions as a carbon sink. [12] The results study show that the number of individual vegetation in City Forest, from 8 point sampling that the number of individual of vegetation (tree, poles, stakes, seedling and puppies) averages 4781.25 individuals ha^{-1}. Mean of biomassa natural vegetation in city forest 108.719 ton ha^{-1} , and carbon deposit 50.01 ton ha^{-1}. Upper plants, plants and necromassas only have a total stored carbon of 50.01 tons ha^{-1}. This is possible because the city forest with natural vegetation is located within the city of Kendari, making it very susceptible to disruptions that could lead to forest degradation.

4.3 Natural Vegetation in Campus Forests

Haluoleo University Campus Forest is a natural vegetation located within the campus in Kecamatan Kambu Kendari with an area of 58.96 Ha. The research results [13] explain that the campus forest, there are 81 species of plants, 65 families, from 4975 specimens. The family has the largest number of species of Myrtaceae, Euphorbiaceae and Fabaceae.

The tabulation of the results of biomass and carbon (C) calculations on each plot of forest in Halu Oleo University Campus can be seen in Table 2 [14].

4.4 Teak stands in the People's Forest

The observed teak stands are located in other areas of use (APL) with the status of land owned by some communities in the sub-district of Labuan, Wakorumba Sub-district, North Buton Regency, Southeast Sulawesi. The width of the Teak stand (*Tectona grandis Lf*) is 20.42 ha and the age of Teak ranges from 5 years to 16 years. [15] The stand of Teak in Labuan Sub-district People's Forest has an average

density of 1025 trees ha^{-1} at the age of 5 years and age 6 to 16 years. Based on the table 3 below shows that, the more the age of the teak stand (*Tectona grandis* Lf), the more carbon deposits are stored in the stands.

Carbon stored in Teak (*Tectona grandis* Lf) shows the increasing age of teak, increasing the amount of carbon stored, where at the age of 16 years there are 78.96 tons ha^{-1} of stored carbon, while the age of 5 years 16.89 tons ha^{-1}. If the average is from the age of 5 to 16 years, then it is assumed that every age has 36.213 tons of carbon stored ha^{-1}.

4.5 Carbon Stored in Mangrove Forest

The area of mangrove forest in Latompa Village, Maligano Sub-district, Muna Regency, Southeast Sulawesi Province 160 Ha. The types of compilers Mangrove Forest consists of *Bruguiera gymnorrhiza, Lumnitzera racemosa, Rhizophora sp., Sonneratia alba,* and *Avicennia alba* [16]. Based on the results [16] study, the amount of biomass and carbon storage in each mangrove species in Latompa Village, Biomassa 148.13 ton ha^{-1} and Carbon storage 68.12 ton ha^{-1}. The total amount of carbon stored is only about 68,12 ton per hectare. . [17] Land use system consisting of trees with species with low wood density values, the tree biomass will be lower when compared to land with species with high wood density values.

4.6 Recapitulation of Estimated Saved Carbon

Carbon stored in several landscapes of forests in Southeast Sulawesi are protected forests, urban forests, campus forests, community forests and mangrove forests show different amounts of stored carbon. This can be seen from the structure of the constituent vegetation, the vegetation type, the age of the plant, the stand site, and the degree of damage to the forest landscape. The more layered growth rate in a stretch (the level of trees, poles, stakes, seedlings), the higher the carbon content stored in the vegetation. Vegetation consisting of various types has a higher stored carbon than a one species vegetation. This can be seen in Table 4 below.

V. CONCLUSIONS AND RECOMMENDATIONS

Forest landscapes in Southeast Sulawesi have different amounts of stored carbon. The largest amounts of stored carbon among forest landscape observed in upper plants, under plants and necromassas, respectively were in the campus forests of 98.181 tons ha^{-1}, then in protected forests (Pinus stands), and urban forest (natural vegetation) of 50, 01 tons ha^{-1}. Forest landscapes in Southeast Sulawesi have different amounts of stored carbon. The largest amount of stored carbonaceous forests, under plants and necromassas, respectively were in the campus forests of 98.181 tons / ha, then in protected forests (Pinus stands), and urban forest (natural vegetation) of 50, 01 ton / ha. While the forest landscape that only observes carbon stored in the upper plants, the highest in the mangrove forest (68.12 tons ha^{-1}), and the lowest in the forest (Teak plant) with 36.213 tons ha^{-1} of stored carbon. The amount of carbon stored in each forest landscape is affected by the structure of the stand, the number of vegetation constituents, the age of the plant, the site where the vegetation develops, and the extent of damage. The natural vegetation composed of complete stand structures (trees, masts, saplings and seedlings) tends to have higher amounts of carbon stored, compared to one standing layer alone. Natural vegetation of mixed species also tends to have higher amounts of stored carbon than vegetation consisting of only one type of constituent. Carbon stored in plants will be higher, as the age of the plant increases. In addition, mangrove vegetation with tidal habitats (tidal vegetation), although a natural vegetation but has a lower amount of carbon stored than in the natural vegetation habitat on land.

Carbon stored in plants will be higher, as the age of the plant increases. In addition, mangrove vegetation with tidal habitats (tidal vegetation), although a natural vegetation but has a lower amount of carbon stored than in the natural vegetation habitat on land. The People's Forest Program is very good at reducing carbon emissions, but it is best to use multi-species cropping patterns with layered structures.

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Table.2: Calculation of biomass and carbon (C) in each plot of forest in Haluoleo University campus

Observation Grid	Average Total Biomass (tons ha^{-1})	Average Total Carbon (tons ha^{-1})
Tree (d>30cm)	151.3385	69.615710
Tree (d 5-30cm)	50.4429	23.203734
Lower Plants	2.9401	1.352446
Nekromassa Wood	3.77065	1.734499
Nekromassa Not Woody or Rough litter	4.9444	2.274424
Amount	213.4365	98.180813

http://dx.doi.org/10.22161/ijeab/3.1.29 *ISSN: 2456-1878*

Table.3: Biomass and carbon stored at each age of teak stand (Tectona grandis) in Labuan Sub-district People's Forest

Age Teak (Year)	Stand Teak		Litter under teak stands		Saved Carbon Amount (tons ha^{-1})
	Biomassa (tons ha^{-1})	Carbon Saved (tons ha^{-1})	Biomassa (tons ha^{-1})	Carbon Saved (tons ha^{-1})	
5	26,34	13,17	7,43	3,72	16,89
6	32,26	16,13	7,66	3,83	19,96
7	36,21	18,11	8,22	4,11	22,22
8	43,13	21,57	8,15	4,08	25,65
9	49,40	24,70	8,35	4,17	28,87
10	56,47	28,23	10,44	5,22	33,45
11	73,08	36,54	11,03	5,51	42,05
13	102,84	51,42	12,91	6.45	57.87
16	140,56	70,28	17,36	8.68	78.96
	Average				**36.213**

Table.4: Recapitulation of stored carbon estimates in various forest landscapes in Southeast Sulawesi.

Forest Landscape	Type Vegetation	Estimated Saved Carbon **(**tons ha^{-1}**)**				
		Plant on	Lower plants	**Nekromassa**		amount **(**tons ha^{-1}**)**
				Woody	Not woody	
Protected forest	Pine stands (*Pinus merkusii*)	64,047	0,181	1,515	0,249	65,992
Forest City	Natural vegetation	47,962	0,259	0,541	1,248	50,010
Campus Forest	Natural vegetation	92,819	1,352	1,734	2,274	98,181
Forest People	Teak Plant (*Tectona grandis Lf)*	36,213	-	-	-	36,213
Mangrove forest	Standby Mangrove	68,12	-	-	-	68,12