Estimation of Above Ground Carbon Sequestration in Trembesi (Albizia saman) and Johar (Senna siamea) at PT Multi Harapan Utama, East Kalimantan

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Research Article

Estimation of Above Ground Carbon Sequestration in Trembesi (*Albizia saman*) and Johar (*Senna siamea*) at PT Multi Harapan Utama, East Kalimantan

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ABSTRACT

The open-pit mining method has a very large ecological impact. It causes the loss of forest vegetation which decreases CO_2 absorption. Measuring the amount of carbon stored in plant biomass can represent the amount of CO_2 that can be absorbed in the atmosphere. The objective of this research is to determine the carbon sequestration of *Albizia saman* and *Senna siamea* in different age classes at PT MHU Busang Jonggon Block, Kukar, East Kalimantan. Estimation of carbon sequestration in the stands of *A. saman* and *S. siamea* was carried out by non-destructive methods using biomass allometric equations while in understorey and litter using the destruction sampling. The results showed that the highest carbon absorption value of *A. saman* was 314.28 tons/ha which appear at six years old stands and the lowest value was 193.31 tons/ha at three years old stands while the highest carbon absorption value of *S. siamea* was 113.65 tons/ha which appear at nine years old stands and the lowest value was 24.64 tons/ha at three years old stands. *A. saman* could be more promising plant species than *S. siamea* according to its higher level of carbon sequestration and their high adaptation level. All data from this study could suggest several information for increasing carbon sequestration level in forest ecosystem as well as achieving forest rehabilitation purpose.

Keywords: *Albizia saman, Senna siamea,* biomass, carbon sequestration and mining activity

INTRODUCTION

Climate change is a change of the atmospheric composition and climate variability over a period of time (Regulation of the Minister of Environment and Forestry, 2017). It is caused by the rising temperatures of the earth or known as global warming due to an increase in greenhouse gases (GHG) in the atmosphere. Greenhouse gases have formed by carbon dioxide (CO_2), carbon monoxide (CO), NOx nitrogen oxides, chlorofluorocarbons (CFC), fluoride sulphate, methane, hydrocarbon, water vapour, and others (Bhattacharjee, 2010).

As the terrestrial carbon absorbers, forest plays a vital role in the carbon cycle and able to minimize greenhouse gases in the air. It is because plants can absorb carbon dioxide in the process of photosynthesis (Canadell and Raupach, 2008). Indonesia is one of the countries with a large forest area, which is around 109,961 million hectares consisting of 29,037 million hectares of protected forest, 23,214 million hectares of natural reserves, and the remaining 57.7 million hectares as production forests (Forestry Minister Regulation, 2011). This land cover condition has the potential to store large amounts of carbon stocks.

Forest vegetation in Indonesia can conserve more than 14 billion tons of biomass with total carbon storage of 3.3 billion tons (Nandika, 2005). However, over time the rate of deforestation and forest degradation in Indonesia has increased, thereby reducing the effectiveness of forests in reducing carbon emissions in the air. One of the causes of deforestation and forest degradation in Indonesia is the activity of conversion of forest land used as mining businesses (Masripatin *et al.*, 2010b).

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Reclamation and revegetation activities of post -mining land are very important in reducing greenhouse gas emissions. According to Hairiah *et al.* (2011), one of the conditions in implementing a reduction in carbon emissions through a REDD+ scheme (Reducing Emissions from Deforestation and Degradation) using the MRV system (Measurable, Reportable and Verifiable). It requires substantial research to strengthen the measurement and estimation of biomass and carbon transparently which can support data as an effort to conserve and increase carbon stocks in the converted forest areas, especially on post-mining revegetation land.

The company that succeeds in implementing revegetation efforts to organize the area disrupted by the mining activities is PT Multi Harapan Utama (MHU). The dominant species planted at MHU are *Falcataria moluccana, Acacia mangium, Acacia auriculiformis, Macaranga gigantea, Vitex pinnata, Peronnema canescens, Gliricidia moculatam, Albizia saman,* and *Senna siamea*. The results of the study prove that the pioneer plants over five years old are dominated the reclamation area (Maharani *et al.*, 2010). Based on factual data, *Senna siamea* and *Albizia saman* have the complete age ranges than the other type.

Another example of revegetation effort at Sorowako, South Celebes by local mining company was implemented using the following species, such as johar (*S. siamea*), bitti (*Vitex cofassus*), kayu angin (*Casuarina* sp.) and sengon buto (*Enterolobium macrocarpum*) (Setiadi and Adinda, 2012). *Cassia siamea* Lamk. was measured its growth and carbon stocks at a coal mining area after revegetation (Ilyas, 2013). Moreover, *A. mangium* and *F. moluccana* were calculated their carbon stocks in three consecutive years at PT. Jorong Barutama Greston, South Kalimantan (Hilwan and Nurjannah, 2014). Carbon sequestration for supporting the revegetation process was estimated on pine stands of a post-mining area at PT. Holcim Indonesia Tbk. (Fahmi and Rusdiana, 2016). Johar (*S. siamea*), along with Laban (*Vitex* sp.) and sengon (*F. moluccana*) was planted on modified media at a post-mining area in KHDTK Labanan, Berau District, East Kalimantan (Cahyani and Hardjana, 2017).

The results of the Ilyas (2013) research on *S. siamea* stands in the revegetation area with a range of ages three to seven years showed a value of biomass deposits of 69.95-108.56 tons/ha whereas in non-mining areas with an age of seven years biomass deposits were obtained in stands of 136.39 tons/ha.

The objective of this research is to determine the carbon sequestration *of A. saman* and *S. siamea* in different age classes at PT MHU, Kukar, East Kalimantan.

MATERIALS AND METHODS

This research was conducted from March to June 2018 in a revegetation land of PT Multi Harapan Utama, Kutai Kartanegara, East Kalimantan. Based on Figure 1, the studied area was conducted in Loa Kulu sub-district, Kutai Kartanegara, East Kalimantan geographically located at 116º 29'– 117º 03 'EL and 0º26'– 0º54'SL.

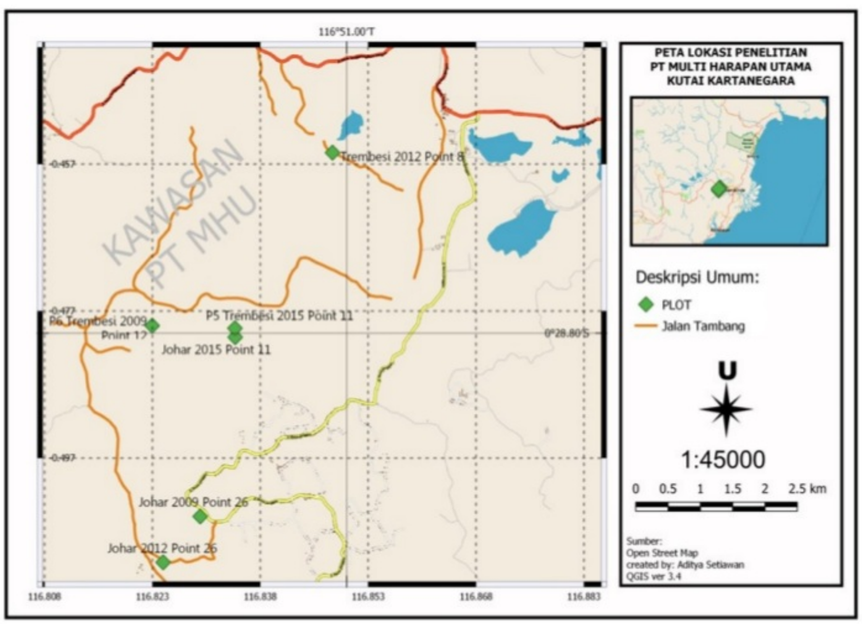

Figure 1. Map Location of Revegetation Area in PT Multi Harapan Utama, Busang Jonggon Block, Kutai Kartanegara, East Kalimantan.

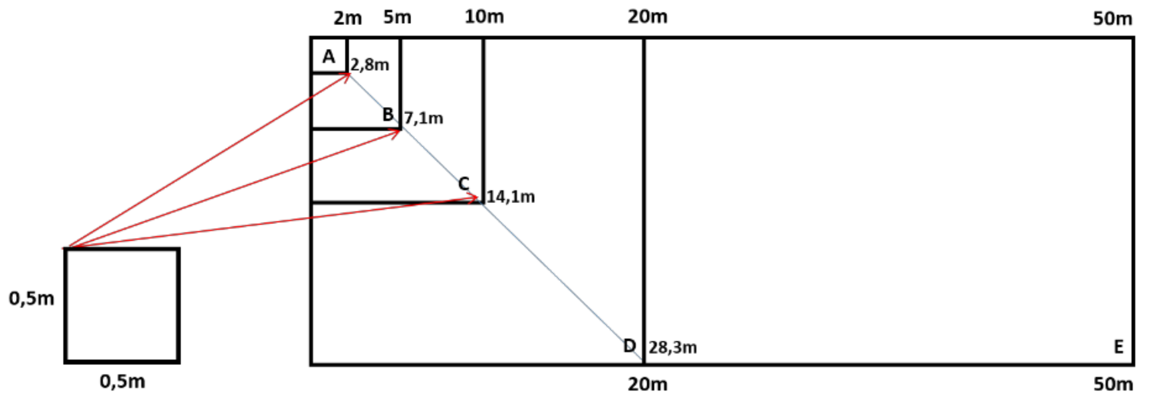

Figure 2. Placement of a 20 x 50 m rectangular plot and subplot size of 0.5 x 0.5 m for understorey and litter biomass sampling.

Determination of Points and Making Plots

The starting point for making a plot is determined by choosing the condition of the vegetation that can represent all the types of land cover in that location (Hairiah *et al.*, 2011). Figure 2 showed that the data retrieval was done by making a rectangular plot measuring 20 x 50m in which there are subplots of size 0.5 x 0.5 m for measuring understorey biomass and litter (Rusolono *et al.*, 2015).

Measuring Stand Biomass, Lower Plants and Litter, Necromass

Measuring tree stand biomass is done by using non-destructive methods by measuring the diameter of the stem at a DBH (Diameter at Breast Height) or about 1.3 m from the ground surface and the total height of the tree (Hairiah *et al.*, 2011).

Measurements of understorey biomass were carried out using destructive methods in which all live plants in the form of seedlings of <5cm, herbs, and shrubs that were in plots of 0.5 x 0.5m and separated between woody plant species and not woody weighed around 100-300g to find out the wet weight. Drying was done using an oven with a temperature of 80-100°C for 48 hours and weighed to determine the dry weight (Hairiah *et al.*, 2011).

Estimation of above-ground biomass was carried out using destructive method, which alive plants (or seedlings) ± 5 cm height, either herbs or shrubs were collected from previous subplot, were determined between woody or non-woody plants, and were weighed about 100 – 300 g to obtain its fresh weight. Drying was conducted using an oven at a temperature of 80 – 100 °C for 48 h, then re-weight to obtain its dry weight (Hairiah *et al.*, 2011).

Necromass measurements were carried out on the main plots with data collected from each plot, namely the diameter, height, or length of woody necromass and necromass specific gravity (Rusolono *et al.*, 2015).

Data Analysis

Calculation of stand biomass

Calculation of stand biomass was carried out using allometric equations of species that has been developed by the accordance with ecosystem types (Krisnawati *et al.*, 2012). The allometric equation estimates the stand biomass and volume as follows:

A. saman (Hairiah *et al.*, 2011):

$$DW = \pi * exp(-1.499 + 2.148 \ln(D) + 0.207 (\ln(D)) 2 - 0.0281 (\ln(D)) 3)$$

S. siamea (Ilyas, 2013):

$$AGB = 0.3699 * D^{1.9374}$$

Where, AGB is Above Ground Biomass; DW is dry weight (kg); π is Trembesi specific gravity of 0.6 g / cm^3 (IPCC, 2006); and D is stem diameter at breast height (cm).

Calculation of Lower Plant Biomass and Litter

Calculation of understorey above ground biomass and litter was carried out by calculating the total dry weight (Hairiah *et al.*, 2011) by the formula:

$$TDW = SDW / SWW \times TWW$$

Where TDW is the total dry weight (kg); SDW is sample dry weight (kg); SWW is sample wet weight (kg), and TWW is the total wet weight (kg).

Calculation of Necromass Trees, Poles, and Dead Piles Potentials

The calculation of tree, pole and stake deadness is carried out using tree biomass values multiplied by the level of tree integrity (Figure 3) with reference to the formula obtained from National Standardization Agency (2011) as follows:

$$Ni = Bi \times f$$

Where, Ni is necromass (kg); Bi is stand biomass (kg), and f is the integrity of dead trees.

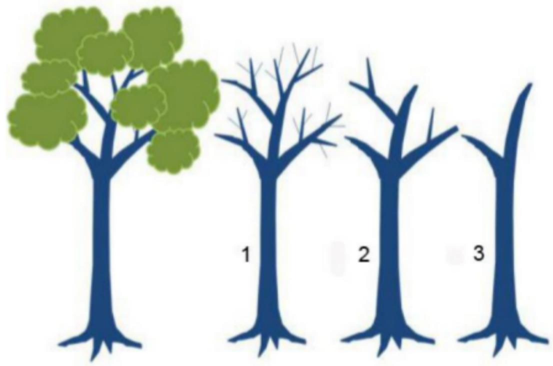

Figure 3. The integrity of Trees, Poles, and Stakes. 1. The level of dead trees integrity without leaves with a correction factor of 0.9; 2. the level of tree integrity without leaves and twigs with a correction factor of 0.8; 3. The level of tree integrity without leaves, twigs, and branches with a correction factor of 0.7 (Rusolono *et al.*, 2015).

Calculation of Carbon Reserves in Stands, Lower Plants and Litter, Necromass

Calculation of carbon from biomass uses the following formula:

$$C = B \times \% C$$
$$C = TDW \times \% C$$
$$C = N \times \% C$$

Where, C is carbon content from biomass (kg); B is total biomass (kg); TDW is dry weight of understorey kilns and litter (kg); Nis total necromass, expressed in kilograms (kg); %C is the percentage value of carbon content, which is 0.47 which is a conversion factor of international standards for estimating carbon or using the percent carbon value obtained from measurements in the laboratory.

Calculation of Carbon Absorption (C-sequestration)

Carbon absorption value (C-sequestration) is obtained by the conversion factor of C atoms in CO_2 compounds which is equal to 3.67 (Sutaryo, 2009). This value is multiplied by the value of carbon stocks by the formula:

$$CO_2 = C \times 3.67$$

Where, CO_2 is the amount of CO_2 absorption; C is carbon stocks stored, and 3.67 is the conversion factor of C atoms in CO_2 compounds.

Calculation of carbon per hectare for above-ground biomass

The accumulation of the area per hectare is obtained by the calculation results. The formula used (National Standardization Agency, 2011) is:

$$Cn = (Cx / 1000) \times (10000 / A)$$

Where, Cn is carbon content per hectare in each carbon pool in each plot (ton/ha); Cx is carbon content in each carbon pool in each plot (kg), and A is the plot area in each pool (m^2).

Statistical Analysis Two Way ANOVA using IBM SPSS 22

Analysis of Two Way ANOVA with replication was conducted to interpret the differences between carbon sequestration of both species *A. saman* and *S. siamea* and the interaction of the plant species and the age class on carbon sequestration ability.

RESULTS AND DISCUSSION

Deposits of Above Ground Biomass

The location of PT MHU has a wet tropical climate with relatively high average rainfall. According to Koppen classification, this region categorized as an Af or tropical region which indicates the coldest average temperature of more than 18ºC with an average level of precipitation not less than 60 mm per month. According to statistical data of BPS (2018), the rainfall average was 169 mm with the highest rainfall in April was 303 mm.

Based on Table 1, the highest total biomass deposits from various components found in six-year -old *A. saman* stands planted in 2012 which were 177.12 tons/ha, and the lowest was the three-year-old *S. siamea* stand planted in 2015 which was 13, 31 tons/ha. Concerning the several components, the highest biomass deposits found in stands dominated

Table 1. Soil Biomass Deposits in *A. saman* and *S. siamea* stands at PT Multi Harapan Utama (ton/ha).

No	Component	Biomass (ton/ha)					
		Albizia saman			***Senna siamea***		
		2009	**2012**	**2015**	**2009**	**2012**	**2015**
1	Stands	113,23±0,25	176,01±0,16	106,79±0,17	100,56±0,13	60,00±0,02	13,25±0,004
2	Understorey	0,011±0,001	0,010±0,001	0,01±0,001	0,002±0,001	0,007±0,001	-
3	Litter	0,032±0,002	0,019±0,001	0,016	0,025±0,002	0,015±0,001	0,006±0,001
4	Necromass	1,35±0,002	1,08±0,02	0,60±0,003	0,99±0,001	1,97±0,01	0,05 ±0,001
	Total	**114,62**	**177,12**	**107,42**	**101,58**	**61,99**	**13,31**

Sources: Hairiah *et al.* (2011) and Ilyas (2013).

by categories of stakes with the diameter ranges about 4-28 cm. Biomass deposits in *A. saman* are not directly proportional to the addition of plant age due to differences in the location of planting which causes the differences in physical and chemical conditions, especially on the soil (Hairiah *et al.*, 2011).

The component of soil organic matter is very influential in storing plant biomass because it is interrelated with the growth in diameter and height of plants (Hairiah *et al.*, 2011). Generally, reclaimed land has lower levels of organic matter compared to natural forests (Arsyad, 2010). The lowest value of biomass deposits in *S. siamea* stands in 2015 was caused by the soil conditions which dominated by the overburden. According to Sofyan (2013), the form of topsoil mixed with overburden can decrease plant growth so that it has the potential to reduce the value of biomass deposits.

Along with the increase in plant life, the component of soil organic matter will increase caused by an increase in the amount of weathered litter produced by plants in the form of leaves, stems or twigs (Arsyad, 2010) and the total biomass deposit will tend to be greater on older age revegetated land. However, from the table, it can be seen that the value of biomass deposits in *A. saman*, which is nine years old, was decreased compared to six-year-old plants. This is due to an increase in the type of plant at the site of the nine-year-old *A. saman* research plot which resulted in a large number of other species found in the plot through reducing the number of *A. saman* stands that can be measured compared to other observation points which tend to be dominated by one particular species.

The factor that affects biomass deposits is the diversity of conditions, which results in differences in yield between stand conditions that grow in each area. According to Krisnawati *et al.* (2012), particularly variations in plant diameter and height are influenced by the differences in growing conditions including slope, place quality, and silvicultural treatment applied to the area.

Understorey biomass and litter are the smallest fractions of total carbon in most forests (Brown, 2002). In this study, understorey biomass was inversely proportional to stand biomass due to the increasing age of the plant. Whereas the litter biomass is directly proportional to stand biomass because of the higher age of the plant causing the complexity of the plants inside. So, it increases the amount of litter that can be counted.

The largest necromass deposit found in the six -years-old *S. siamea* stands which was 1.97 tons/ha with the largest proportion from dead poles without leaves. The number of stands measured in the plots is higher than the other locations. Based on the condition of the dead poles and canopy size, there is competition in the absorption of nutrients and sunlight which causes an effect of the stands growth. The smallest necromass deposit found in the three-years-old *S. siamea* stands which was 0.05 tons/ha. The youngest stand was dominated by saplings so that the stand mortality rate is low. Some dead stands were characterized by the loss of young leaves stands, stagnant stand conditions due to inundation, and topsoil conditions still dominated by the overburdened soil types. According to Adinda (2012), water torrent results in compaction of the soil that can damage the water system (water percolation) which occurs in the inhibition of water absorption into the soil through obstructing the development and circulation of air inside the roots.

Deposits of Above Ground Carbon Stock

Based on Table 2, the value of total carbon deposits on PT MHU revegetated land is directly proportional to the total biomass value obtained. The highest total carbon stock value of various components found in *A. saman* stands which were six years old at 83.42 tons/ha, and the lowest was three years old of *S. siamea* stand which was 6.28 tons/ha because the calculation of total carbon deposits has obtained by the sum of biomass from several components. It was measured and converted by the percentage value of carbon content of 0.47 which means that 47% of the biomass is composed

Tabel 2. The Total Deposits of Above Ground Carbon Stock in *A. saman* and *S. siamea* Stands at PT MHU.

No	Component	Carbon stock (ton/ha)					
		A. saman			***S. siamea***		
		2009	**2012**	**2015**	**2009**	**2012**	**2015**
1	Stands	53,22	82,73	50,19	47,26	28,20	6,23
2	Understorey	0,07	0,06	0,06	0,01	0,04	-
3	Litter	0,20	0,12	0,10	0,16	0,10	0,03
4	Necromass	0,63	0,51	0,28	0,47	0,93	0,02
	Total	**54,12**	**83,42**	**50,63**	**47,9**	**29,27**	**6,28**

of carbon elements (National Standardization Agency, 2011) an extension in biomass content has followed by an increase in stored carbon stocks because these two components have a positive correlation (Chanan, 2012).

The Total Absorption of CO_2

Carbon absorption values can describe the amount of CO_2 in the atmosphere that can be absorbed by plants. Based on Chanan (2012), the biomass content will also affect carbon sequestration. The factors that cause an increase in carbon potential are thinning which causes competition between trees that will increase the quality of tree growth and stand dimensions, age class of tree will increase the amount of carbon sequestration because the more age increases the stand size increases so that carbon potential increases. Estimation of the potential of CO_2 uptake in revegetation, understorey, litter and necromass stands in the post-mining area of PT Multi Harapan Utama was presented in the graphs below.

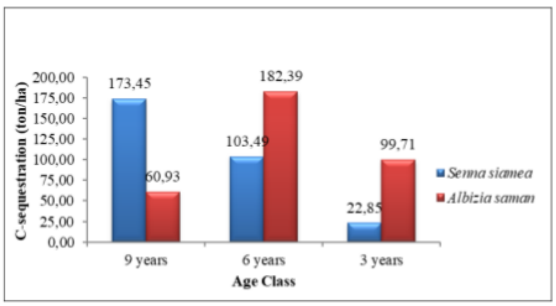

Figure 4. The Potential of C-sequestration values of the stands at PT Multi Harapan Utama.

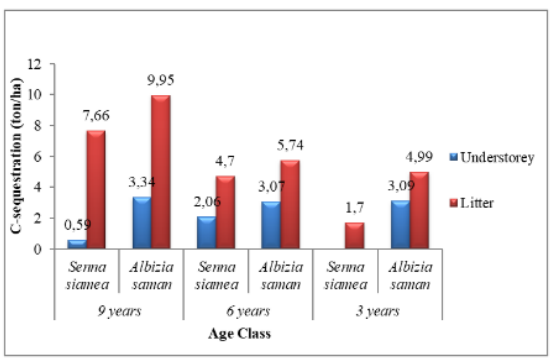

Figure 5. The potential of C-sequestration values of Understorey and Litter at PT Multi Harapan Utama.

Based on figures 4, 5 and 6, the lowest carbon sequestration value of various components was found in the three years old *S. siamea* stand of 2015 planting year. Due to the factual conditions in the field showed stagnation in the young *A. saman* plant which caused a significant difference in the size of the diameter and height of the plant compared to the six years old *A. saman*. The *A. saman* planting location in 2015 is directly around the former mining pond with very dry soil conditions and has a relatively low soil productivity rate (MHU, 2016).

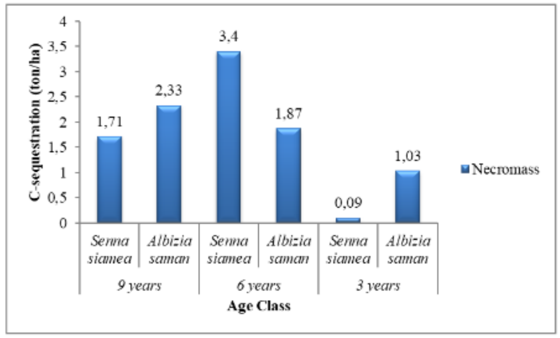

Figure 6. The potential C-sequestration values of Necromass at PT Multi Harapan Utama.

Based on Table 3, the highest potential value of carbon absorption (C-sequestration) in PT MHU, i.e six years old *A. saman* of the planting year of 2012, which was 314.28 tons/ha and the lowest value was found in the three years of *S. siamea* amounting to 24.64 tons/ha. However, when viewed from the ability of carbon sequestration per year by dividing the total carbon sequestration with plant age, the highest potential value of carbon absorption, precisely three years *A. saman* which was 64.44 tons/ha.

Tabel 3. The Potential total carbon sequestration value in *A. saman* and *S. siamea* stands at PT Multi Harapan Utama.

Age Class (year)	CO_2 Absorption (ton/ha)		CO_2 Absorption (ton/ha/year)	
	A. saman	***S. siamea***	***A. saman***	***S. siamea***
9	210.93	183.41	23.44	20.38
6	314.28	113.65	52.38	18.94
3	193.31	24.64	64.44	8.21

The statistical analysis using Two-way ANOVA with replication shows the P-Value of the variable plant species is 0.056917 (P-value ≤ 0,05) which means the variable type of plant has significant differences in the carbon absorption. The P-Value value of the variable plant age plant is 0.000495 (P-value ≤ 0,05) meaning that there is a substantial difference in the variation of plant age on carbon absorption. Besides that, the P-value of plant species is 0.056917 (P-value ≤ 0,05), it means that the interaction of plant type and plant age also shows the significant differences in the carbon absorption.

Based on the results of the field measurements in both species, *A. saman* has the ability to store higher carbon stocks than *S. siamea*. Due to the morphological advantages through the growth stage. It can grow up to 15-25 meters with a maximum DBH reaching 2 meters. Using these characteristics, *A. saman* is able to store greater biomass compared to other species.

According to Cahyani and Hardjana (2017), *S. siamea* has a relatively low percentage of life in the first ten months compared to two other species of fast-growing plants i.e *Falcataria moluccana* and *Vitex* sp. of 62.63% because the young plant is generally susceptible to several health problems in plants such as stagnation, chlorosis, necrosis, loss to black spots on leaves, through reducing adaptability to extreme conditions on mining land (Adinda, 2012).

This type of plant is highly influential on the ability to absorb carbon in the atmosphere. *A. saman* (trembesi) are alternative plants that used for revegetation of ex-mining land. This plant is a type of fast-growing species that spread in tropical and sub-tropical countries. The litter produced from this plant can increase the soil nitrogen content more than other N-fixing legumes and reduce the concentration of aluminium in the soil. In addition, this plant also can adapt to soil types with high pH (6.0-7.4) and tolerant to pH 8.5 and a minimum pH of 4.7. *A. saman* is a tree species that has the ability to absorb carbon dioxide from large air which is able to absorb 28,488.39 kg CO_2/tree every year Bashri *et al.* (2014).

Plant growth rates have a large influence on stand biomass and carbon stock conditions. According to Pamoengkas and Randana (2013), the decrease in crop increment was caused by an increase in plants. The increasing photosynthetic energy used to support metabolic processes such as respiration, translocation, and absorption of mineral nutrients. According to Chanan (2012), an increase in carbon content of plant life is due to an increase of photosynthesis to increase plant size.

The difference in the number of carbon deposits is quite large due to differences in climate, soil quality and also silvicultural treatment given at each location. Post-mining land generally has the land quality which tends to be lower when compared to forest land (Hilwan and Nurjannah, 2014).

The carbon uptake values obtained in this study were higher, namely at three to nine years old *S. saman* at 193.31-314.28 tons/ha and *S. siamea* from three to nine years old at 24.64-183.31 tons/ha when compared to carbon uptake in the revegetation stand planted with eight to ten years old of *A. mangium* and *F. moluccana* in South Kalimantan at 90.10-147.09 tons/ha (Hilwan and Nurjannah, 2014). However, when compared with natural forests, the value of carbon stocks obtained in this study was lower, which amounted to 6.28-83.42 tons/ha for stands aged three to nine years. According to Samsoedin *et al.* (2009), dipterocarp natural forest in Malinau, East Kalimantan, which is dominated by stands with a diameter of 7-70 cm, stores carbon stocks of 204.92-264.70 tons/ha. In primary lowland natural forests in the same area with stands of 7-70 cm in diameter stored carbon stocks, which amounted to 230.10-264.70 tons/ha. The study in Sungai Wain protected the forest, East Kalimantan which was dominated by stands with DBH 5-40 cm, the value of stored carbon reserves was 211.86 tons/ha. In addition, the measurement of carbon stocks in logged-over secondary forests in the Malinau Research Forest, East Kalimantan, which is dominated by stands with DBH 7-70 cm in logged-over age after five to thirty years stores carbon stocks of 171.8-249.1 ton/ha (Masripatin *et al.*, 2010a).

More intensive conservation of post-mining land must be done, especially in improving soil quality which has a substantial impact on plant growth. In addition, it should be evaluated to determine the percentage of plant life regularly and discover the most relevant plant conservation techniques. The use of appropriate silvicultural techniques has a generous impact on the amount of carbon stored in the plant.

Data and information regarding carbon stocks in various types of forest and plant ecosystems are very important to be used as a reference in efforts to maintain forest areas, especially for companies with activities that affect the structure and function of forest land. So that with this data all parties can consider the most optimal rehabilitation techniques in improving the land to restore the function of the forest as usual. Rehabilitation of forest ecosystems is carried out to accelerate the natural succession process and biological productivity, increase soil fertility, and increase biotic control of biogeochemistry flows in plant-covered ecosystems. An increase in the amount of carbon sequestration in an ecosystem can illustrate the success in ecosystem rehabilitation efforts (Setiawan, 2003).

CONCLUSION

Carbon sequestrations content was different among age classes. *A. saman* has the highest number in carbon sequestration about 314.28 tons/ha at 6 years old stands, while the lowest number was 193.31 tons/ha at 3 years old stands. On the other hand, *S. siamea* has the highest number of about 113.65 tons/

ha at 9 years old stands, while the lowest number was 24.64 tons/ha at 3 years old stands. *A. saman* has a higher number in carbon sequestrations than *S. siamea* because of its fast-growing ability, including various soil type and soil pH (even tolerate from 4.7 – 8.5). Meanwhile, *S. siamea* has lower carbon sequestration presumably because, since a young age, the seedlings must cope with various health problems and maintain its adaptability during the harsh condition in the mining area. Lastly, all data from this study could be useful for using as a reference to improve the carbon sequestration level in the forest ecosystem through achieve forest rehabilitation purposes.

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