International Journal of Agriculture and Forestry 2016, 6(5): 181-186
DOI: 10.5923/j.ijaf.20160605.02

# Carbon Stock Analysis of Land Reclamation in Coal Mining Post (Studies in Tanah Bumbu District of South Kalimantan Province)

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**Abstract** Conversion of forests for mining activities cause of increasing release of greenhouse gases in the air. The Indonesian government requires that mining companies do post-mining land reclamation to be able to function again as a carbon sink. The purpose of this study to analyze the amount of carbon stored in tree biomass of reclaimed land cover, cover crop, necromass and soil organic matter at various ages after coal mining reclamation plants. The study method makes the plot size 10x50 m to measure necromass trees and woody biomass. Measurement of biomass understorey and litter necromass using sub plot measuring 0.5 x 0.5 m. Measurements of carbon in the soil by measuring C-organic at a depth of 0-30 cm. The results of measurements of carbon stocks in the highest growth rate of reclamation plants reach the age of 5-6 years 28,04 ton/ha - 31,61 ton/ha, whereas the reclamation plant age 1-4 years ranged between 4.45 ton/ha - 9.30 to/ha. Likewise, the total soil carbon stocks biggest reclamation plants aged 5-6 years with soil carbon stocks between 18,21 ton/ha - 46,37 ton/ha, while the 1-4 year age of the plant carbon stocks ranged between 10,24 ton/ha - 12,15 ton/ ha. Estimated carbon stock in plants and in the soil the plant the largest in the 5-6 years age range between 46,13 ton/ha - 77.98 ton/ha, while the reclamation plants aged 1-4 years estimates the total carbon stock in plants and soil in between 14.89 ton/ha - 21,42 ton/ha. Carbon stocks tend to increase with age reclamation plant. Indicators recoverable land carbon stocks from land disturbed by mining its significant ($P < 0.005$) started reclamation plants aged 5 and 6 years, under 5 years of age still crop establishment that is not optimal in its function as a Carbonsink.

**Keywords** Carbon Stock, Reclamation Plant, *Coal Mining Post*

## 1. Introduction

Conversion of tropical rainforest for various industrial activities of mining and plantation became one of the causes of increased release of greenhouse gases (radiatively active gases) such as $CO_2$, $CH_4$, and $N_2O$ (Lusiana et al., 2005; Novis, 2015). Indonesia is under the United States and China, with the amount of emissions produced two billion tonnes of $CO_2$ per year, accounted for 10% of $CO_2$ emissions in the world (Hairiah et al., 2001; Hairiah et al., 2003).

Forest degradation and changes in land use helps increase levels of carbon dioxide in the atmosphere in two ways directly through forest burning and indirectly because forests act as carbon sinks (MacKinnon et al., 2000). Natural forests are storing carbon (C) is the highest when compared with the system of agricultural land use. Therefore, a natural forest with a diversity of long-lived trees and litter many storage warehouses C is the highest. When forests changed the amount of C stored function will decline. The amount of C stored between the land vary, depending on the diversity and density of existing plants, the soil type and the way it is managed (Hairiah et al., 2003). According Lusiana et al (2005) states that one of the reductions of emissions can be done by doing good by doing silviculture to increase carbon stocks by planting woody plants.

Various companies engaged in mining in Indonesia with the utilization of mineral excavation mining coal through open pit mining, contributed to changes in land cover in the form of initial land natural forest and forest stands of acacia (*Acacia mangium*) into the area of mining activities. The Indonesian government require companies coal mine reclamation and post-mining site revegetation. This serves as the company's commitment to restore disturbed land into land revegetation thus restoring the function of the area in increasing carbon uptake through C-sequestration is an attempt accumulation in the body of living plants. The amount of C stored in plants is stored in the body of living plants (biomass) in the landscape can describe the amount of $CO_2$ in the atmosphere is absorbed by plants (Hairiah et al., 2000).

Land restoration efforts in improving the uptake of $CO_2$ is done by planting activities reclamation area (revegetation).

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Published online at http://journal.sapub.org/ijaf

Reclamation and revegetation done as soon after the completion of mining activities. Post-mining land with site conditions are already unalterable requires seriousness in doing revegetation that fast growing plants so as to provide the function of reducing carbon emissions in the air. Uptake of C-sequestration of carbon through the reclamation plant will vary according to the age and development of the reclamation plant. Therefore, research is needed to measure how far the effectiveness of reclamation and revegetation of the uptake of carbon in the air that is stored in plants.

The study was conducted on post-mining reclamation area with a coal plant revegetation at the age of 1 year to 6 years old. It is to analyze the carbon stocks stored in each age reclamation plant. The greater the carbon stocks in the form of tree biomass, understorey, necromass and soil biomass show a success rate of reclamation in reducing $CO_2$ and stored in the form of carbohydrates in plants so as to contribute in reducing the greenhouse gas effect.

The types of crops grown on land reclamation include covering cover crop and woody plants such as Sengon (*Paraserianthes falcataria*), *Mahagony* (*Swietenia macrophylla*), Jackfruit (*Arthocarpus integra*), Acacia (*Acacia mangium*), Turi (*Sesbania grandiflora*) and Jabon (*Anthocepalus cadamba*). The purpose of this study is to measure and analyze the amount of carbon stored in land reclamation cover Tree biomass, understorey, necromass and soil organic matter at various ages after the reclamation plant shows coal mining reclamation plant effectiveness in reducing the greenhouse gas effect.

# 2. Research Methods

**a. Place and Time of Study**

The study was conducted at the plant reclamation plant age 1 to 6 years in the land after coal mining in Tanah Bumbu District, South Kalimantan Province of Indonesia. The study was conducted for 3 months, namely between February and April 2016 covering the activities preparatory to reporting.

**b. Materials and Methods**

The materials used are reclaimed plants aged 1 to 6 years include biomass plants (trees, understorey and necromass) and soil organic carbon. The method of collecting data by Hairiah and Rahayu (2007) to create a plot measuring 10 x 50 m north-south direction to measure the biomass of trees and woody necromass, Tree biomass measurements performed on trees diameter over 5 cm. Biomass measurements understorey using sub plot measuring 0.5 x 0.5 m by cutting down all the plants (shrubs, grasses, herbs) contained in sub-plots.

Measurements necromass woody done on plots measuring 10 x 50 m by measuring the diameter and length/height all necromass woody stand or fall with a diameter above 5 cm and a minimum length of 50 cm. Necromass litter is taken in the sub-plots measuring 0.5 m x 0.5 m by taking the entire litter on a sub plot. For fine litter (parts of plants that are biodegradable and roots) located at ground level contained in sub-plots do sieved with 2 mm pore holes.

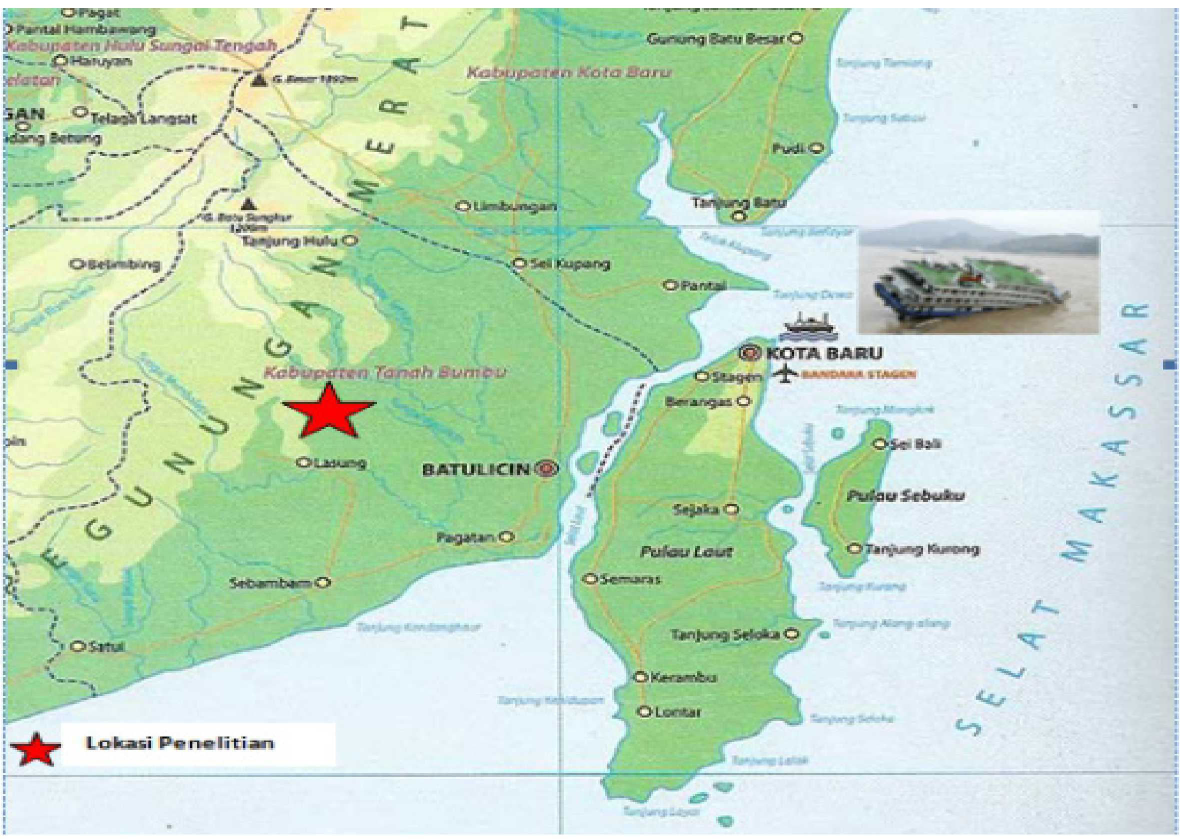


**Figure 1.** Location Map

Measurement of soil organic matter in soil samples using the sample ring at the same point sample plots with soil sampling at a depth of 0-10 cm, 10-20 cm and 20-30 cm in each planting age. Wood specific gravity measurement is done by cutting the stem of the plant and put into oven to get dry at a temperature of 105°C for 48 hours (Nugroho, 2015). The oven for example litter and undergrowth to create a sample of 100 grams then in an oven at 105°C for 24 hours and converted on the weight of sub-plots. The study was conducted at the Tanah Bumbu District, South Kalimantan Province of Indonesia. Location of the study can be seen in the map above.

# 3. Empirical Result

### 1. Data Analysis

Calculation of tree biomass using allometric developed by Hairiah and Rahayu (2007) is as follows:

$$(AGB)\ est = 0.0509 \times \dot{\rho}\ D^2H$$

Information:

(AGB) est = Tree biomass topsoil, Kg / tree;
D = Rod diameter, centimeter
H = total height of plants, meters
$\dot{\rho}$ = BJ wood, g $cm^{-3}$

Calculation of the dry weight of woody branching necromass using a formula allometric like a tree of life, while for the tree unbranched calculated based on the volume of the cylinder as follows:

$$BK\ (kg\ /\ Necromass) = \pi\dot{\rho}\ H\ D2\ /\ 40\ (\mu = phi = 3.14)$$

Information:

D = Necromass diameter
H = Length / High necromass (m)
$\dot{\rho}$ = BJ wood, g $cm^{-3}$

The calculation of the amount of C stored per land in organic materials do conversions by 46%, therefore the estimated amount of C stored per component can be calculated by multiplying the total weight of the mass with a concentration C as follows:

Total storage C = (BK + BK Biomass Necromass) x 0.46

### 2. Discussion of Research Results

**a. Biomass and Carbon Stock in Plants**

Land reclamation to restore the lands disturbed by coal mining activity performed as an obligation in order to function effectively as a store of land carbon stocks to absorb $CO_2$ from the air and store it in the form of carbohydrates. The biomass plant biomass include trees, undergrowth and necromass. The success of reclamation plants one of which is characterized by the large amount of carbon stocks in tree biomass. The amount of carbon stocks in tree biomass is directly proportional to the growth and development of trees (Hairiah and Rahayu, 2007). Tree biomass is strongly influenced by the value of the density of the wood. Value density of wood is very influential in the calculation of estimated dry weight biomass of trees (Nugroho, 2006). The higher the value of the density of the wood, the greater the value of tree biomass dry weight and the higher the value of the carbon stored in trees (Nugroho, 2006; Hanafi, 2008; Soares, 2009). The results of measurements of biomass and carbon stocks at the plant level are presented in Table 1.

Based on the results analysis size of tree biomass and carbon stocks in each year of planting as shown in Table 1 indicate that the biomass and carbon stocks for mature trees over 5 cm in diameter will be increased according to age reclamation plant. The carbon stocks in plants reclamation plant age 6 years, the tree biomass of 57.81 tons/ha (carbon stock of 26.59 tons/ha) and plant age of 5 years with tree biomass of 51.83 tons/ha (carbon stocks amounted to 23.84 tons/ha). A decline is very high at the young age of the plant more crops such as age 1 to 4 years with a maximum biomass of 13.01 tons/ha (5.98 ton of carbon stocks/ha). This shows that the reclamation plant growth 1-4 years of age is still under establishment, so that the establishment of this stage is not optimal growth and development. According Hairiah and Rahayu (2007) carbon stocks largely determined by the species composition, structure and age of the plant.

**Table 1.** The amount of Biomass and Carbon Stock of Plant Level in Each Age of Reclamation Plant

| Age of Trees | Trees Biomass (ton/ha) | Understorey Biomass (ton/ha) | Necromass biomass (wood and litter) (ton/ha) | Total Plant Biomass (ton/ha) | Total carbon stocks at Trees Level = 0,46 (ton/ha) |
|---|---|---|---|---|---|
| 1 | 0 | 7,41 | 2,27 | 9,68 a | 4,45 a |
| 2 | 6,65 | 4,35 | 4,08 | 15,03 a | 6,92 a |
| 3 | 8,77 | 4,58 | 4,27 | 17,71 a | 8,15 a |
| 4 | 13,01 | 2,83 | 4,30 | 20,23 a | 9,30 a |
| 5 | 51,83 | 2,80 | 6,06 | 60,95 b | 28,04 b |
| 6 | 57,81 | 2,49 | 8,43 | 68,73 b | 31,61 b |
| Note:<br>LSD = Least significant different; SD= Standar deviasi; (alpha = 0,05) | | | | Lsd: 15,12<br>Mean:32,06<br>SD: 7,39 | Lsd: 6,99<br>Mean:14,75<br>SD: 3,40 |

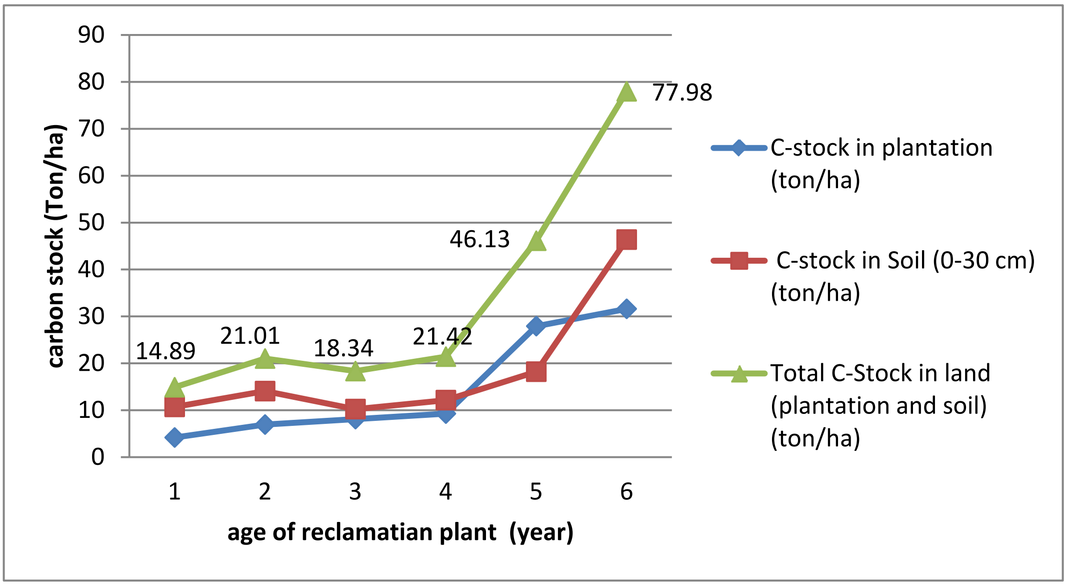


**Figure 2.** Carbon Stocks in Land Reclamation

According Hairiah, et al (2001) suggest that the growth and development of plants as well as high wood density, will give tree biomass is higher than the land that has species with plant growth and development and a low wood density. The amount of carbon stocks in tree biomass is directly proportional to the growth and development of plants (Soares, 2009; Hanafi, 2008; Hairiah and Rahayu, 2007). Tree as part of the carbon stocks in aboveground greatest contribution as "Sink" the carbon on the mainland when compared with other components such as plant vegetation below, necromass and litter (Hairiah, et al., 2001).

Lower carbon stocks in plants decreased with increasing age of the plant. Carbon stocks are the lowest undergrowth at the age of 6 years with Biomass plant understorey of 2.27 tons/ha (carbon reserves of 1.04 tons/ha). The highest carbon stocks at 1 year of age reclamation plant with biomass in understorey at 8.43 tons/ha (carbon reserves by 3.14 tons/ha). Age aging reclamation plant will reduce the intensity of light to the surface of the soil as a result of the reclamation plant canopy grows denser (Daniel and Baker, 1992). The light intensity is low to the ground surface would lead to plant growth under pressure, it is because of lower plants tend to require high light intensity. Carbon stocks stored in understorey in each year of planting dominated by reed (Imperatacilindrica), Kirinyuh (Eupatorium Odorata) and the type of LCC (legume cover crop) as Centrosemapubescens (CP), Puerariajavanica (PJ), Calopoginiummucunoides (CM) and the fragrant root (Vetiverzizanioides).

Based on examination of Table 1 shows that the biomass and carbon stocks stored in the highest necromass oldest plant age is the age of 6 years. Necromass content of biomass (woody or on necromass litter) at the age of 6 years amounted to 8.43 tons/ha (carbon reserves by 3.88 tons/ha). The amount of biomass and carbon stocks in this necromass tends to decrease at the young age of the plants, ie at the age of 1 year plants that only produce biomass of 2.27 tons/ha (carbon reserves of 1.04 tons/ha). The amount of biomass and carbon stocks in woody and necromass litter will increase with increasing age of the plant. Increasing age of the plant will affect the amount of plant growth and development that influences the plant canopy, the greater crop canopy, the production of litter generated will be even greater. Increased litter is also caused by decomposition obstacles litter the floor area of the reclamation plant as a result of some species such as acacia has leaves that contain substances that are difficult to decompose litter properly (Baker and Daniel 1979). The lower the quality of the material, the longer the material decays, resulting in the accumulation of litter that is thick on the surface of the forest land (Nugroho, 2011; Suprayogo et al., 2003).

Total reserves of carbon in plants include carbon stocks in trees, understorey and necromass. Total carbon stocks highest level of vegetation reclamation plant age 5-6 years with a total biomass of plants between 60,95 ton/ha-68,73 ton/ha yield carbon stock of 28,04 ton/ha - 31,61ton/ha. Total carbon stocks plant level at a young age (1-4 years old) is still low with the total biomass of plants between 9,68 ton/ha - 20,23 ton/ha yield carbon stock of 4,45 ton/ha - 9,30 ton/ha. Increasing age reclamation plant will increase the uptake of carbon in the air that is stored in plant parts in the form of carbohydrates (Hariah, et al., 2001; Hairiah and Rahayu, 2007).

**b. Stored Carbon in Soil Organic Matter**

The carbon stored in the soil is an indicator of soil fertility. Carbon is a major component of organic materials. The high carbon in the soil would affect soil properties become better, whether physical, chemical or biological. The organic material is part of the land which is a complex and dynamic system, which is sourced from the rest of the plant or animal contained in the soil which continually change shape, because it is influenced by biology, physics, and chemistry. Effect of organic matter to the soil depends on the decomposition process. In general, the factors that affect the decomposition process factors include organic material that is chemical composition, C/N ratio, lignin and the size of the material, while the soil factors include temperature, humidity, texture, structure and oxygen supply, as well as soil reaction, nutrient availability, especially N, P, K and S (Hanafi, 2005).

Soil organic matter in coal mine reclamation area comes from the existing vegetation on the surface soil of lower plants, shrubs, to tree. The high soil organic matter showed a positive development towards the restoration of vegetation on the surface of the land reclamation area. The results of measurements of soil organic carbon content in the area of reclamation plants are shown in Table 2.

**Table 2.** Carbon Stored in Soil at a depth of 0-30 cm in the area of Reclamation Plant

| No | Age of Reclamation Plant (Year) | Soil Carbon In Soil Layer 0-30 cm (tonnes/ha) |
|---|---|---|
| 1 | 1 | 10,71 |
| 2 | 2 | 14,07 |
| 3 | 3 | 10,24 |
| 4 | 4 | 12,15 |
| 5 | 5 | 18,21 |
| 6 | 6 | 46,37 |

The above table shows that the content of soil carbon reserves in the reclamation area, the highest in the plant age of 6 years, with a carbon content in the soil at a depth of 0-30 cm reached 46.37 tons/ha, and carbon organic content in the soil tends to decrease with age plants getting younger. The value of the carbon content in the soil tend to be proportional to the production necromass litter, at the age of 6 years necromass plant litter tends to be high and decreases with the age of the plants are getting younger. The carbon content in the soil is influenced by litter biomass production by plants, decomposition of litter will increase the amount of carbon in the soil. The speed of litter decomposition by microorganisms will influence the enhancement of carbon stocks in the soil (Hanafi, 2008). Wet tropical areas with high rainfall and high temperatures will increase the speed of litter decomposition in the soil, it is due to litter decomposition process is influenced by several factors, one of which is the temperature and humidity (Nugroho, 2015). The population of trees found in plants reclamation age of 6 years are likely meeting with the rapid growth causing higher canopy density, canopy density will create a microclimate under stands that support the activity of microorganisms decomposers in tanh will increase.

**c. Carbon Stored in Land Reclamation**

Estimated total carbon stocks on a land use system is the sum of carbon stocks in the top of the soil and in the soil. Carbon stock above ground is measured from the sum of the carbon stocks stored in the biomass of trees, undergrowth and necromass. Estimated total carbon stocks on land reclamation is shown in Figure 2.

The results of measurements of total carbon stocks both of plants and carbon below the ground surface shows that the reclaimed land with plant age 6 years has the largest carbon stocks at the landscape level (above the ground and below the ground surface to a depth of 0 - 30 cm) that is equal 77.98 tons/ha and decreases with a decrease in the age of the plant. Carbon stocks at the age of 1 year plant carbon stocks on land the smallest level of 14.89 tons/ha. Reclamation plant at the age of 6 years occurred in both the carbon cycle with $CO_2$ capture by plants from the air and stored in the form of carbohydrates soil around the plant and subsequently released by the trees through necromass (both wood and leaf litter) to be degraded and become an addition to the carbon element in the soil.

## 4. Conclusions

Carbon stocks stored on reclaimed land will increase with age reclamation plant, carbon stocks are increasing rapidly at the age of reclamation plants 5 to 6 years which is the indicator of the recovery of land carbon stocks disturbed land due to coal mining. Reclamation plant age 1-4 years of carbon stock is low because the plants are still experiencing a period establishment.

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