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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]:

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

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

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]:

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

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

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

whereas: B_{tb}= total under storey biomass in each ecosystem ($Mg.ha^{-1}$); C_{tb}= estimation of understorey carbon in each ecosystem ($Mg.ha^{-1}$); **Σ** = mean of 5 repetitions; $CO_{2\ tb}$ = understorey carbon dioxide; bk $_{tb}$= understorey dry weight (gr); 1000 = conversion value of gr to kg; total sampling area = 0,25 m^2; 10 = conversion value of $kg.m^{-2}$to $Mg.ha^{-1}$; % C organic = default value of organic matter carbon content of 47 %; Fk= conversion factor of carbon element on carbon dioxide of 3.67.

Litter biomasa is drawn from dried litter 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]:

$$B_s = (bk_s/1000) \times (1/\text{total sampling area}) \times 10 \quad \ldots\ldots (6)$$

$$C_s = \Sigma (B_s \times \%\ C\ organic) \quad \ldots\ldots (7)$$

$$CO_{2\ s} = C_{bs} \times Fk \quad \ldots\ldots (8)$$

whereas : B_s = total litter biomass in each ecosystem ($Mg.ha^{-1}$); C_s = litter biomass carbon in each ecosystem ($Mg.ha^{-1}$); **Σ** = mean of 5 repetitions; $CO_{2\ s}$ = litter carbon dioxide; bk_s = litter dry weight (gr); 1000 = conversion value of gr to kg; total sampling area = 0,7739 m^2; 10 = conversion value of $kg.m^{-2}$ to $Mg.ha^{-1}$; % C organic = default value of organic matter carbon content of 47 %; Fk = conversion factor of carbon element on carbon dioxide of 3.67.

Soil organic carbon content is calculated by the equation as follows [12]:

$$C_t = K_d \times Bd \times \%\ C\ organic \quad \ldots\ldots (9)$$

$$C_{t\ ha} = Ct \times 100 \quad \ldots\ldots (10)$$

whereas: CO_t = soil organic carbon content (in $g.cm^{-2}$); K_d = sample soil depth (in cm); Bd= bulk density(in $g.cm^{-3}$); % C organic = percentage of carbon as laboratory analysis result. It shows carbon weight (g) per 100 g soil; $C_{t\ ha}$= soil organic carbon content per ha (in $Mg.ha^{-1}$); 100 = conversion factor of $g.cm^{-2}$ to ton. ha^{-1}.

The measurement of total carbon stocks in each observed ecosystem (plot) is calculated by the equation as follows [11]:

$$C_{plot} = C_{bba} + C_{btb} + C_{bs} + C_t \quad \ldots\ldots (11)$$

whereas: C_{plot} = total carbon stocks (Mg. ha^{-1}); C_{bba} = carbon estimation of aboveground biomass ($Mg.ha^{-1}$); C_{btb} = carbon estimation of understorey biomass (Mg. ha^{-1}); C_{bs} = carbon estimation of litter biomass (Mg.ha-1); C_t = soil carbon estimation (Mg. ha^{-1}).

Results of the observation presented in descriptive quantitative. Analysis of the data used the software of Microsoft Office Excel 2007 with data tabulation and calculation in the form of tables, graphs, lines and correlations.

Table 1. Allometric model for aboveground biomass measurement of various stands in Coal Open-Mining area.

Tree	Allometric Model	Description and Reference
Branched tree	$B_{BA} = 0,11*\rho*d^{2.62}$	Ketteringset *al*., 2001
Non-branched tree	$B_{BA} = \mu*\rho*t*d^2/40$	Hairiahet *al*, 1999 in Hairiah and Rahayu (2007)
Shorea spp.	lnB_{BA}= 2,193+2,371 ln(d)	Basukiet *al*. (2009).
Shorea leprosula	$B_{total} = 0,067*d^{2,859}$	Hardjana (2011)
Shorea leprosula	$B_{BA}=0,032*d^{2,7808}$(R^2=0,98)	Heriansyahet *al*. (2009) in Krisnawatiet *al*. (2012)
Hopea	lnB_{BA}= 1,813+2,339 ln(d)(R^2=0,98)	Basukiet *al*. (2009).
Mixed dipterocarpaceae natural forest	lnB_{BA}= 1,201+2,196 ln (d)(R^2=0,96)	Basukiet *al*. (2009).
	lnB_{BA}= 0.744+2,188 ln(d)+0.832 ln (ρ) (R^2=0,97)	
Mixed dipterocarpaceae natural forest	$B_{BA}=0,19999*d^{2,14}$ (R^2=0,93)	Adinugroho (2009) in Krisnawatiet *al*. (2012)
Acacia mangium	$B_b = 0,4668*d^{1,8287}$ (R^2= 0,99) $B_r = 0,078*d^{2,0038}$ (R^2= 0,95) $B_d = 0,0648*d^{1,9348}$ (R^2= 0,95)	Ilyas (2013)
Cassia siamea	$B_b = 0,3699*d^{1,9374}$ (R^2= 0,99) $B_r = 0,1782*d^{1,7148}$ (R^2= 0,95) $B_d = 0,1651*d^{1,5272}$ (R^2= 0,95)	Ilyas (2011a)
Sengon	$B_b=0,3328\ d^{1,8549}$ (R^2=0,98) $B_r=0,4406\ d^{1,4344}$ (R^2=0,90) $Bd=0,4064\ d^{1,265}$ (R^2=0,95)	Ilyas (2011b)
Sengon	$B_{BA} = 0,1126\ d^{2,3445}$ (R^2=0,94)	Siringoringo and Siregar (2006) in Krisnawatiet *al* (2011a)
Sengon	log B_{BA} = -1,239 +2,561 logd(R^2=0,97)	Rusolono (2006) in Krisnawatiet *al. (*2012)

3. Result and Discussion

All tables should be numbered with Arabic numerals. Every table should have a caption. Headings should be placed above tables, left justified. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately. Below is an example which the authors may find useful.

3.1. Aboveground biomass and carbon stocks of forest stands

The aboveground biomass found in the secondary forest stand (HD0) was 157.6 Mg. ha^{-1}, consisted of 75.4 $Mg.ha^{-1}$ (48 %) tree biomass, 42.9 $Mg.ha^{-1}$(27 %) pole biomassa (dbh10 to < 20 cm) and 39.3 $Mg.ha^{-1}$ (25 %) stake biomass (dbh 2 cm to < 10 cm). Deforestation as the result of land clearing for coal mining in HT0, HT1 and HT2 ecosystems affects the loss of the entire stands as well as the loss of stand biomass (Figure 1). It leads to the loss of carbon stocks and carbon sequestration potential of the stands. Re-vegetation with fast growing species in post open coal mining after 7 years will have aboveground biomass about 80-100 $Mg.ha^{-1}$ (Figure 1).

[13] reported that the worldwide average of aboveground woody biomass in forests was 109 $Mg.ha^{-1}$. Aboveground biomass production at the end of the rotation (6 year-old plantations) differed significantly among the site classes. Biomass on the good, moderate and poor sites was 120 $\pm$ 12 $Mgha^{-1}$, 90 $\pm$ 17 $Mg.ha^{-1}$, and 40 $\pm$ 20 $Mg.ha^{-1}$, respectively [14]. [15] reported the aboveground biomass of the yemane in Sarawak to be 85 $Mg.ha^{-1}$, which is similar to productivity in this field. [16] reported total aboveground biomass for roughly 6-year-old yemane to be 60 to 122 $Mg.ha^{-1}$ in Brazil and 63 to 137 $Mg.ha^{-1}$ in Nigeria. These tendencies implied that production can be increased by choosing suitable sites. In general, better soil and site class would produce more biomass and minimize the risks that may cause land degradation.

The productivity of fast growing species in post open coal mining at tropical region after 7 year-old was comparable to average worldwide biomass and 6 year-old *Eucalypt* plantations in tropical regions of Congo (96 $Mg.ha^{-1}$) [17]. Nevertheless, the productivity of yemane seemed relatively low compared to those in *Acacia mangium* (146 to 190 $Mg.ha^{-1}$ at 9 years) in South Sumatra [18] or *Eucalyptus grandis* (124 $Mg.ha^{-1}$ at 7 years) in South Africa [19]. On the other hand, the productivity of this study was greater compared to short rotation plantations (5 year-old) of balsam poplars (*P. trichocarpa*), aspen (*P. tremula x tremuloides*) and willow (*S. viminalis*) in Central and Northern Europe which ranges from 10 to 37 $Mg.ha^{-1}$ at first rotation [20]. Although the soil properties of post open coal mining area at tropical regions is poorer than in other tropical or temperate regions, biomass productivity in post open mining is higher than in temperate regions, possibly due to the higher temperature, rainfall, humidity, soil microorganisms and growth periods in tropical regions over the years.

Stand biomass and carbon stocks tend to increase along with the process of growth and the aging of the trees. However, it is not necessarily linier as it is influenced by the stand density factor. Plot HS9 with older stands than HS7, turns out to produce lower biomass and carbon stocks due to the numbers of stand in each plot. HS9 is composed of 17 sengon and 1 dead-sengon while HS7 is composed of 39 sengon and 11 dead-sengon. Meanwhile, the average dbh of constituent tree is almost similar, so that the basal area of HS9 is higher than HS7. Smaller number of stands in HS9 than in HS7 is caused by the number of dead trees.

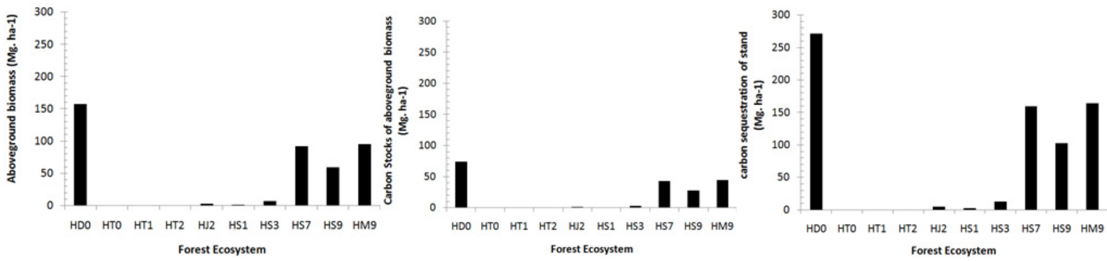

Fig. 1. Quantification of Aboveground biomass (BBA), carbon stocks of aboveground biomass (CBBA) and carbon sequestration of stand (CO2BBA) in various ecosystems in coal mine concession area.

Stand biomasa of 157.6 $Mg.ha^{-1}$ in secondary forest is similar to carbon stocks of 74.1 Mg.ha-^{1} or CO_2 sequestration of 271.8 Mg.ha-^{1} in HD0 may lose due to the process of land conversion for coal mining. Recovery capability of carbon stocks on the degraded land will gradually be restored as there vegetation occurs. However, recovery cannot occur as quickly as the damage, it needs more than a decade for a new forest to be completely recovered. It can be proven by comparing the biomass and carbon sequestration value of the 9-year-old re-vegetation (HS9 and HM9) which was only 30-50 $Mg.ha^{-1}$, and have not been able to produce biomass as HD0 (Figure 1).

Carbon stocks in aboveground biomass of fast growing species in the rehabilitation area of open coal mining area were almost similar with the carbon content in aboveground biomass of 6 year-old of G*melina arborea* at moderate site that was 46 $Mg.ha^{-1}$ of C [21]. The carbon content in aboveground biomass of 3 year-old of yemane plantation forest at good site was 27 $Mg.ha^{-1}$ of C that has higher nutrient content compared to those of in moderate site. Timber harvesting in the end of the rotation would also harvest about 60% of nutrient content in the hardwood biomass, so the same amount of nutrient harvesting must be added for sustainable nutrient & forest management in the next generations [14].

Yemane that planted at moderate site in the tropical region could absorb carbon at the level of 10.5-13 $Mg.ha^{-1}$ yr^{-1} of C that equivalent to 38.5 - 47.7 $Mg.ha^{-1}$ yr^{-1} of CO_2 from atmosphere [21]. The ability of yemane to absorb CO_2 will increase 25-50% at a good site but all of them will be lost again through the litter fall (38%) and harvesting (62%). [22] reported that yemane could absorb 76 $Mg.ha^{-1}$ of C that equivalent to 279 $Mg.ha^{-1}$ of CO_2 from atmosphere during the first rotation. [21] stated that gross primary production (GPP) also includes plant respiration, which accounted for 67 - 87% of GPP in the three available tropical forest. So, the gross carbon absorption in yemane was about 228-509 $Mg.ha^{-1}$ of C that equivalent to 836 - 1866 $Mg.ha^{-1}$ of CO_2 from atmosphere during the first rotation.

3.2. Understorey biomass and carbon stocks

Understorey on the early re-vegetation forest floor (1-2 year-old), especially in plot HS1 was dominated by LCC (legume cover crops) cultivated during the rehabilitation program. Variety of plant species increased after 2 years as shown in plot HJ2 in which grasses were also found out in the plot. Understorey species diversity increased as shown in the plot HS3 in which there were weeds and young shrubs besides of LCC.

Forest floor covered by understorey reached a climax in the plot HS7. Increased species diversity was dominated by various types of grasses and ferns of Nephrolepis biserrata/Nephrolepis cordifolia. Moreover, the understorey density on the forest floor began to decline in old re-vegetation stands (HS9 and HM9). Plot HS9 was dominated by grasses while plot HM9 was dominated by shrubs. The decline in old re-vegetation forest as in plot HS9 and HM9 was caused by environmental and human disturbance factors. Human disturbance is related to the pathways activity for enrichment planting as the stand was 6 years old.

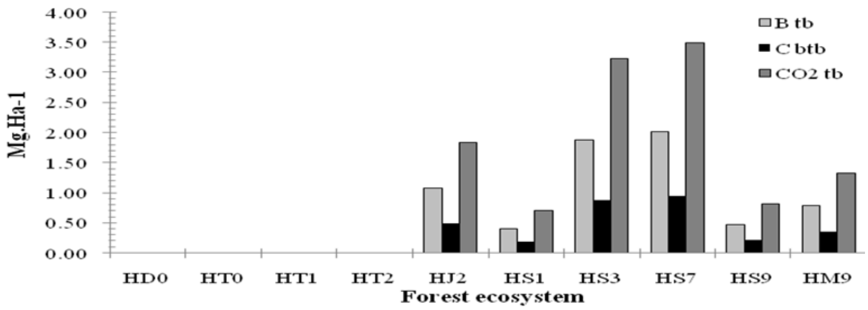

Fig. 2. Understorey biomass (Btb), understorey biomass carbon stocks (Cbtb plot) and understorey carbon sequestration (CO2 tb) in various ecosystems in coal mine concession area.

Figure 2. shows the understorey biomass (B_{tb}) of plot HD0, HT0, HT1 and HT2 is zero, due to the exploitation of open coal mining activities and their heavy acid toxic soil. There was an absence of any litter and understorey in plot HT0, HT1 and HT2 due to anthropogenic damage. In the early re-vegetation (HJ2 and HS1) biomass contributions were drawn from LCC which was intentionally planted.

Introductions of LCC in early re-vegetation undoubtedly important and profitable as the initial producer of biomass for soil organic matter supply after the coal mine that benefit the environment and the beginning of the cropping system in re-vegetation area. [23] states that the LCC as soil amelioration material of post-mining is very useful because it is useful as a source of biological N, there cycle leached nutrients, erosion protection, moisture regime and supply of soil organic matter. [24] reported that the aboveground biomass of LCC at 4 MAP were about 2.1 - 2.9 $Mg.ha^{-1}$, whereas the total biomass (aboveground plus below ground) was 3.8 - 4.7 $Mg.ha^{-1}$.

Understorey biomass (B_{tb}) in plot HS3 tends to increase compared to biomass in plot HJ2 and HS1 (Figure 2). Biomass contribution comes from LCC and other natural plants such as weeds (*Imperata cylindrica*), grasses and herbs. The development of cover and abundance of understorey species reaches the optimal in the age of 7-year-old (plot HS7) with biomass (B_{tb}) of 2.02 $Mg.ha^{-1}$. The density is declining in the age of 9-year-old (plot HS9 and HM9) as well as the value of B_{tb} compared with plot HS7 of 0.47 and 0.78 $Mg.ha^{-1}$.

The role of understorey carbon especially legume is not as high as tree carbon [23]. Hence, biomass production of understorey in each plot makes a benefit both for carbon stocks and carbon sequestration from the atmosphere.

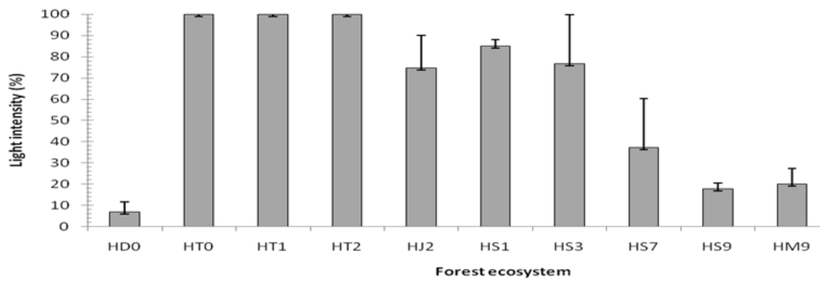

Fig. 3. Light intensity (%) on the forest floor in various ecosystems in coal mine concession area.

The variety of understorey biomass (B_{tb}) is caused by the influence of sunlight as an abiotic factor of understorey growth. The absence of understorey cover in the secondary forest (HD0) was due to the fact that this plot had the lowest light intensity among ecosystem(Figure 3). It is connected to the density of canopy and tree in a stand causing low sunlight penetration into forest floor, thus the photosynthetic capability of the understorey is disturbed and it affects the growth and survivals [25].

3.3. Litter biomass and carbon stocks in the forest floor

The soil litter thicknesses observed in 5 points spread systematically in each plot vary widely both within and between ecosystems in the coal mining area. Based on Figure 4. it can be seen that there are three plots namely HT0, HT1 and HT2 without any litter. The absence of litter on the plot HT0, HT1and HT2 was due to the ecosystems disturbance without ground cover. Post-mining re-vegetation indicates the effort of environmental restoration which is shown by the presence of litter. Figure 4. shows plot HS7 has the highest litter thickness (2 cm) compare to plot HD0 and other re-vegetation areas, or even secondary forest (1 cm).

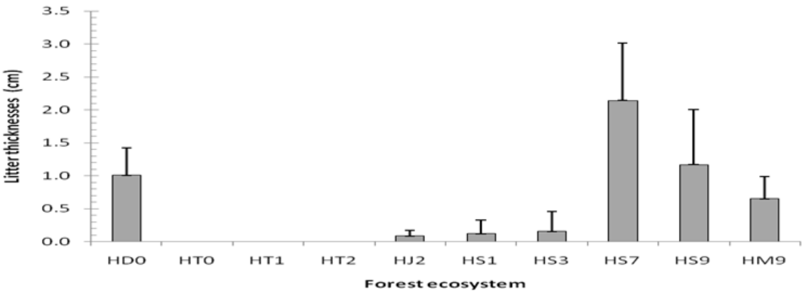

Fig. 4. Litter thicknesses on the forest floor in various ecosystems in coal mining area.

The value of litter thickness (Figure 4) has the same trend as the value of litter biomass and carbon content (Figure 5). It means the litter thickness on the forest floor affects the biomass amount. Meanwhile, the dynamic of litter thickness, biomass and carbon is the contribution of stand and understorey covers. Even understorey has significant positive contribution on the quantity of litter biomass and carbon on the forest floor as shown in plot HS7.

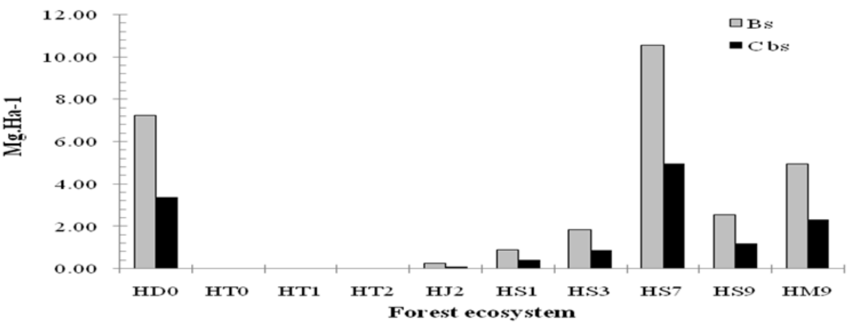

Fig. 5. Litter biomass (Bs) and litter carbon (Cbs) in various ecosystems in coal mining area.

Litter thickness in the forest floor becomes an indicator of the amount of biomass accumulation. The thicker of the litter, the higher of litter biomass on the forest floor (Figure 6).

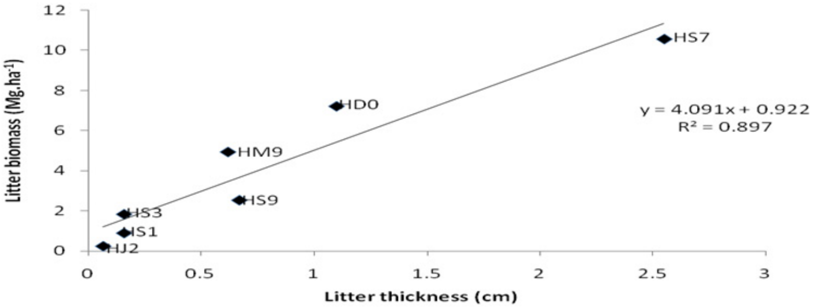

Fig. 6. The relation of litter biomass (Bs) and litter thickness of various ecosystems in coal mining area.

Litter as organic material residual from vegetation in the form of foliage, twigs, and branches play a role in the provision of soil organic matter [26]. There is a close relationship between the litter biomass and soil organic matter and soil C-organic (Figure 7). Litter is also an essential indicator for the health of the forest and became one of the distinguishing characteristics of a forest ecosystem with one another [27]. It is an evident that the land clearing for the coal mining as in plot HT0, HT1 and HT2 result in the loss of forest floor litter which change and damage the environment.

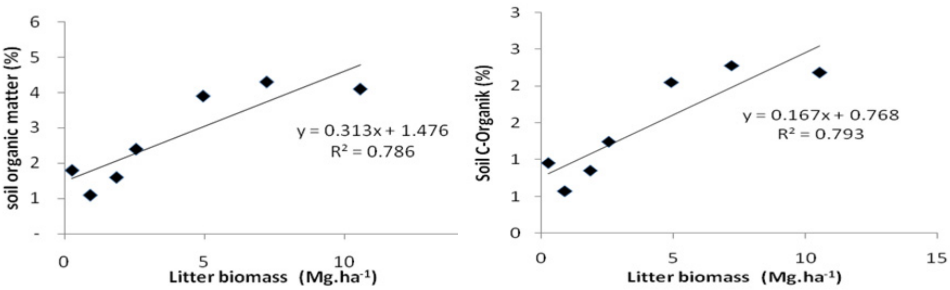

Fig. 7. The relation of: (a) Litter biomass and soil organic matter; (b) Litter biomass and C-organik of various ecosystems in coal mining area.

3.4. Soil organic carbon in the forest

The study on coal mining area shows soil organic carbon stocks tends to decrease as the forest is disturbed (Figure 8). Soil organic carbon decreases as the natural forest (HD0) is opened, previous carbon was 28.5 $Mg.ha^{-1}$ reduced to 4.3 $Mg.ha^{-1}$ in post open coal mining area (HT0). This drastically decline is caused by the removal of vegetation cover and topsoil in the process of landclearing. Soil organic carbon stocks are gradually increased during the first decade of post-mining activities conducted through re-vegetation of pioneer plants. The increase tendency of soil organic carbon stocks is in line with the carbon supply of vegetation biomass residual influenced by the phase of stand age, species and understorey biodiversity.

Soil organic carbon of various ecosystems, soil types and depths in Indonesia ranges on 5.7 – 6.394 $Mg.ha^{-1}$ [28]. The highest soil organic carbon is found in organosol in Riau of 6394 $Mg.ha^{-1}$ with the soil depth of 362 cm [28]. [28] states the estimation of soil organic carbon stocks of various forest with mineral soil type based on reports of; [29] studied soil organic carbon in *Shorea javanica* forest in Krui - West Lampung of 30.32 in the soil depth of 0-10 cm; [30] [31] [32] [33] and [34] state that Dipterocarpaceae natural forest, deforested secondary forest, diverse species forest have soil organic carbon stocks of 28.8 – 174.4 $Mg.ha^{-1}$ in the soil depth of 0-20 cm.

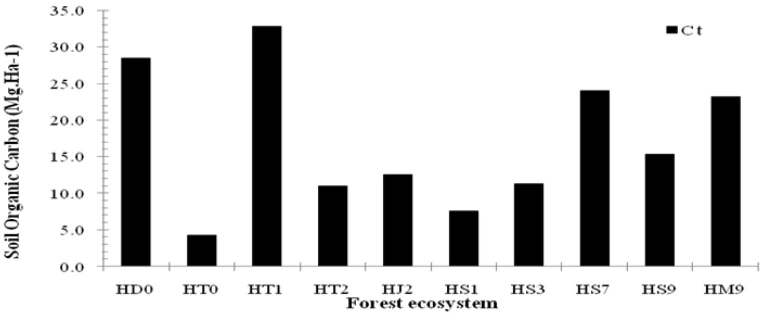

Fig. 8. Soil Organic Carbon (COt) on the depth of 0-10 cm of various ecosystems in coal mining area.

The high soil organic carbon in plot HT1which even exceed the base line (HD0) is an anomaly of the land change and degradation. The percentage of C- organic plot HT1 as the results of laboratory analysis showed a fairly high rate. It is an indication of the carbon content of the fossil fuel pool in the form of a coal mining residual instead of the value of organic carbon in the topsoil.

4. Conclusion

The re-vegetation program after 9 years for rehabilitation on post-open-mining land in tropical areas were able to restore aboveground biomass at two-thirds of the previous secondary forest ecosystem. Understorey biomass in the 1-9 year-old of re-vegetation forest by fast growing species were ranges at 0.19-0.95 Mg of $C.ha^{-1}$. Carbon stocks in the litter of 7-year-old sengon re-vegetation area were higher than that of natural forest, because of their supply from understorey. Soil organic carbon in re-vegetation areas of 9-year-old *Acacia mangium* stand was 23.2 $Mg.ha^{-1}$, almost equal to the value at the former secondary forest (28.5 $Mg.ha^{-1}$), although its value during land clearing just only 4.3 $Mg.ha^{-1}$. To restore the forest role in the post-mining are associated with accelerated effort on carbon sequestration and storage, an enrichment planting with the types of secondary plant succession should be conducted soon on the 5-year-old pioneer plants

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