Effect of Reduced Impact Timber Harvesting on Carbon Mass in Tropical Rain Forest, North Kalimantan, Indonesia

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Abstract: The improvement of forest management through reduced impact timber harvesting (RITH) techniques can be minimized forest degradation. The aimed of this research was found potency of carbon content and carbon mass in tropical rain forest after forests harvesting. Study site is located in license for utilization of timber forest products areas of PT Inhutani II, North Kalimantan. There were three research blocks as a follows : (a). Conventional timber harvesting blocks; (b) reduced impact timber harvesting blocks; and (3) virgin forests. The research showed that the carbon content on stems of tree was 253.31 kg or 71.14% of total tree carbon. Potency carbon mass in the conventional timber harvesting blocks was 99.16 Mg C ha^{-1}, in the reduced impact timber harvesting was 139.17 Mg C ha^{-1}, and in virgin forest was 159.44 Mg C ha^{-1}, respectively. This research indicated that carbon mass in the tropical rain forests caused after conventional timber harvesting blocks is lower when compared to the reduced impact timber harvesting blocks.

1 INTRODUCTION

One of emissions reduction scheme that is being developed is Reducing Emissions from Deforestation and Forest Degradation (REDD). Better forest management through the implementation of sustainable forest management in line with climate change mitigation efforts. One of them is the improvement of forest management and harvesting policies and technologies to improve existing forest capacity for carbon sequestration and storage. REDD + as a general concept that includes a variety of actions locally, nationally and globally to reduce emissions caused by deforestation and forest degradation, and enhance forest carbon stocks in developing countries (Angelsen et al., 2011). To minimize the impact of climate change, efforts are needed to stabilize the concentration of CO_2 in the atmosphere. In this protocol, afforestation and reforestation taken into account as a source of carbon sinks whose activities included within the framework of the CDM (Clean Development Mechanism).

Timber harvesting and silvicultural measures in natural forests, which until now carried out by holders result in damage to remaining trees, changes in the composition and structure of forest vegetation, residual stand, soil and land openness (Elias, 1999). Those changes resulted in the ability of the forest vegetation to absorb or release carbon in the atmosphere. The growth of tropical secondary forest vegetation responds quickly to changes in environmental conditions. Slashing and canopy treatments both have the potential to improve survival, height and biomass increment of under-planted dipterocarp seedlings (Rommel et al., 2008).

Reduced impact timber harvesting is being promoted as practices forestry that increase sustainability and lowers CO_2 emissions from logging, by reducing collateral damage associated with log transportation. Reduced impact timber harvesting is to minimize the impact of selective forest harvesting on biodiversity (Bicknell *et al.*, 2015). Muhdi *et al.* (2016) reported that logging activities contribute to changes in species diversity. Another research reported that reduced impact timber harvesting did not affect the biodiversity and species composition but also abundance of vertebrates (Laufer *et al*., 2015).

The effect of timber harvesting on biodiversity and structures and composition of the stand can not expect from a natural procession of succession, even

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though the area is included in a fixed and unharmed forest area of humans (Lopes *et al.*, 2012). If deforestation and forest degradation are not controlled it is feared wide impact including increased concentrations of greenhouse gases (GHGs) in the atmosphere that is causing an increase in the earth's temperature and climate change.

Some studies have showed that conventional timber harvesting (CTH) has a large negative impact on the residual stand (Elias, 1999; Purwoko *et al.*, 2018). The reduced impact timber harvesting (RITH) technique is an attempt to minimize damage, so that sustainable forest management can be achieved. On the basis of the description of the problems presented above, the question arises that need to be answered in this research is how big is the carbon stock reserve of tropical natural forest after harvesting the wood with RITH technique compared with CTH technique in tropical rain forest? The aimed of this research was found carbon content and potency of carbon mass in tropical rain forest after forest harvesting.

2 METHODS

2.1 Study Site

Study site is located in license for utilization of timber forest products areas of PT Inhutani II, North Kalimantan in November – Desember 2010. Analysis of carbon content was carried out in the Laboratory of Forest Products Chemistry, Faculty of Forestry, Bogor Agricultural University in January - April 2011.

There were three resech blocks as a follows : (a). Conventional timber harvesting blocks; (b) reduced impact timber harvesting blocks; and (3) virgin forests. Before logging, all trees 20 cm diameter at breast height (dbh) (stem diameter at 1.3 m or above buttresses) were identified with a common name, dbh was measured, and the trees were tagged.

2.2 Content of Volatile Matter

Procedures determination of volatile matter content using the American Society for Testing Materials (ASTM) D 5832-98. The procedure is as follows: (a). Samples of trees are cut into small parts of a matchstick; (b). Samples were then roasted at a temperature of 80 °C for 48 hours; (c). Dried sample is ground into a powder with a grinding machine (Willey mill); (d). Milled powder is filtered by filtering devices (mesh screen) size 40-60 mesh; (e). Powder with 40-60 mesh size of the test sample as much as ± 2 g; (f). Test sample is inserted into the electric furnace temperature of 950 °C for 2 minutes; (g). The difference in initial weight and final weight are expressed in percent of the dry weight of the specimen is a volatile matter content; and (h). Measurement percent volatile matter on samples from each part of the tree is performed three replications.

2.3 The Ash Content

The procedure of determining the ash content using the American Society for Testing Materials (ASTM) D 2866-94. The procedure is as follows: (a). The remainder of the test sample from the determination of volatile matter put into the electric furnace temperature of 900 °C for 6 hours; (b). Further cooled in eksikator and then weighed to find the weight eventually; (c). Final weight (ash) is expressed as a percent of the dry weight of the test sample furnace ash content of the sample; (d). Ash content measurement on samples from each part of the tree is performed three repetitions. Determination of the carbon content of the test sample of each part of the tree using the Indonesian National Standard (SNI) 06-3730-1995, wherein the carbon content of the sample is the result of a 100% reduction of the levels of volatile matter and ash content.

2.4 Carbon Mass of Forests Stands

Carbon trees in the blocks were determined using allometric equations tree carbon. The total number of carbon derived from necromass the trees in the block stated amount of carbon per unit area of the block. Total carbon potential above ground level consists of tree carbon, carbon and litter, and carbon understory.

2.5 Carbon Mass of Understory

Variables understory measured in the field is wet weight, whereas in the laboratory measured is moisture, volatile matter content, ash content and carbon content. Data taken from five plots measuring 2 m x 2 m. All vegetation of seedlings and understory in the plot 2 m x 2 m is taken and weighed to obtain wet weight.

2.6 Litter and Necromass

Plots were the same litter analysis with analysis of understory plots. All of the remains of dead parts of plants, leaves and twigs which fall contained in the plot, put in a paper bag and labeled. All litter is then dried in the sun and weighed and then taken sub-sample of litter as much as 100-300 g of dried in an oven at a temperature of 80 °C for 48 hours.

Measurement necromass (dead plant parts) on the surface of the soil. Necromass measurement is by measuring the diameter and length (height) all dead trees standing or fallen, the stumps of dead plants, branches and twigs.

3 RESULTS AND DISCUSSION

3.1 Volatile Substance Levels

The levels of volatile substances and ash content are part of the chemical properties of the tree. Results of laboratory analysis showed that the highest rate of volatile substance was in the leaves (72.35%). The average volatile content of each part of the sample tree based on the diameter class can be seen in Table 1.

Table 1: The average volatile substances in the part of tree sample based on diameter at breast height (DBH).

Diameter	Volatile content (%)		
(cm)	Stems	branch	leaves
5 – 10	46.31	53.87	72.74
10 – 20	50.55	57.47	71.73
20 – 30	48.62	56.89	72.43
30 – 40	48.33	56.47	69.35
40 – 50	49.78	59.58	73.12
50 - 60	45.89	54.12	73.59
≥ 60	47.32	53.27	73.18
Average	47.93	55.74	72.35

The results of this study are consistent with (Kusuma, 2009) that in tropical forests of logged-over West Kalimantan, Indonesia which states that the largest percent volatile matter are found in leaves of 66.45% and the smallest content of fly substances is 52.06%. Similarly, the results of Febrina (2012) studied in Riau, Sumatera, Indonesia in peat swamp forests stated that the highest percent volatile matter was found in leaves of 64.53% and the smallest content of the substance was found in 34.82% of stems.

3.2 Content of Ash Substances

Ash is the burning residue of materials containing organic materials. The organic ingredients are elements of calcium, potassium, magnesium, manganese and silicon. The results of the analysis of ash content of sample trees can be seen in Table 2. Table 2 showed that the highest average of ash content is found on leaves of 4.44% and the smallest ash content is in the stem part of 0.56%.

Table 2: Average of ash content in the part of tree sample based on diameter at breast height (DBH).

Diameter	Ash Content (%)		
(cm)	Stems	branch	leaves
5 – 10	0.55	1.68	4.55
10 – 20	0.62	2.10	4.58
20 – 30	0.48	1.97	5.37
30 – 40	0.55	2.12	3.95
40 – 50	0.46	2.15	4.53
50 - 60	0.59	2.03	3.94
≥ 60	0.70	1.00	4.16
Average	0.56	1.86	4.44

The result of this research is in line with research of Widyasari (2010) which states that the biggest ash content is found in leaves of 5.65% and the smallest in the stalk is 0.63%. Similarly, the research results Febrina (2012) which states that the largest ash content is found on the leaves of 5.79% and the smallest in the stem of 1.04%.

3.3 Carbon Content of Tree Sample

The results of carbon content of sample trees can be seen in Table 3. In Table 3 showed that the average carbon content based on the diameter class has varying carbon content. The largest carbon content was in the stem section (45.75%) that the average carbon content range was 40.29 - 53.12%. This is due to the stem levels has a low volatile and ash content. In addition to the stems contained cell walls and accumulation of food reserves in the stem. Then followed by the branch has 39.51%, with a range of carbon content 32.64 - 43.85%, roots was 36.66%, with a range of carbon content 28.85 - 40.09% and leaves has 19.61%, with an average carbon content 15.31 - 22.58%.

Table 3: Average carbon content of each part of the sample tree based on the diameter at breast height (DBH).

Diameter (cm)	Carbon content (%)		
	Stems	branch	leaves
5 – 10	47.23	42.21	19.01
10 – 20	43.13	40.28	20.40
20 – 30	43.73	36.22	19.00
30 – 40	40.97	41.23	22.58
40 – 50	40.29	32.82	22.35
50 - 60	53.12	43.85	16.19
≥ 60	51.77	32.64	15.31
Average	45.75	38.46	19.26

The smallest level of carbon content in the leaves is 19.61%, with an average carbon content range of 15.31 - 22.58% because the leaves have high levels of fly and ash content. In addition, the leaves contain only a few wood composite materials so that the carbon content is stored slightly. The results of this study are similar to Kusuma (2009) resulted that the highest average carbon content is on the base of the stem of 61.62%. Febrina (2012) which states that the largest carbon content is on the stem of 63.49%.

3.4 Effect Forest Harvesting on Carbon Mass

Potency carbon mass in the conventional timber harvesting blocks was 99.16 Mg C ha^{-1}, in the reduced impact timber harvesting was 139.17 Mg C ha^{-1}, and in virgin forest was 159.44 Mg C ha^{-1}, respectively. This research indicated that carbon mass in the tropical rain forests caused after conventional timber harvesting blocks is lower when compared to the reduced impact timber harvesting blocks.

Figure 1 showed that the average carbon mass above ground level on a block of conventional timber harvesting, timber harvesting and virgin forest RITH average of 132.59 Mg C ha^{-1}, consisting of a carbon mass by vegetation amounting to 34.03 Mg C ha^{-1} and litter as well as necromass amounted to 98.56 Mg C ha^{-1}.

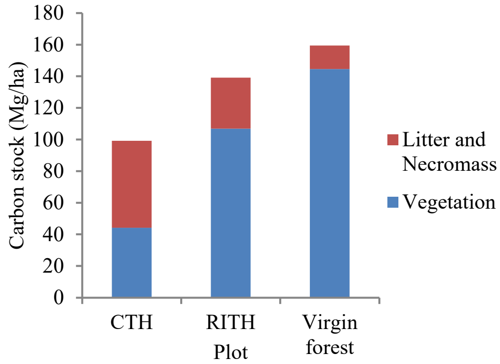

Figure 1: Carbon mass in conventional timber harvesting (CTH), reduced impact timber harvesting (RITH) and virgin forests.

Carbon mass in conventional timber harvesting blocks is lower when compared to the blocks of timber harvesting RITH, that the carbon mass in conventional timber harvesting and reduced impact timber harvesting was 99.16 Mg C ha^{-1} and 139.17 Mg C ha^{-1}, respectively. In conventional timber harvesting blocks for carbon mass of vegetation significantly lower than the carbon mass in timber harvesting RITH blocks were 44.16 Mg C ha^{-1} (44.53%) and 106.87 Mg C ha^{-1} (76.79%) of the total carbon mass, respectively. Carbon mass derived from litter and necromass compartments conventional timber harvesting higher than RITH that were 55.00 Mg C ha^{-1} (55.46%) and 32.30 Mg C ha^{-1} (23.21%), respectively. This shows that the composition of the carbon mass of vegetation and litter as well as necromass on both blocks of different timber harvesting. Carbon mass derived from the vegetation as a result of damage to remaining trees and understory in a conventional timber harvesting blocks cause carbon mass decreased vegetation and litter carbon mass and increased necromass.

Based on this study, the blocks of timber harvesting RITH is good enough to keep the carbon mass in natural tropical forests. This is because the residual stand damage caused by timber harvesting can be suppressed so that the residual stand damage and death due to the continued impact can be minimized. This research indicates the carbon mass from conventional timber harvesting activities and RITH in natural tropical forests.

The carbon mass stock reserve at each study site ranged 6.82 to 8.41 Mg C ha^{-1}. Primary forests have the highest carbon mass reserve potential of 8.41 Mg C ha^{-1} compared to conventional logged-over areas and RITH techniques.

The massive contribution of carbon mass of tree vegetation is due to a positive relationship with tree diameter size. So the larger the diameter of the tree causes the higher the carbon mass. Latifah et al (2018) reported that in North Sumatra obtained total carbon mass in agroforestry system was 2.88 Mg C ha^{-1}.

Changes in carbon mass were negetively related to forest haresting instensity, but any effect or reduced impact timber harvesting was obscured. Residual forest stands in logged forests with lower intensity and continue to decline in high intensity logged forests (Martin *et al*., 2015). Establishing realistic post-harvesting recovery rates is critical for setting harvest rates that ensure sustainable forest management and environmentally functioning (Hawthorne *et al.*, 2012).

4 CONCLUSION

Carbon mass in conventional timber harvesting blocks is lower when compared to the blocks of timber harvesting RITH. In conventional timber harvesting blocks, carbon mass of vegetation was lower than RITH blocks. The results indicated that reduced impact timber harvesting is good enough to maintain a reserve of carbon in tropical rain forests.

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REFERENCES

Angelsen, A., Brockhaus, M., Kanninen, M., Sills, E., Sunderlin, W.D., Wertz-Kanounnikof, S. (Ed.)., 2011. Mewujudkan REDD+ : Strategi Nasional dan Berbagai Pilihan Kebijakan. Bogor: Center for International Forestry Research.

Elias, 1999. Reduced Impact Timber Harvesting in the Indonesian Selective Cutting and Planting System. IPB Press, Bogor.

Febrina, Y., 2012. Estimating the potential of above ground biomass and carbon on four peat land condition, Riau. [Thesis]. Bogor Agricultural University, Bogor. [Indonesian].

Hawthorne, W.D., Sheil, D., Agyeman, V.K., Juam, M.A., Marshall, C.A.M., 2012. Logging scars in Ghanaian high forest: Towards improved models for sustainable production. *Forest Ecology and Management* 271:27–36.

Kusuma, G., 2009. Estimating of above ground carbon potentials in logges over forests [Thesis]. Bogor Agricultural University, Bogor. [Indonesian].

Laufer, J., Michalski, F., Peres, C.A., 2015. Effects of reduced-impact logging on medium and large-bodied forest vertebrates in eastern Amazonia. *Biota Neotropica* 15(2). http://dx.doi.org/10.1590/167606032015013114.

Lopes, C.G.R., Ferraz, E.M.N., de Castro, C.C., de Lima, E.N., dos Santos, J.M.F.F., dos Santos, D.M., de Lima Araújo, E., 2012. Forest succession and distance from preserved patches in the Brazilian semiarid region. *Forest Ecology and Management* 271:115–123.

Martin, P.A., Newton, A., Pfeifer, M., Khoo, M., Bullock, J., 2015. The effects of reduced impact logging and logging intensity on stand damage, biomass loss and tree species richness in tropical forests: a meta-analysis. PeerJ PrePrints 3: e846v1https://doi.org/10.7287/peerj.preprints.846v1.

Muhdi, Elias, Murdiyarso, D., Matangaran, J.R., 2016. Effect of reduced impact logging to species composition and forest structure in tropical rain forest, North Borneo. International *Journal of Bioscience* 9(5):28-34.

Purwoko, A., Muhdi, Hanafiah, A.S., 2018. Residual stand damages caused by conventional and reduced impact timber harvesting in the natural forest. International Journal of Mechanical Engineering and Technology 9(3): 313–325.

Romell, E., Hallsby, G., Karlsson, A., Garcia, C., 2008. Artificial canopy gaps in a Macaranga spp. dominated secondary tropical rain forest-Effects on survival and above ground increment of four under-planted dipterocarp species. *Forest Ecology and Management* 255:1452–1460.

Widyasari, N.A.E., 2010. Estimation above ground biomass and carbon tied inburnt peat forest in South Sumatra [Thesis]. Bogor Agricultural University, Bogor. [Indonesian].