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# Organic carbon stock and their dynamics in rehabilitation ecosystem areas of post open coal mining at tropical region

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**Abstract**

Exploitation of open coal mining in tropical forest ecosystem is drastically leading to land degradation and damages. Rehabilitation of extremely degraded areas through re-vegetation by fast growing species is expected to speedily recover their dynamic of organic-carbon stocks.The purposes of the study were to compare carbon stock in the aboveground biomass, understorey, litters, and soil organic under land use changes areas of open coal mining areas. The study was conducted in the coal mine concession area of PT. Berau Coal, at Site Binungan in Berau, East Kalimantan, Indonesia from September 2013 to October 2014. Data were collected from 10 plots representing ecosystem dynamics of coal mining land, consisting of: secondary forest, degraded forest; non-active mining pits; backfilling post-mining; re-vegetation forest by 2 years-old Johar (*Senna siamea)* stand*;* 1, 3 and 7 years-old Sengon (*Paraserianthes falcataria);* mixed forest 7 years-old Sengon (*Paraserianthes falcataria) and* 3 years-old meranti (*Shorea sp.)*, and mixed forest of 9 years-old mangium (*Acacia mangium)* and 2.6 years-old *Shorea sp.* Allometric method was used to calculate the aboveground biomass and their carbon stocks. Destructive method was used to obtain the biomass of understorey, litters, and soil organic carbon. The re-vegetation programs with fast growing species after 9 year rehabilitation at post-open-mining land in tropical areas were able to restore aboveground biomass at two-thirds of previous secondary forest ecosystem. Understorey biomass in the 1-9 years-old of fast growing species were ranges at 0.19-0.95 Mg C.$ha^{-1}$. Carbon stocks in the litter of 7-years-old sengon re-vegetation area were higher than that of natural forest, because of their supply from litterfall and understorey. Soil organic carbon in re-vegetation areas of 9-years-old *Acacia mangium* stand was 23.2 Mg.$ha^{-1}$, almost equal to the value at the former secondary forest (28.5 Mg.$ha^{-1}$), whereas its value during land clearing just only 4.3 Mg.$ha^{-1}$. Environmental restoration in open coal mining areas through re-vegetation by fast growing plantation will restore their biomass and carbon stocks, nearly similar to their former secondary forest conditions.

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*Keywords:* carbon stocks; ecosystem changes; land rehabilitation; open mining; tropical region

## 1. Introduction

Coal mines become one of anthropogenic disturbance on tropical forest ecosystem drastically leading to land damage and degradation. It is the impact of coal exploitation process using surface mining method by dismantling the vegetation, soil and rock. These activities includes the change of landscape, the change and loss of the stands structure, the increase of green house gases, the decrease in soil productivity due to changes in the nature and condition of the physical, chemical and biological properties of soil such as the decrease of soil pH and the increase of soil solubility of heavy metals [1] [2] [3]. Environmental damage may be worse as post-mining land left opened without any restoration and rehabilitation efforts.

Exploration C-coal mining in tropical region increases (1,336 million ha) and gives impact on world environmental damage due to the emission of $CO_2$ and extensive of buried heavy metal. Coal mining especially opencast coal mining requires vast land to explore or to exploit. This exploitation causes environmental problems including soil erosion, pollution of dust, noise and

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water, and negative impact on biodiversity. Remedial action in mining purification aims to reduce these impacts. Good planning of environmental management will reduce the impact of mining on the environment and help preserve the biodiversity [4].

According to [5], stock of coal in Indonesia is decreasing gradually due to high exploitation especially by foreign investor, and the increase of its industries. According to Indonesia Ministry of Energy and Mineral Resources, in 2005 [6], East Borneo had the biggest coal production in Indonesia (57,693,479.71 ton in 2003 and 68,396,462.38 ton in 2004). The increase of mining activity means the increases of environmental issues. Those activities have impact on environmental quality and give serious consequences not only for local area but also global area. The most widespread impact is on degradation of land quality, land instability, water contamination, air pollution, and even climate change. Land was disturbed, topography was changed, and hydro-geological conditions were affected adversely [7]. This land degradation is more increasing due to lack of research, bad handling, and failure of disturbed land rehabilitation in Borneo especially in post mining areas.

Giant holes created by opencast mining are likely difficult to be closed by back filling and have resulted in pools of water with very high acid content. The acid water in post mining pool consists of hazardous chemical elements such as Fe, Mn, $SO_4$, Hg and Pb. Fe and Mn, which are toxic and inhibit plant growth. Sulphate acid ($SO_4$) is an acidic substance having an effect on soil pH and soil fertility. Meanwhile, Hg and Pb are heavy metals that cause skin disease in humans. Besides acid pools of water, waste generated from the tailing process also pollutes soil and kills various plants [8].

Mining causes a change in the balance of the natural carbon cycle as it accelerates the dismantle of carbon sinks in to the atmosphere from fossil fuel and terrestrial biosphere reservoirs in the form of organic compounds in vegetation, aboveground and soil residual organic matter biomass [9] [10]. The considered issue of climate change and global warming related to coal mine is an attempt of reclamation/restoration of post-mining environment through rehabilitation and re-vegetation which are able to increase carbon stocks and reduce terrestrial ecosystem carbon emissions as pay off of carbon emissions from mining activities.

This study aimed to compare the carbon stocks of various terrestrial ecosystems in the coal mining area through the measurement of aboveground, understorey, litter, and soil organic carbon biomass.

## 2. Materials and Methods

The study was conducted from September 2013 – October 2014 in the coal mine concession of PT. Berau Coal Site Binungan in Sambaliung, Berau District, East Kalimantan ($102^0$ 35' 02'' – $102^0$ 37' 03'' east longitude and $03^0$ 53' 35'' – $03^0$ 55' 37'' north latitude). The precipitation analysis in Januari 2000 - Desember 2012 indicated Type B climate. The annual mean precipitation was 2,134 mm/year, with the highest was in 2010 at 3,725 mm/year and the lowest was in 2004 at level of 1,253 mm/year.

Data were collected from 10 plots representing the terrestrial ecosystem dynamics in the coal mine areas are: HD0 (secondary forest); HT0 (post-clearing forest); HT1(non-active post-mining forest); HT2 (backfilling post-mining forest); HJ2 (2-years-old johar re-vegetation forest); HS1(1-year-old sengon re-vegetation forest); HS3(3-years-old sengon re-vegetation forest); HS7 (7-years-old sengon re-vegetation forest); HS9 (9-years-old sengon and 2.8-year-old meranti re-vegetation forest); and HM9(9 years-old *Acacia mangium* and 2.6-years-old meranti re-vegetation forest). Each plot was established in each observed ecosystem purposively. The site is determine dafter the survey of observed ecosystem types throughout the mining concession therefore the plot can represent the condition of various ecosystems through the land use change management of coal mining activities.

The aboveground biomass of stand in each ecosystem derived from the census inventory of all vegetation level by using sample plot of 30 m x 30 m. In the natural forest ecosystems, the inventory used nesting plot of woody vegetation of 2 m x 2 m for seedlings, 5 m x 5 m for saplings; 10 m x 10 m for pole, and 30 m x 30 m for tree level [11]. Stand parameters collected include total tree species (both living and dead), diameter at breath height (DBH) and canopy height. Inventory of stand sample plots in each ecosystem was conducted with 3 replications.

Measurement of understorey biomass was conducted by destructive method with sample plot establishment of 50 cm x 50 cm quadrant of 5 replicates in a systematic sampling within each unit plot. In the understorey plot, litter biomass on surface soil was measured at a circle of 31.4 cm in diameter by 5 replicates. Soil samples of 0-10 cm depth were taken in a replicate using a ring sample on the middle of the plot unit of each observed ecosystem.

Aboveground biomass (AGB) was calculated using allometric method by the equation presented in Table 1. As the tree and stand biomass are figured out, carbon stocks and stand carbon dioxide are measured by the equation as follows [12]:

$$C_{bba} = \Sigma\ (B_p x\ \%\ C\ organic) \quad \ldots\ (1)$$

$$CO_2 = C_{bba}\ x\ Fk \quad \ldots\ (2)$$

whereas: $C_{bba}$ = i carbon content of stand aboveground biomass ($Mg.ha^{-1}$), $B_p$= total stand aboveground biomass ($Mg.ha^{-1}$); %C organic = default value of organic matter carbon content of 47 %; $CO_2$ = stand carbon dioxide; FK = conversion factor of carbon element in carbon dioxide of 3.67.

The understorey biomass was derived from dried sample in the temperature of $70^o$ C until it reached its constant weight. Furthermore, carbon stocks and carbon dioxide were calculated by the equation as follows [12]:

$$B_{tb} = (bk\ tb/1000)\ x\ (1/total\ sampling\ area)\ x\ 10 \quad \ldots\ (3)$$

$$C_{btb} = \Sigma\ (B_{tb}\ x\ \%\ C\ organic) \quad \ldots\ (4)$$

$$CO_{2\ tb} = C_{btb}\ x\ Fk \quad \ldots\ (5)$$