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RESIDUAL STAND DAMAGES CAUSED BY CONVENTIONAL AND REDUCED IMPACT TIMBER HARVESTING IN THE NATURAL FOREST

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ABSTRACT

The objective of this research is to know the effect of reduced impact timber harvesting on residual stand damages in natural tropical forest. The effect of conventional and reduced impact timber harvesting (RITH) on residual stand were studied using the data of three plots with each size of 100 m x 100 m placed in timber collection site, middle skiddtrail and tips of skiddtrail, respectively. Field research was conducted in the concession area of PT. Inhutani II, East Kalimantan. Research plots consisted of timber harvesting plots using conventional technique and timber harvesting plots using RITH technique. The results of the research show that that the potency of commercial timber species in conventional timber harvesting and RITH are as follows: 408 N/ha and 432 N/ha. The degree of residual stand damages based on tree population and stage of vegetation development in conventional timber harvesting and RITH was as follows : for seedlings 34.42 % and 23.17 %, for saplings 35.13 % and 21.72 %, for poles and trees 33.15 % and 19.53 %. Based on the size injury of every individual tree, the degree of the trees damages caused by timber harvesting in conventional timber harvesting and RITH was as follows : trees heavy injury 64.66 % and 57.20 %, trees medium injury 20.30 % and 24.00 % and trees light injury 15.03 % and 18.80 %. The most type stand damage are the falling down 36.84 % and 32.01 % and broken stem 22.78 % and 21.25 %. The research indicates that conventional timber harvesting in the tropical natural forest causes heavier damage on residual stand when compared to reduced impact timber harvesting.

Key words: conventional timber harvesting, natural forest, residual stand damage, reduced impact timber harvesting

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1. INTRODUCTION

The rate of deforestation and degradation of tropical forests in Indonesia today is strongly worrying, it affects the process of CO2 absorption from the atmosphere which can affect global climate conditions, resulting in greenhouse effects (Putz et al., 2008; Taylor et. Al. 2008; Lasco 2002; Brown 2002). Timber harvesting and silvicultural treatment in natural tropical forests can cause significant changes to the forest ecosystem. The research results (Junaedi, 2007; Indrawan, 2000; Elias, 1995) show that the residual stand damages caused by timber harvesting and application of silvicultural systems in forest significant to vegetation are in the form of residual stand damages and changes to the structure and composition of species in tropical natural forests.

Timber harvesting causes high damage to the land and forest stands that affect forest regeneration (Sularso, 1996; Sukanda 1998; Muhdi & Elias, 2004; Dubé, et. Al., 2005). Reducing damages caused by timber harvesting is a prerequisite for achieving sustainable forest management. Reducing soil and stand damages can reduce cutting cycle because it ensures regeneration and growth of commercial stands (Elias 1998; Sist et. Al., 1998; McDonald et al, 2008; Muhdi, 2008; Peña-Claros et. Al., 2008; Rendon-Carmona et. al. 2009). Knowing the development of forest stands in responding damages caused by timber harvesting is very important in the application of forest management practices (Attiwill, 1994; Pham et. Al., 2004; Nagel and Diaci, 2006). Logging and skidding of timber on timber harvesting also cause openness on the forest floor (Rodrego et. Al., 2002; Muhdi, 2003).

The potential of residual stands after timber harvesting needs to be studied to rescue young trees from commercial species in order to avoid production decrease in in the next cutting cycle. One way is to look at the potential of stands after timber harvesting (Bobiec, 2007). The data obtained are expected to be the basis in helping appropriate silvicultural measures and treatments so that the goal of sustainable forest management can be achieved. This study aims to determine the residual stand damages caused by timber harvesting using Reduced Impact Timber Harvesting Techniques (RITH) and conventional techniques, by knowing the level of residual stand damages caused by timber harvesting with RITH and conventional timber harvesting techniques.

2. LITERATURE REVIEW

2.1. Reduced Impact Timber Harvesting

The felling and skidding operations conducted are not based on a timber harvesting plan (climber cutting, skidtrail network layout, directional felling and winching), and also are not based on tree location and topographic map. A tree location and topographic map used for the harvesting plan map serves as a guide for the felling and skidding crew in timber harvesting operations. Generally these activities are uncontrolled. Reduced impact timber harvesting is based on forest prospecting prior to harvesting, and uses this data to design a layout of felling compartments and inventory units, and also to plan the timber harvesting operations (J. Hendrison, 1990).

2.2. Sustainable Forest Management

International Tropical Timber Organization (ITTO, 2013) (http://www.itto.int), defines sustainable forest management (sometimes abbreviated to SFM) as: the process of managing forest to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment. What this means is that forest-related activities should not damage the forest to the extent that its capacity to deliver products and services - such as timber, water and biodiversity conservation - is significantly reduced. Forest management should also aim to balance the needs of different forest users so that its benefits and costs are shared equitably. ITTO's action program is designed to assist tropical member countries to manage and conserve the resource base for tropical timber. It embraces aspects of SFM such as planning, reduced impact logging, community forestry, fire management and biodiversity and transboundary conservation. The Organization also has special themes on criteria and indicators for sustainable forest management, restoration and planted forests, forest law enforcement and the sustainable use and conservation of mangrove ecosystems. (ITTO, 2013).

3. MATERIALS AND METHODS

This research method is Descriptive method. Descriptive method is a method in researching the group of people, an object, a set of conditions, a system of thought, or a class of events in the present (Sirojuzilam *et al*., 2016; Muda *et al*., 2016 & 2018). The purpose of this descriptive research is to make description, picture or painting in a systematic, factual and accurate about facts, properties and relationships between the phenomena investigated. Field research was conducted in the concession area of PT. Inhutani II, East Kalimantan. Research plots consisted of timber harvesting plots using conventional technique and timber harvesting plots using RITH technique. This research plots covered respectively an area of 10-15 hectares in which it was made three (3) permanent /measurement plots with the respective size of 100 mx 100 m (1 ha). Each permanent / measurement plot was divided into 25 sub plots with the size of 20 x 20 m2 (trees), 10 x 10 m2 (pole), 5 x 5 m2 (saplings) and 2 x 2 m2 (seedlings).

Permanent / measurements plots were systematically placed on both research plots in such a way that representing the places as follows: (1) In the location of timber collection (TPN), (2) In the location of main skid trail and (3) In the location of branch skid trail.

3.1. Conventional Timber Harvesting Technique

The implementation was carried out directly by skidding and felling team in accordance with what was applied by the company so far. This timber harvesting included timber felling and skidding operations.

3.2. Reduced Impact Timber Harvesting (RITH) Technique

The felling and skidding teams were the same teams with the conventional timber harvesting, as well as timber harvesting equipment used. Prior to implementation of RITH it was made intensive timber harvesting plan including: determining the direction of fall, skid trail network on a map and marked in the field (Elias, 1998; Putz et. Al., 2008). Before doing timber harvesting activities, felling and skidding teams were given briefing in advance, and at the time of implementation, they were supervised by the researcher. The design of permanent / measurement plots can be seen in Figure 1.

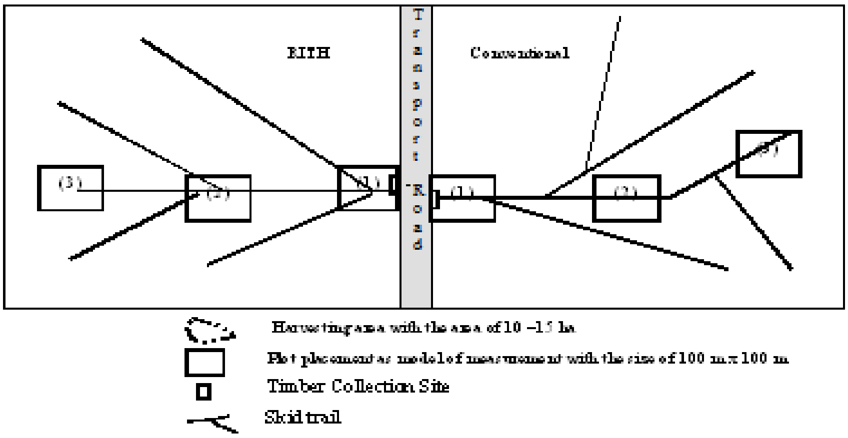

Figure-1, Design of Permanent/Measurement Plot

Secondary data were obtained through interviews and quotes from books or existing reports the data source. Primary data were collected through observation and inventory activities directly in the forest on permanent / measurement plot made. On each observation plot, the data taken for stands of trees and poles include: name of species, tree diameter at breast height (1.3 m) or 20 cm above the buttress and bole height (Cox, 1985; Curtis and McIntos, 1951; Odum, 1971; Mueller-Dombois, D. & H. Ellenberg, 1974; Misra, 1980). The data of stand damages caused by timber harvesting, were collected through observation after felling and skidding of timber, among others: name of tree species, diameter and type of damage (Ministry of Forestry, 1997; Kusmana, 1997).

4. RESULTS AND DISCUSSION

4.1. Potential of Stand

Stands inventory was carried out before felling on the plot with the size of 100 m x 100 m (1 ha) in the research plots of conventional technique and RITH technique to see the potential of stands before the timber harvesting. Potential of stands per ha in plots of conventional and RITH can be seen in Table 1

Table-1. Potential of stands per ha in plots of conventional and RITH.

No.	Conventional Technique		RITH Technique	
Plot	N/ha	m^3/ha	N/ha	m^3/ha
I.	386	242,304	448	225,921
II	382	302,393	430	253,402
III	455	242,655	417	202,602
Total	1223	787,353	1295	681,927
Average	408,0	262,451	432,0	227,308

To see the illustration of distribution of stand potential for poles and trees per diameter class can be seen in Figure 2 and Figure 3.

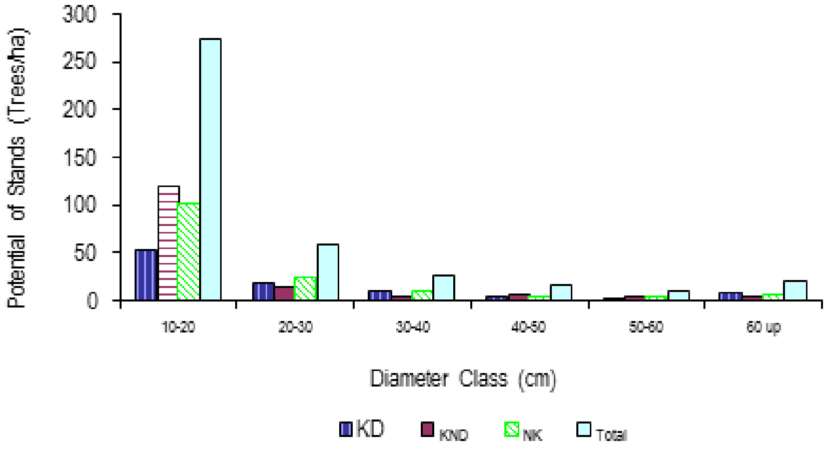

Figure 2 Histogram of stand potential for pole and tree per species group on conventional timber harvesting plot

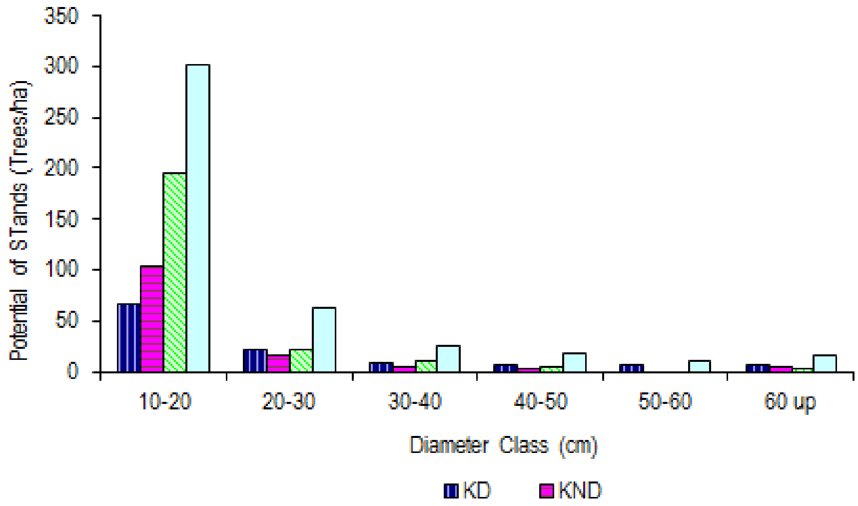

Figure 3 Histogram of stand potential for pole and tree per species group on RITH plot.

By knowing the potential of stand of both timber harvesting stand, non-commercial species group dominate other species groups with the average percentage of 39.27%, then non- Dipterocarpaceae commercial species groups with the average percentage of 34.56% and Dipterocarpaceae commercial species group with the average percentage of 26.17%. Similarly, the distribution of 10-19 cm diameter dominate the number of stands for poles and tree with the average percentage of 40.12%, class of 20-29 cm diameter by 39.33%, class of 30-39 cm diameter by 42.92%, class of 40-49 cm diameter by 33.98%. Dipterocarpaceae commercial species group dominate stand in the class of 50-59 cm diameter by 45.91% and class of 60 cm up diameter by 46.21%.

4.2. Types of Residual Stand Damages

Types of residual stand damages of both conventional technique and RITH technique timber harvesting are determined by the types of activity and the type of damage to individual tree. The types of conventional and RITH techniques timber felling are dominated by broken canopy (39.22%; 32.15%) and broken stem (28.93%; 26.43%), then broken limb, falling down, buttresses/bark and skewed. While the timber skidding activities are dominated by the type of falling down damage (48.48%; 44.07%). Types of broken canopy and broken stem damages due to timber felling on both harvesting plots are mostly from the class of 10 cm - 19 cm diameter by 36.36% and 20-29 cm medium diameter being by 27.27% can be seen in Table 2.

Table-2, Average residual stand damages for pole and tree based on the types of damages caused by conventional and RITH.

Timber Harvesting Technique	Damage Types	After Felling		After Skidding		Total Damage	
		Number of Damage	Percentage	Number of Damage	Percentage	Number of Damage	Percentage
Conventional	Buttresses/Bark	2.3	6.46	10.0	12.65	12.3	10,77
	Skewed	1.3	3.65	3.3	4.17	4.6	4,02
	Broken Stem	10.3	28.93	17.3	21.89	27.3	23,90
	Broken Limb	4.7	13.20	3.0	3.79	7.7	6,74
	Broken Canopy	14.0	39.32	7.0	8.86	21.0	18,38
		3.0	8.42	38.3	48.48	41.3	36,16
Total		35,6	100	78.6	100	114.2	100
RITH	Buttresses/Bark	2.7	11.89	3.7	8.27	6.4	9,49
	Skewed	1.3	5.70	1.0	2.23	2.3	3,41
	Broken Stem	6.0	26.43	9.3	20.80	15.3	22,70
	Broken Limb	3.7	16.30	5.3	12.75	9.0	13,35
	Broken Canopy	7.3	32.15	5.7	11.85	13.0	19,28
		1.7	7.48	19.7	44.07	21.4	31,75
Total		22,7	100	44.7	100	67.4	100

The average number of damaged trees per hectare caused by felling with conventional technique is 35.6 tree in which by felling 1 tree will damage 5.95 trees. The number of damaged trees caused by felling with RITH technique is 22.7 trees / ha or 1 tree felled can damage 4.28 tree. The results show that timber harvesting with RITH technique can reduce / suppress the number of residual stand damage of pole and tree by 1.65 trees / ha or 27.73% compared to the results caused by felling activities using conventional timber harvesting.

Figure 4 shows the magnitude of residual stand damage based on the type of damage as a result of timber felling by conventional technique or by RITH technique, which are dominated by broken canopy and broken stem, then broken limb, falling down, peeled bark, and skewed. The number of residual stand damages for pole and tree caused by felling based on the types of damage can be seen in Figure 4.

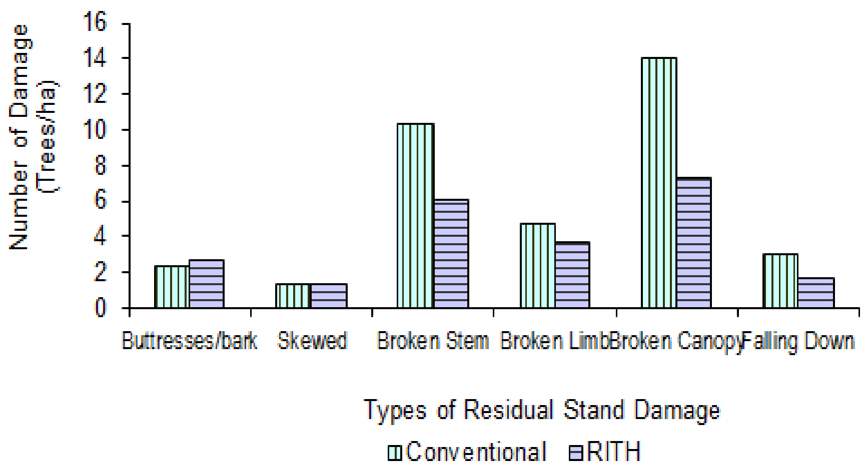

Figure 4 The number of residual stand damages for pole and tree caused by felling based on the types of damage

The average percentage of residual stand damages for pole and tree caused by skidding with conventional and RITH techniques are dominated by the damage types of collpased by 48.48% and 44.07%, then broken stem by 21.89% and 20.80%; broken canopy by 8.86% and 11.85%; peeled bark/buttresses by 12.65% and 8.27%; and broken stem 3.79% and 12.75%; and skewed by 4.17% and 2.23%. The number of stand damage for pole and tree caused by skidding based on the types of damage can be seen in Figure 5.

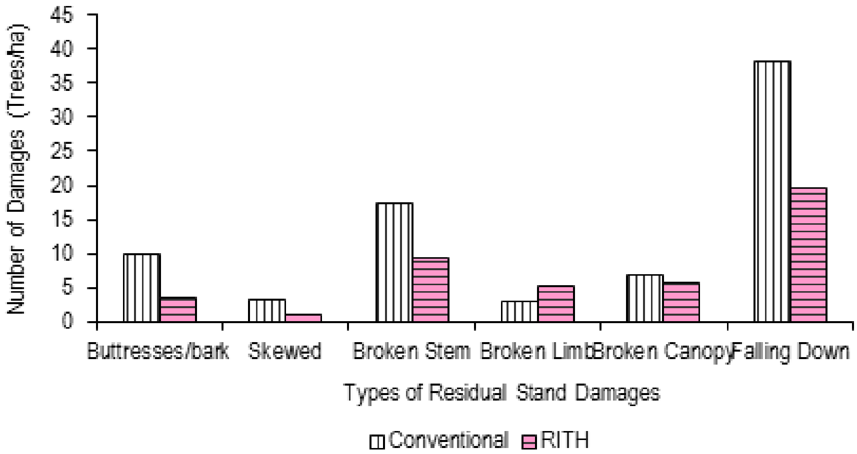

Figure 5 The number of stand damage for pole and tree caused by skidding based on the types of damage.

On skidding activities, especially in the making of skid trail, there is damage on trees passed by tractor due to displaced, uprooted and pushed to the left or to the right of skid trail causing damage to other surrounding trees in the form of falling down, broken stem, broken canopy, skewed, and broken bark/buttress.

The number for pole and tree damage caused by skidding with conventional technique is 78.6 trees / ha. While the damage caused by skidding with RITH technique is 44.7 trees / ha. The data of damage show that timber skidding with RITH technique can suppress / reduce residual stand damage for pole and tree by 4.67 trees / ha or 35.64%. The number of stand damage for pole and tree caused by timber harvesting based on the types of damage can be seen in Figure 6.

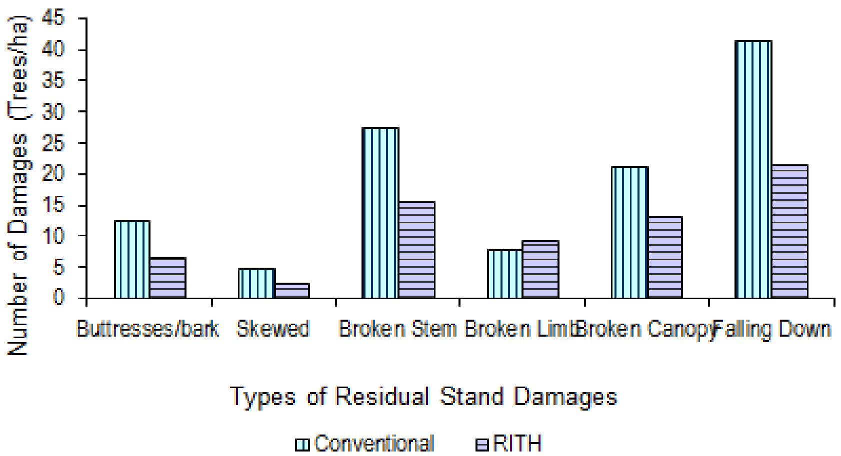

Figure 6 The number of stand damage for pole and tree caused by timber harvesting based on the types of damage.

The average number of stand damages for poles and trees per hectare caused by conventional timber harvesting is 114.2 trees. The average damage caused by RITH is 67.4 trees. The results show that applying RITH technique can reduce / suppress residual stand damage for pole and tree by 6.36 trees / ha or 33.38% of produced in conventional timber harvesting plot.

4.3. Level of Residual Stand Damage

The following is the order of damage level and difference of damage magnitude caused by RITH and conventional timber harvesting, presented in Figure 7. Figure 7 shows that the levels of damage on RITH and conventional techniques timber harvesting are dominated by light, medium, and heavy damage level. Histogram of damage level based on the magnitude of wound for pole and tree caused by timber harvesting can be seen in Figure 7.

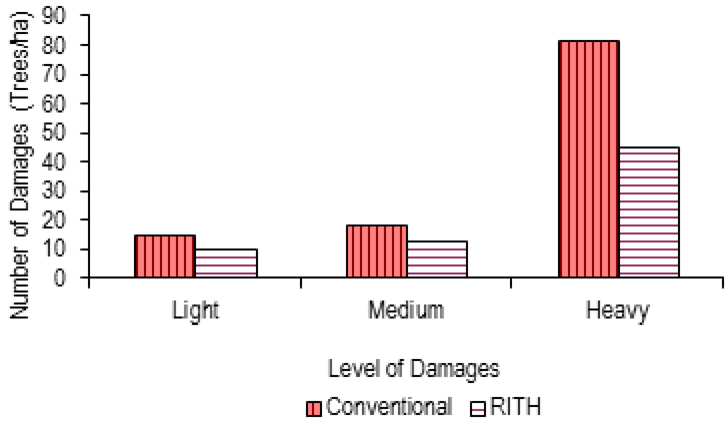

Figure 7 Histogram of damage level based on the magnitude of wound for pole and tree caused by timber harvesting.

Timber harvesting using heavy equipment such as bulldozers cause stands damage and land openness bigger than the use of a cable system or a helicopter. Investment in timber harvesting is quite big, ranging from 60% - 70% of the cost of forest exploitation. However, the use of this equipment is more convenient and flexible to produce large quantities of timber.

Table-3, The average level of stand damages for pole and tree caused by timber harvesting based on population in the plot

THTech	Stand Density (N/ha)		Harvesting Intensity		Number of Residual Stand		Number of Damaged Tress by				Total Damages	
							Felling		Skidding			
	N	V	N	V	N	V	N	V	N	V	N	V
Conv.	407.6	262.45	6.0	32.70	375.3	229.75	35.7	25.37	78.6	43.72	114.3	69.09
RITH	432.0	227.30	5.3	38.14	426.7	189.16	22.7	7.32	44.7	15.47	67.3	22.79
Mean	419.8	244.88	5.7	35.42	401.0	209.45	29.2	16.35	61.7	29.60	90.8	45.94

To maintain the continuity of company in the field of forest exploitation, mechanical activities in forest production, should get the supervision and good planning both from internal of the company and the government, because errors in timber harvesting will cause damage and openness, erosion, flooding and greater loss of vegetation. The average level of stand damages for pole and tree caused by timber harvesting based on population in the plot can be seen in Table 3.

RITH technique timber harvesting shows the average damage percentage per hectare by 15.88%. This damage percentage includes in the light damage (<25%), consisting of stand destruction caused by felling by 5.32% and skidding by 10.48% included in the criteria for light damage (<25%).

RITH technique timber harvesting causes stand damage at the level of light damage (<25%), whereas conventional timber harvesting causes stand damage at the level of medium damage (25% - 50%). Thus, by doing a little marking of felling direction of the trees in the RITH, it is obtained better results than the results obtained in a conventional timber harvesting in forest exploitation and environmentally sound. Total average residual stand for pole and tree after conventional technique harvesting is 287.4 trees / ha (70.44%) with a volume of 165.26 m3 (63.00%). While RITH technique timber harvesting is 358.8 trees / ha (83.13%) with a volume of 163.24 m3 / ha (71.91%). The residual stand above come from a variety of distribution of diameter, even there are some trees with a diameter of 60 cm above which are not harvested because of hollowed, hardwood and there are some species that do not have timber market, protected trees and trees that cannot be felled for safety reasons both for loggers as well as for timber harvested and the residual stand.

Indonesian Selective Logging and Planting (TPTI) requires that there should be a minimum of 25 healthy, commercial trees with the diameter of 20 cm above every acre as the core trees. The trees are expected to form the main stand at the next rotation. Reality on the field is that there are many residual stands for poles and trees with the distribution of 20 cm diameter above and in good condition to be used as a substitute for core trees damaged. Comparison between the criteria set and the number of residual stand after timber harvesting still meet the criteria for a good assessment and Indonesian Selective Logging and Planting (TPTI) guidelines requirements concenred (Department of Forestry, 1993).

Based on the principles of forest products sustainability, as a replacement for the core trees, residual stands should be available in sufficient quantity (Slik, et.al, 2008). According to TPTI guidelines, in order to achieve sustainability principles, there must be at least 75 stems / ha for poles and 25 trees / ha for commercial and healthy species in order to achieve the sustainability principles. From these requirements and seeing the number of residual stands of both plots at various levels of healthy stands, then the requirements can be achieved.

The application in the field shows that conventional timber harvesting has caused damages to residual stands and forest soils. In the area of production forest in Kalimantan, the conventional timber harvesting generally causes the damages more than 50% in the area harvested when the intensity of felling is more than 10 trees / ha (Sist, et al, 2003). In the tropical natural forests, the residual stand damages trees reach an average of 53% and 1.5 g / cm3 bulk density covering 15-40% of felled areas ((Shukri and Kamaruzzaman, (2003) referred by Elias and Vuthy (2006)). This shows a mechanical system using tractor on conventional timber harvesting produces high residual stand and soil damages.

Improved forest management in the form of improvement of timber harvesting techniques from conventional timber harvesting into reduced impact timber harvesting (RITH) show significant reduction to forest damages. Reduced impact timber harvesting (RITH) technique is the timber harvesting intensively planned and controlled by well-trained workers so that in the process of timber harvesting, the negative impacts can be minimized. Implementation of reduced impact timber harvesting technique covers, among others, Timber Collection Site planning, road network planning, skid trail planning, determination of felling direction and lianas cutting. The purpose of RITH practice includes reducing the size and number of Timber Collection Sites, reducing soil and stand damage, reducing damage to trees and increasing increments, as well as reducing the land openness (Putz et al, 2008; Elias, 2006).

Some studies suggest that reduced impact timber harvesting can effectively reduce tree mortality and stand damages. RITH technique is forest management practice that can reduce the impacts of timber harvesting and increase productivity. Peńa-Claros et. al. (2008) states that the use RITH technique in Bolivia tropical forest can reduce the damages caused by timber harvesting. The growth rate of stands of commercial species is 50-60% higher in the areas of RITH compared to conventional area.

Putz et al (2008) states that improved forest management through RITH technique (including felling direction, timber skidding and liana cutting) is able to reduce forest environmental damage up to 50%, and cut emissions by up to 30%. RITH technique can protect higher biodiversity levels and give the ability of forest to recover faster than CL. Improvement of forest management in the form of improvement of timber harvesting technique from conventional timber harvesting into reduced impact timber harvesting show significant reduction against the forest damage.

The average of residual stand damages for pole and tree per hectare caused by conventional timber harvesting technique and RITH is respectively by 133.0 tree (33.15%) and 83.3 trees (19.53%). Based on the severity level, the damages occurring in the conventional timber harvesting belong to medium damage level (25-50%) and in the RITH, the damages belong to light level (<25%). Regeneration damages of seedlings and saplings level per hectare resulting from conventional timber harvesting are respectively 8466.7 seedling stem (34.42%) and 1226.7 saplings stem (35.13%) and from RITH, 3800 seedling stem (23.17%) and 682.7 saplings stem (21.72%). Based on the principles of forest product sustainability, as replacement for the core tree from the levels of seedlings, saplings, poles and trees in plots of conventional wood harvesting and RITH, there are sufficient quantities.

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