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WOOD HARVESTING DAMAGES, REGENERATION AND GROWTH IN THE RESIDUAL STAND OF DIPTEROCARP FORESTS (A Case Study in the Forest Concession Area of PT. Narkata Rimba, East Kalimantan, Indonesia)

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ABSTRACT

This research was conducted in the concession area of PT. Narkata Rimba (NR), Muara Wahau, Kabupaten Kutai, Kalimantan Timur, Indonesia. The result obtained indicated that the levels of residual stand damages positively correlated to the wood harvesting intensity, the incident of damages on small trees was greater and most of the damaged trees were heavily injured. The tree's mortality occurred during the wood harvesting year was 6.0-26.6% and one year after wood harvesting was 2.0-13.6%. After than the tree's mortality was 0.5-3.6%, meanwhile the mortality of trees in a virgin forest was 0.9-3.4% per year. It seems that higher damage occurred in residual stands causes the higher tree mortality. The seedling density of commercial dipterocarp species, in both the logged-over forests and a virgin forest were more then the recommended minimum amount (1,000 seedlings per ha) as stated in the regulation of the Indonesian Selective Cutting and Planting (*Tebang Pilih Tanam Indonesia/TPTI*) System. The average growth of diameter and volume of 25 nucleus trees hectare per year during the first five years after wood harvesting was 0.70 cm/year and 1.4235 m^3/ha/year, respectively. To anticipate the second cutting cycle, it is recommended to control the residual stand damages with an optinal wood harvesting intensity and to improve the technique of silviculture of dipterocarp forest, with the purpose to increase the diameter growth of nucleus trees.

Keywords : wood harvesting damage, residual stand, dipterocarp forest, regeneration, growth

For the management of a natural tropical rain forest, almost all of forest concession holders in Indonesia use the Indonesian Selective Cutting and Planting (*Tebang Pilih Tanam Indonesia*) System.

The cutting cycle of TPTI-System is 35 years. The TPTI-System is a system in which commercial trees with a diameter above 50 cm in a Permanent Production Forest and diameter above 60 cm in a Limited Production Forest are removed from a site and leaving a minimal of 25 young commercial and healthy trees per hectare distributed uniformly in the area.

An important criterion for the judgement of TPTI-System is the condition of the residual stand after wood harvesting, i.e. damage on the residual stand, tree's mortality, regeneration and growth of the residual stand. The objective of this research is to describe the actual situation of the residual stand, regeneration and growth of Dipterocarp forest in the forest concession area of the PT. Narkata Rimba (NR) East Kalimantan, after wood harvesting with TPTI-System.

The stages of the TPTI-System are as follows:

Table 1. The Stages of the TPTI-System

No.	Stages of Activities	Year of Implementation (-) : Before (-) : After Wood Harvesting
1.	Working area ordering	Et-3
2.	Inventory of stand before wood harvesting	Et-2
3.	Opening up forest	Et-1
4.	Wood harvesting	Et-0
5.	Horizontal clearance	Et+1
6.	Inventory of residual stands	Et+2
7.	Release I	Et+2
8.	Seed supply	Et+2
9.	Enrichment planting	Et+3
10.	Maintenance	Et+3, 4, 5
11.	Release II and III	Et+4, 6
12.	Spacing of residual stands	Et+10, 15, 20

Source : Direktorat Jenderal Pengusahaan Hutan. 1993. Departemen Kehutanan, Jakarta, Indonesia

METHODS

Research Location

This research was conducted in the forest concession area of PT. NR. Located in the district of Kutai in East Kalimantan, Indonesia. The forest concession of PT. NR covers an area of 68,000 ha which consists entirely of Limited Production Forest.

Vegetation type in PT. NR is highland natural forest, with the soil type consist of podzolic (68%), latosol (27%) and litosol (15%). The topography is undulating until hilly (70%) and steep slope (30%). The type of rainfall, based on Schmidt and Ferguson classification, is rainfall type A, with a mean annual rainfall amounted to 2.290 mm.

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Plots Design and Measurements

The research plots consists of 4 permanent plots, namely:

Plot I : plot before and after wood harvesting with slope 0-15%

Plot II : plot before and after wood harvesting with slope 16-25%

Plot III : plot before and after wood harvesting with slope > 25%

Plot IV : plot control or virgin forest

The size of each plot is 100x100 m. Figure 1 shows the plot design and Figure 2 shows the design of strip 2 and 4 for vegetation analysis.

The degree of residual stand damages was measured in 1992 and repeated measurements were conducted annually until 1996 on mortality of trees, regeneration and growth.

RESULTS

The Degree of Residual Stand Damages

The degree of residual stand damages based on tree population and the stages of vegetation development were 30.0% seedlings, 27.2% saplings and 24.6% poles and trees. Table 2 presents the data on the degree of tree (diameter of 10 cm and above) damages based on the wood harvesting intensity. The residual indicated that the higher intensity of wood harvesting causes heavier damages to the residual stands.

Table 2. Degree of Residual Stand Damages Based on Wood Harvesting Intensity

Permanent Plot	Number of Tree Before Wood harvesting ($\phi \geq$ 10cm)	Wood Harvesting Intensity (trees/ha)	Tree Damages ($\phi \geq$ 10cm) (trees/ha)	Degree of Damages (%)
I	620	2	58	9.4
II	697	6	146	21.1
III	748	17	259	35.4

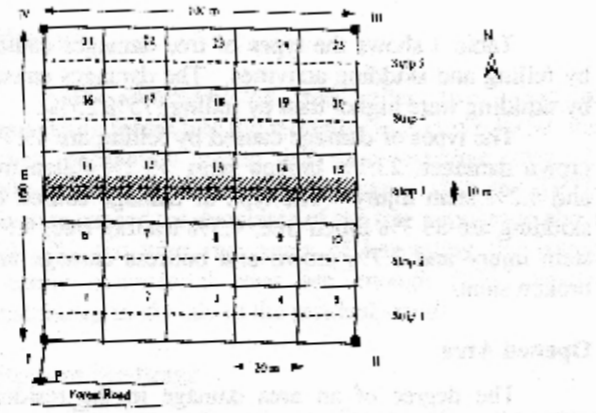
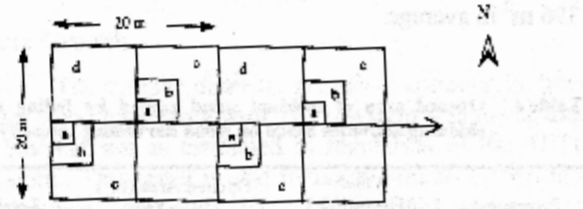


Figure 1. Constructed permanent plots design in the research site



a : Seedlings (hight <1.5 m) are measured on subplots 2x2 m
b : Saplings (hight ≥ 1.5 dbh < 10 cm) are measured on subplots 5x5 m
c : Poles (dbh ≥ 10-19 cm) are measured on subplots 10x10 m
d : Trees over 20 cm dbh are measured on subplots 20x20 m

Figure 2. Design of nested sampling for trees and regeneration

Most of the damaged trees were small sizes, namely 65.2% damaged trees with diameter of 10-19 cm and 21.2% with a diameter of 20-29 cm. Based on the size injury of each individual trees, the degrees of the damages caused by wood harvesting were 82.1% trees with heavy injury, 13.2% trees with medium injury and 4.6% trees with light injury. An analysis of the effects of diameter and height of trees and slopes on residual stand damages shows, that the effects on the residual stand damages were not significant.

Table 3. Types of tree damages caused by felling and skidding activities

Permanent Plot	Wood Harvesting Intensity (trees/ha)	Types of Tree Damage (%)					Total (%)
		Fallen Tree	Broken Stem	Crown Damages	Bark & Stem Injury	Root & Buttress Injury	
I	2	5.5	1.0	2.6	-	0.3	9.4
II	6	17.8	0.9	1.6	0.6	0.5	21.1
III	17	21.9	3.2	8.1	1.6	-	35.4

Table 3 shows the types of tree damages caused by felling and skidding activities. The damages caused by skidding were higher than by felling (75%:25%).

The types of damage caused by felling are 49.5% crown damages, 23.1% broken stem, 19.2% fallen tree and 8.2% stem injury. The type of damage caused by skidding are 83.3% fallen tree, 4.5% leaning tree, 9.5% stem injury and 2.7% crown and buttress damage and broken stem.

Opened Area

The degree of an area damage in the residual stand caused by felling and skidding depends largely on the wood harvesting intensity, mainly the opened area caused by felling. The higher intensity of wood harvesting causes a larger opened area of the residual stand. Table 4 shows the size of opened area caused by felling and skidding activities based on wood harvesting intensity. The size of the opened area caused by harvesting of one tree ranged between 285 and 512 m^2 to 396 m^2 in average.

Table 4. Opened area of residual stand caused by felling and skidding activities based on wood harvesting intensity

Permanent Plot	Wood Harvesting Intensity (trees/ha)	Opened Area (m^2) Caused by		Total (m^2)
		Felling	Skidding	
I	2	92	596	688
II	6	808	2,008	2,816
III	17	2,512	2,324	4,836

Mortality of Trees

Table 5 shows the mortality of trees with a diameter ≥ 10 cm. in the residual stand of Et-0, Et+1, Et+2, Et+3 and in the virgin forest. In general, the dead trees consisted of small trees with diameter of 10-39 cm. The mortality occurred in the current wood harvesting was 6.0-26.0 % and one year after wood harvesting was 2.0-13.6%. These figures decreased drastically after two years of wood harvesting (0.7-3.6%) and three years of wood harvesting (0.5-3.6%). It seems that higher damage occurred in residual stands causes the higher tree mortality. The mortality of trees in a virgin forest was 0.9-3.4% per year.

The Stock of Seedling

The stock of seedling of commercial Dipterocarp species before wood harvesting, one and two years after wood harvesting and in a virgin forest are as presented in Table 6.

Table 5. Mortality of trees with a diameter of 10 cm and above in the residual stand and virgin forest

Permanent Plot	Diameter Class (cm)	Mortality (%) Et-0	Et+1	Et+2	Et+3
I	10-19	7.0	2.9	0.6	0.8
	20-29	4.5	1.0	0	0
	30-39	2.5	1.3	1.3	0
	40-49	4.2	0	4.3	0
	50-59	15.4	0	0	0
	≥ 60	0	0	0	0
	Total	6.0	2.0	0.7	0.5
II	10-19	20.2	16.1	3.9	0.8
	20-29	16.1	9.9	3.9	3.7
	30-39	7.8	13.6	2.0	2.7
	40-49	9.1	5.0	5.3	0
	50-59	0	12.5	0	0
	≥ 60	0	5.6	0	8.3
	Total	17.0	13.6	3.6	2.3
III	10-19	22.3	14.6	0.6	4.0
	20-29	19.6	10.8	2.0	3.4
	30-39	22.5	9.1	0	0
	40-49	14.8	8.7	0	0
	50-59	7.1	0	0	0
	≥ 60	15.4	4.5	0	0
	Total	26.6	12.5	0.8	3.6
IV (Virgin Forest)	10-19	1.2	3.2	1.2	1.9
	20-29	1.9	0	0	1.8
	30-39	0	4.8	2.5	4.6
	40-49	9.5	0	0	8.7
	50-59	7.1	0	0	0
	≥ 60	0	0	0	0
	Total	1.6	2.4	0.9	3.4

Table 6. The Seedling Density of Commercial Dipterocarp Species in the Research Site

Permanent Plot	Et-0 (Seedlings/ha)	Et+1 (Seedlings/ha)	Et+2 (Seedlings/ha)
I	28,000	21,000	12,875
II	4,250	11,625	25,875
III	13,625	13,500	11,1225
IV (Virgin forest)	-	22,750	25,500

Table 6 shows that the total amount of seedlings of commercial Dipterocarp species, both in the logged over forests and the virgin forest were more than the minimum amount of 1,000 per hectare, as required by the regulation contained in the TPTI-System.

Growth of Nucleus Trees

Diameter measurements of nucleus trees are recorded for five consecutive years within the permanent plots in the logged-over forests and virgin forest. Table 7 shows the growth of diameter and volume of 25 nucleus trees per hectare. The average growth of diameter and volume of 25 nucleus trees after wood harvesting were 0.70 cm/year and 1.4235 m^3/ha/year.

Table 7. The growth of diameter and volume of 25 nucleus trees after wood harvesting in the concession areas of PT. NR

Permanent Plot	Period of growth	Growth of	
		Diameter (cm/year)	Volume (m^3/ha/year)
I	1st year	0.94	2.1120
	2nd year	0.50	1.1990
	3rd year	0.63	1.1050
	4th year	0.59	1.1116
	Average	0.67	1.5320
II	1st year	0.96	1.7679
	2nd year	0.40	0.6853
	3rd year	0.54	0.9582
	4th year	0.69	1.2765
	Average	0.65	1.1720
III	1st year	1.10	1.9866
	2nd year	0.53	1.0581
	3rd year	0.60	1.2926
	4th year	0.93	1.9285
	Average	0.79	1.5665
I + II + III	Average	0.70	1.4235

DISCUSSION

Wood Harvesting Intensity

The degree of residual stand damages was found correlated to the intensity of wood harvesting. The higher wood harvesting intensity causes the heavier of residual stand damages. This result has been shown also by Abdulhadi *et al.* (1981), Butar Butar (1991), Yanuar (1992) and Bertault & Sist (1995). For the implementation of this result, it should be possible to control the degree of residual stand damage by regulating the optimal wood harvesting intensity in TPTI. If level of residual stand damages is under control, an adequate number of seedlings, saplings and young commercial and healthy trees will be secured due to the fact that stocking of seedlings, saplings, poles and young trees of commercial species before wood harvesting with TPTI-System in the dipterocarp forest in East Kalimantan, were more than adequate.

Mortality

The mortality of trees after two years of harvesting seems like the mortality in a virgin forest and trees' population during that time increased about 2-10%. Although the wood harvesting with the TPTI-System caused the decreases of the tree population about 10-37%, but after two years of harvesting the young healthy commercial trees are enough (>25 trees/ha distributed uniformly in the residual stand).

Stock of Seedlings

The amount of seedlings of commercial Dipterocarp species in one and two years after wood harvesting can be considered enough. There were about 11,000-25,000 seedlings/ha. It was 11-25 times of the minimum amount of 1,000 seedlings per ha as required by the regulation of the TPTI-System. Therefore, it is not necessary to plant seedlings in the residual stand after wood harvesting.

Tree Growth

The average diameter growth of commercial trees after wood harvesting with TPTI-System was lower than 1 cm/year not as estimated in regulation of the TPTI-System. This result is also found by Sutisna (1990) in a concession area of PT. ITCI, Balikpapan, East Kalimantan. The average diameter growth of meranti group was about 0.7-0.8 cm/year and commercial trees of non Dipterocarp group were 0.6-0.8 cm/year. According to Continuos Forest Inventory (CFI) in East Mindanao, Philippines (Weidelt & Banaag, 1982), the average diameter growth of some commercial tree species is as follows:

- white lauan (*Pentacme contorta*) : 0.8-1.2 cm/year
- mayapis (*Shorea squamata*) : 0.7-1.0 cm/year
- red lauan (*Shorea negrosensis*) : 0.6-0.8 cm/year
- almond (*Shorea almon*) : 0.6-0.7 cm/year
- bagtikan (*Parashorea plicata*) : 0.4-0.6 cm/year
- apitong (*Dipterocarpus grandiflorus*) : 0.3-0.5 cm/year
- yakal (*Shorea gisok*) : 0.3-0.4 cm/year

The volume growth of 25 nucleus trees hectare during the first five years after wood harvesting with TPTI-System were 1.1720-1.5665 m^3/ha/year or 1.4235 m^3/ha/year in average. Compared to the result of CFI in the Philippines, the periodic annual increment (PAI) in dipterocarp forest in East Mindanao was 1.7 m^3/ha/year. Those results a similar one to another.

Diameter growth of 25 nucleus trees during the first five years after wood harvesting were about 0.65-0.79 cm/year or 0.70 cm/year in average. It seems after the first cycle of wood harvesting with the TPTI-System (35 years), most of the nucleus trees with diameter between 20-35 cm, still not achieve a diameter bigger than 60 cm (diameter limit in Limited Production Forest). So, those trees can not be cut in the second

cycle according to TPTI-regulation, unless the government (c.q. Department of Forestry) allows the reduction of the cutting diameter limit. To avoid this, we should improve the technique of silviculture of dipterocarp forest with the purpose to increase the diameter growth of nucleus trees.

CONCLUSION & RECOMMENDATIONS

The degree of residual stand damages ranged from 28 to 45% and the incidence of damages to small trees greater (ca. 87%). Most of the damaged trees were heavily injured (ca. 82%) and had little chance to recover since their growth would be affected by the damage.

The degree of residual stand damage was found correlated to the intensity of wood harvesting. The mortality rate of young trees left after wood harvesting was between 6.0-26.6%. During the fist year 2.0-13.6% and then the mortality decreased drastically to 0.5-3.6%. The mortality of trees in virgin forest was 0.9-3.4% per year.

It is not necessary to plant seedling in the residual stand after wood harvesting in dipterocarp forests. The natural regeneration is sufficient. The average growth of diameter and volume of 25 nucleus trees per hectare during the first 5 years after wood harvesting with TPTI-System were 0.70 cm/year and 1.4235 m3/ha/year in average.

For the implementation of this research result, it is recommended to TPTI regulation as follows:

1. To control the residual stand damages caused by wood harvesting with optimal logging intensity.
2. The diameter growth of nucleus trees after wood harvesting with TPTI-System is smaller than 1 cm per year. To anticipate the next cycle, it is necessary to improve the technique of silviculture of dipterocarp forest, with the purpose to increase the diameter growth of nucleus trees.

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