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Estimation of carbon stocks of galam (*Melaleuca cajuputi*) Swamp Forest at each growth stage

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Key words: Galam swamp forest, Growth, Carbon stock, Biomass, Growth stage.

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Abstract

Research on biomass estimation and carbon stocks in the peat and swamp forest has been done by many researchers, but especially in the galam swamp forest has not been much studied. The present research analyzed the number of carbon stocks in the galam swamp forest at each growth stage. The method used was a destructive sample method. The result showed that the galam swamp forest at the tree stage has the highest carbon stocks followed by the pole and belta stages. The total amount of carbon stocks in the galam swamp forest was 6.606 tons/ha that consisted of 0.057 tons/ha for the belta stage, 1.724 tons/ha for the pole stage, and 4.825 tons/ha for the tree stage. Based on the Paired-Samples T-Test of SPSS, carbon stocks of the tree stage were significantly higher than those of the belta stage at a significant level of 99%, and they were significantly higher than those of the pole stage at a significance level of 95%. Furthermore, carbon stocks of the pole stage were not significantly different from those of the belta stage because it had more stands per hectare than those of the pole and tree stages. It is needed to do research on biomass and carbon stocks either in the vegetation or in the soil holistically in order to reveal the real amount of carbon stocks stored in galam forest sites.

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Introduction

The Ministry of Forestry of the Republic of Indonesia (2008) cited by Achmad (2017a) stated that the total area of Indonesian state forests is 120.35 million hectares that consist of permanent forests, which are 112.27 million hectares, and conversion forests, which are 8.08 million hectares. Unfortunately, the forests in Indonesia are in crisis due to rapid deforestation. Similarly, the areas of highly potential galam (*Melaleuca cajuputi*) forest in South Kalimantan has also been threatened because of massive exploitation (Karim, 2009). This situation significantly reduces the carbon source stored in forest biomass regardless of the atmosphere and the ability of the earth to absorb CO_2 from the air through reduced forest photosynthesis. In addition to these impacts, the intensity of the greenhouse effect will increase and cause a rise in the earth's surface temperature.

This is what triggered allegations that tropical forest damage has caused global warming (Soemarwoto, 2001). This global warming will have a great impact on human welfare in general, has even led to various natural disasters in the world, such as rising sea levels, increasing atmospheric storms, increasing species and populations of disease-causing organisms (Soedomo, 2001). One way to reduce that impact is to control the concentration of carbon through the development of program sinks, where organic carbon resulted from photosynthesis will be stored in forest biomass on woody trees or forest floors (litter and forest soil).

Research on biomass estimation and carbon stocks in a tropical forest is still very little done; while estimating biomass in the tropical rainforest is essentially indispensable because of the potency of large forest biomass in reducing CO_2 levels through conservation and forest management (Brown *et al.*, 1996). In the course of the development of this program required data about carbon stock estimation. For some types of natural forests and plantations there has been a lot of research on this issue, but especially in the galam swamp forest has not been much studied.

Galam is the genus Melaleuca of the Myrtaceae family. The physical properties of the galam tree are long straight cylindrical stems without buttresses; tree height reaches 15 m or more. Free branch height (boles) can reach 60% of the total tree height. The stem is encased in a thin layer of skin that is layered to form a thick, yellowish skin and very easily removed. The wood is hard, specific gravity is 0.85, durability class III and strength class II.

Galam forest is a typical forest of peat swamp forest that does not require high growth requirements with high acidity of soil (pH value 3-5). Generally, galam forest is a homogeneous forest and is very tolerant of the condition of the soil that is less fertile, sour and inundated. Galam growth originated from seed (generative) is generally relatively straight and has a monopodial branching, so that the stem is widely used for building materials. The stems grown from coppices have the shape of the stems tends to be bent with sympodial branching, so the utilization of stems is for firewood, except when the diameter > 20 cm with the length of the free stem branch > 4 m is used as wood carpentry. Besides, the galam trees have versatile uses starting from the fruits, leaves, and wood to the bark. However, until now they are mostly used is in the form of wood sticks and firewood. Galam leaf is used as raw materials for medicines and the fruit after drying is utilized as a substitute for black pepper and mixed herbal medicine ingredients.
The galam swamp forest spreads across Southeast Asia from the Malacca Peninsula to the Maluku Islands and the Philippines. Particularly in South Kalimantan, it spreads naturally in peat and tidal swamplands (freshwater swamps) and is also found on relatively dry land (ex-kerangas forest).

Increased human activities and natural damage in the form of land use changes, deforestation, industrial waste, and forest fires have led to high levels of carbon emissions in the atmosphere and triggered the process of global warming. This will have a major impact on human well-being in general, and has even led to natural disasters in the world, such as rising sea levels, rising atmospheric storms, increasing species and population of disease-causing organisms. One way to reduce this impact is to control carbon concentration through the development of program sinks, where organic carbon resulted from photosynthesis will be stored in forest stand biomass or woody trees. In the course of the development of this program, data information on the amount of biomass and carbon stocks is very important to study. The study was aimed at analyzing the potential of biomass and carbon stocks in the galam swamp forest in South Kalimantan province, Indonesia. It is hoped that the results of the study can provide information on the potential of biomass and carbon stocks especially in the galam swamp forest, so that it can support the Indonesian Government to participate in carbon trading and efforts to suppress global climate change through increasing carbon fixation in forest biomass, thus reducing CO_2 in the air.

Materials and methods

Study area

The research was conducted in the galam swamp forest, in Liang Anggang Sub-district, Banjarbaru City, South Kalimantan province, Indonesia. Geographically, the research locations spread from 030° 25' 40″ to 030° 28' 37'' SL and from 1140° 41' 22'' to 1140° 54' 25'' EL with a height of 66 feet from sea level.

Materials

The materials used were stands of galam swamp forest located in the Landasan Ulin Barat and Landasan Ulin Selatan villages. The equipment used in this research was stationery, tally sheet, haga, measuring tape, digital scales, scales, sacks, chain saw, oven, machetes, axes, cameras, GPS and a set of computers.

Methods

Types of data and collection

The types of data used were primary and secondary data. Primary data were obtained from the measurement of galam stands in the field. Parameters observed included diameter, total height, boles of the galam trees at all growth stages. Secondary data needed were about general conditions of the research location and data of literature study results.

The study for the tree stage applied the technique of circular sample plots with a radius of 17.8 m (an area of 0.1 ha) with purposive sampling. In the circular sample plot, the subplots were made of 10 m × 10 m for the pole stage, and 5 m × 5 m for the belta stage. The number of sample plots made was 10 plots, namely 5 sample plots in the Landasan Ulin Barat village and 5 sample plots in the village of Landasan Ulin Selatan. Primary data were collected by conducting a census in all plots including identification of tree species on tree, pole, and belta stages, and measurement of tree diameter and height. The criteria of vegetation were classified according to Kartawinata *et al.*, (1976) as follows:

First, trees are woody plants with a diameter at breast height (1.3 m) ≥ 10 cm (D ≥ 10 cm). Data for the trees were observed on the circular plot (r = 17.8 m) or an area of 0.1 ha. Data recorded were tree species, diameter, and height of trees.

Second, poles are woody plants with a diameter at breast height (1.3 m) ≥ 5 cm - < 10 cm. The data observed in the sample plots of 10 m × 10 m were species, diameter, and height of poles.

Third, beltas are woody plants with a diameter at breast height (D > 2 cm - < 5 cm). Data observed in the sample plots of 5 m × 5 m were species, diameter, and height of plants.

The calculation of biomass used the formula of carbon stocks, and samples were taken using destructive sampling method, which was to cut and then weigh the wet weight directly on each part of the vegetation components (leaves, branches, stems, and roots) and converted them to dry weight (biomass) using dry weight of each sample of the vegetation section of each sample tree. Leaf samples were taken as ± 100 g while the branches, stems and root samples were sampled with the size of ± 2 cm × 2 cm × 2 cm at the base, middle and end parts of trees. The steps were done after getting the description of the diameter and height distribution of stands, then selected a sample tree purposively which is expected to represent the diameter distribution of trees at the research location, then did the clearance of the area around the sample tree and logging. Furthermore, the separation of tree parts (leaves, branches, stems, and roots) was done.

Leaves

In order to calculate the leaf biomass of the sample tree, each sample tree that has been cut, the whole leaves were then weighed for the wet weight, then sampled as much as ± 100 g for the calculation of dry weight.

Branches

In each sample tree, it was separated the branch portion of the main stem, collected and then weighed for the wet weight. After weighing the wet weight, the samples were taken at the base, middle and end of the branches for all samples to calculate the dry weight in the laboratory.

Trunks/stems

Each main stem was cut into pieces to facilitate the weighing of wet weight and separated the main stem free of the branch and after the branch. After weighing the overall wet weight of the main stem, it was taken a sample of the stem at the base, middle and end of the branch for calculating the dry weight of the stem in the laboratory.

Roots

To facilitate the taking of roots, before the trees were cut down the excavation of large roots was done so that when the tree was falling the roots will be lifted. After that, the whole roots were collected and then weighing them for the wet weight. For the calculation of dry weight, it was taken the samples at the base, middle and tip of roots. The process was done in the laboratory.

Analysis

The density of trees per hectare was obtained from the number of trees recorded in all plots. Data of diameter and total height were used to calculate the stand volume and in this study, the stem volume was limited without counting the canopy (branches, twigs, leaves, flowers, and fruit). The formula used was as follows:

V = 1/4. Π.d2.t ....(1)

Where:

V = tree volume (m3);

Π = constant (3.14)

D = tree diameter at breast height (cm)

t = total height (m).

To calculate the biomass or dry weight of plants according to Heriyanto and Subiandono (2012) it was used the formula:

Biomass = tree volume × density of wood............ (2)

Where:

Wood density = Dry weight: Volume .... (3)

Based on the result of the laboratory test it was found that the density value of galam wood was 0.78.

The calculation of the total dry weight of biomass, it was used the destructive sampling method of each part of the tree that was calculated with the formula (Hairiah *et al.*, 1999):

$$TDW = \frac{DWS}{WWS} \times TW \text{..} (4)$$

Where:

TDW = Total dry weight (g)

DWS = Dry weight of samples (g)

WWS = Wet weight of samples (g)

TWW = Total wet weight (g).

Carbon stocks in plants were calculated using the formula (Brown, 1997; International Panel on Climate Change/IPCC, 2003):

Carbon Stocks= Dry Weight of Plants × 50% ....(5)

Results and discussion

Distribution of diameter classes

Diameter class, density, and percentage of growth stage of the galam swamp forest at each plot were described in Table 1.

Table 1. Diameter class, density, and percentage of growth stage of the galam swamp forest at each plot.

No. Plot	Growth stage	Diameter class (cm)	Density (N/0.1 ha)	Percentage (%)
1	Belta	2 - < 5	240	57
	Pole	≥ 5 - < 10	160	38
	Tree	≥ 10	23	5
Total			423	
Average			141	
2	Belta	2 - < 5	360	74
	Pole	≥ 5 - < 10	80	16
	Tree	≥ 10	46	9
Total			486	
Average			162	
3	Belta	2 - < 5	280	75
	Pole	≥ 5 - < 10	50	14
	Tree	≥ 10	42	11
Total			372	
Average			124	
4	Belta	2 - < 5	360	75
	Pole	≥ 5 - < 10	80	17
	Tree	≥ 10	40	8
Total			480	
Average			160	
5	Belta	2 - < 5	240	56
	Pole	≥ 5 - < 10	130	31
	Tree	≥ 10	55	13
Total			425	
Average			141.67	
6	Belta	2 - < 5	240	63
	Pole	≥ 5 - < 10	120	31
	Tree	≥ 10	22	6
Total			382	
Average			127.33	
7	Belta	2 - < 5	200	67
	Pole	≥ 5 - < 10	80	27
	Tree	≥ 10	18	6
Total			298	
Average			99.33	
8	Belta	2 - < 5	200	52
	Pole	≥ 5 - < 10	170	43
	Tree	≥ 10	20	5
Total			390	
Average			130	
9	Belta	2 - < 5	120	39
	Pole	≥ 5 - < 10	170	54
	Tree	≥ 10	22	7
Total Average			312 104	
10	Belta	2 - < 5	80	47
	Pole	≥ 5 - < 10	60	36
	Tree	≥ 10	29	17
Total Average			169 56.33	
Total (N/Ha)			3,737	
Average/plot			124.56	

Table 1 indicated that the potential of the galam stands in the research location in terms of the number of was still high, i.e. 3,737 stands per hectare that consisted of 2,320 stands (62.08%) for the belta stage, 1,100 stands (29.44%) for the pole stage, and 317 stands (8.48%) for the tree stage. Based on the Paired-Samples T-Test of SPSS, the number of stands at the belta stage was significantly (95%) higher than that of the pole stage and it was significantly (99%) higher than that of the tree stage. Similarly, the number of pole stands was significantly (99%) higher than that of the tree stage. This indicated that the galam trees that had a large diameter had been cut down by the community so that the remaining galam trees were the trees with a smaller diameter. Apart from that, it was because of frequent forest fires during the dry season. After a forest fire, the trees usually grow back young shoots (regeneration) through branches or remaining tree stems. Heriyanto and Subiandono (2012) stated that regeneration is a natural phenomenon whereby a young tree will replace the mature tree for some reasons, such as being felled, burned, fallen (natural disaster) or physiologically dead.

Table 2. Distribution of galam height per plot in swamp forest based on growth stages.

No. Plot	Average height (m)		
	Belta	Pole	Tree
1	2.7	3.6	3.6
2	2.0	3.8	3.7
3	2.9	3.3	3.5
4	2.8	2.9	3.4
5	2.8	3.7	3.7
6	2.2	3.3	3.8
7	1.6	2.8	4.1
8	1.2	3.2	3.5
9	2.3	3.0	3.7
10	1.8	2.9	3.6
Average	2.23	3.25	3.66

Tree density at observation plots in the Landasan Ulin Barat village (from plot 1 to plot 5) was relatively higher than that at observation plots in the Landasan Ulin Selatan village (from plot 6 to plot 10). This can be seen from their larger average density. This might happen because of the age difference of stands where the age of trees in the village of Landasan Ulin Selatan is relatively younger than that in the Landasan Ulin Barat village because of a forest fire.

Distribution of tree height

Distribution of galam height per plot in swamp forest based on growth stages can be seen in Table 2.

Table 3. Biomass and carbon stocks of the galam swamp forest at the belta stage.

No. Plot	Number of trees (N/0.1 ha)	Volume (m^3/0.1 ha)	Biomass (Ton/0.1 ha)	Carbon stock (Ton/0.1 ha)
1	240	0.016	0.012	0.006
2	360	0.018	0.014	0.007
3	280	0.024	0.019	0.010
4	360	0.029	0.023	0.012
5	240	0.018	0.014	0.007
6	240	0.014	0.011	0.006
7	200	0.009	0.007	0.004
8	200	0.005	0.004	0.002
9	120	0.008	0.006	0.003
10	80	0.004	0.003	0.002
Total (Ton/ha)	2,320	0.145	0.113	0.057

Table 2 showed that the average height of the galam forest was 2.23 m for the pole stage, 3.25 m for the pole stage, and 3.66 m for the tree stage. Based on the average height of the galam forest, the average height of the galam forest at pole and tree stages at each observation plot was relatively the same except at the belta stage. Based on the Paired-Samples T-Test of SPSS, the mean height of the tree stage was significantly (95%) higher than that of the pole stage and significantly (99%) higher than that of the belta stage. Likewise, the pole stage was significantly (99%) higher than the belta stage. At the belta stage, height distribution was much different, i.e. plot 1 through plot 5 was relatively higher than that of plot 6 through plot 10. This was due to the different ages of the galam trees. The galam trees at plot 6 through plot 10 located in the Landasan Ulin Selatan village were younger than those at plot 1 through plot 5 in the Landasan Ulin Barat village.

Table 4. Biomass and carbon stocks of the galam swamp forest at the pole stage.

No. Plot	Number of trees (N/0.1 ha)	Volume (m^3/0.1 ha)	Biomass (Ton/0.1 ha)	Carbon stock (Ton/0.1 ha)
1	160	2.10	1.638	0.819
2	80	1.20	0.936	0.468
3	50	0.07	0.055	0.028
4	80	0.09	0.070	0.035
5	130	0.20	0.156	0.078
6	120	0.17	0.133	0.067
7	80	0.08	0.062	0.031
8	170	0.24	0.187	0.094
9	170	0.19	0.148	0.074
10	60	0.08	0.062	0.031
Total (Ton/ha)	1,100	4.42	3.448	1.724

Biomass and Carbon Stocks

Biomass and Carbon Stocks at the belta, pole, and tree stages can be seen in Table 3, Table 4, and Table 5.

Based on the three tables above, the amount of biomass and carbon stocks at the tree stage was higher than those of the belta and pole stages. Based on the Paired-Samples T-Test of SPSS, biomass and carbon stocks of the tree stage were significantly higher than those of the belta stage at significance level of 99% (p-value 0.00 < 0.01), and they were significantly higher than those of the pole stage at a significance level of 95% (p-value 0.015 < 0.05).

Table 5. Biomass and carbon stocks of the galam swamp forest at the tree stage.

No. Plot	Number of trees (N/0.1 ha)	Volume (m^3/0.1 ha)	Biomass (Ton/0.1 ha)	Carbon stock (Ton/0.1 ha)
1	23	0.87	0.679	0.340
2	46	1.76	1.373	0.687
3	42	1.70	1.326	0.663
4	40	1.23	0.959	0.480
5	55	2.09	1.630	0.815
6	22	0.87	0.679	0.340
7	18	0.73	0.569	0.285
8	20	0.91	0.710	0.355
9	22	1.01	0.788	0.394
10	29	1.20	0.936	0.468
Total (Ton/ha)	317	12.37	9.649	4.825

Furthermore, biomass and carbon stocks of the pole stage were not significantly different from those of the belta stage because the smaller diameters of the galam swamp forest, the higher density of galam stands. Although the galam trees have been being over-exploited by communities without banning from the government (actually the areas were included as protected forests), biomass and carbon stocks of the tree stage were still higher than those of the pole and belta stages. Conversely, Alpian *et al.* (2013) found that in Central Kalimantan biomass content of poles was the highest, followed successively by that of saplings, trees, and seedlings.

That meant that in Central Kalimantan most trees of the galam swamp forest had been cut. Overall at the present research in South Kalimantan, the amount of biomass in the galam swamp forest for the three stages was 13.21 tons/ha, while the carbon stocks amounted to 6.61 tons/ha as presented in Table 6.

Table 6. The amount of biomass and carbon stocks of the galam swamp forest.

Growth stage	Biomass (Ton/ha)	Carbon stock (Ton/ha)	Percentage (%)
Belta	0.113	0.057	0.86
Pole	3.448	1.724	26.10
Tree	9.649	4.825	73.04
Total	13.210	6.606	100.00

As for comparisons of the number of carbon stocks based on previous research, the number of carbon stocks in the galam forest was lower than that of the previous research results. For examples, the number of carbon stocks at ex-fired natural forest in East Kalimantan was 8.88 tons/ha (Adinugroho *et al.*, 2006), at mangrove forest in West Sumatera was 24.56 (Bismark *et al.*, 2008), at secondary natural forest in South Kalimantan was 81.59 tons/ha (Yamani, 2011), and at the mangrove forest of Alas Purwo National park in East Java was 108.61 tons/ha (Heriyanto and Subiandono, 2012).

Total carbon stock of understory, seedlings, saplings, poles, and trees was 73.08 tons/ha at primary peat forest; 4.93 tons/ha at annually burnt forest; 13.64 tons/ha at peat forest after 3 years being burnt; and 26.13 tons/ha at peat forest after 3 years being burnt in Central Kalimantan (Dharmawan *et al.*, 2013), and the amount of carbon stocks at red meranti stands aged 6, 8, and 10 years was 43.21 tons/ha on average (Achmad, 2017b). This was understandable because of the different types of forests and their location and other factors such as the occurrence of forest fires in the dry season that occur almost every year, as well as illegal logging activities that cause forest destruction which may eventually reduce the galam forest potential. According to the results of the Fransisco (2009) study, average carbon stocks in the soil in galam farms on peatlands were 259.83 tons/ha at a depth of 0.15 m. This means that carbon stocks of galam are higher in the soil than those in the vegetation. Moreover, at the present research; seedlings, saplings, and undergrowth were not included in the carbon stock calculation, and only one species was studied namely galam (*Melaleuca cajuputi*).

Conclusions

The potential of the galam swamp forest in terms of the number of stands was still high, i.e. 3,737 stands per hectare. When viewed from the percentage of the number of stands at each growth stage, the belta stage had the highest percentage (62.08%); followed by the pole stage (29.44%) and the tree stage (8.48%).

The average height of stands in the galam forest for the belta stage was 2.23 m, the pole stage was 3.25 m and for the tree stage was 3.66 m. The amount of biomass in the swamp forest for the tree, pole, and belta stages was 13.21 tons/ha and the number of carbon stocks was 6.61 tons/ha. It is recommended that the stands of galam swamp forest should be kept and maintained properly and earnestly because the potential of the wood continues to increase along with increasing age that is still relatively young today. It is needed to do research on biomass and carbon stocks either in the vegetation or in the soil holistically in order to reveal the real amount of carbon stocks stored in galam forest sites.

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