

Application of silviculture treatment to Support Rehabilitation on Logged Over Area (LOA) of Tropical Rainforest, Central Kalimantan, Indonesia

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Abstract

The tropical rainforest cover of Indonesia is the second largest in the world and represents 48% of South-East Asia's or 24% of the world's tropical forest cover. One of the main tree families in Indonesian's rainforest is dipterocarpaceae. This family is also the most important timber family. Indonesia's tropical rainforest has been deforested rapidly and the remaining forest is largely degraded. The enrichment of the degraded forest using native dipterocarp species is required.

A plantation trial was established with two spacing types, two fertilizer dosages and five *Shorea* spp tree types as treatment. The highest and lowest survival rate at 6.5 years old were 86.7% for *Shorea johorensis* and 55.5% for *S. virescent*, respectively. The result of statistical analysis using ANOVA at 6.5 years old showed significant effects of treatments; (1) interactive effect of spacing x dosage ($F=18.49, p<0.0056$) on diameter growth, (2) interactive effect of spacing x dosage ($F=7.58, p<0.033$) on height growth and (3) species effect ($F=3.19, p<0.021$) on height growth. While the other treatments were not significant at a significance level of 0.05 for either diameter or height growth. *S. leprosula* exhibited the highest diameter and

height growth with MADI of 2.2 cm. year⁻¹ and MAHI of 1.32 m. year⁻¹ at 6.5 years. Almost equivalent growth was recorded by *S. johorensis* and *S. parvifolia*. Those species known as fast growing species with high survival rate were recommended as the species for rehabilitation.

Keywords: growth, spacing, fertilizer, *Shorea* spp.

Abbreviations:

ANOVA	: Analysis of Variance
D	: Diameter
H	: Height
LOA	: Logged over area
MADI	: Mean Annual Diameter Increment
MAHI	: Mean Annual Height Increment
TPTI	: Tebang Pilih Tanam Indonesia - selective cutting system
TPTJ	: Tebang Pilih Tanam Jalur - selective cutting and strip planting method

1. Introduction

Indonesia is categorized as a mega biodiversity country and is ranked first in the world for number of mammals, palms, swallowtail butterflies, and parrot species [1]. One of the ecosystem types with mega diversity is tropical rainforest which occupies about 6% of total Earth's land surface but supports more than half of the total species diversity both land plants and animals [2,3]. Tropical rainforest cover of Indonesia is the second largest in the world and represents 48 % of South-East Asia's or 24 % of world's tropical forest cover. One of the main tree families in Indonesian tropical rainforest is Dipterocarpaceae. This family is distributed from India to New Guinea [4]. In Indonesia, the diversity of dipterocarp species is highest in Sumatra and Borneo Island where the number of dipterocarp species are 106 (10% endemism) and 267 (58% endemism) [5].

Dipterocarp trees in the forest are harvested to produce wood products because the wood is categorized as "fancy wood". The timber of dipterocarp (round-wood logs) accounts for 25% of total global consumption of tropical hardwood [6]. In the primary tropical rainforest the wood volume was estimated to be 212 m³ ha⁻¹ where dipterocarps account for 86.9% of total volume [7].

In Indonesia, the tropical rainforest is mainly managed by two silviculture systems, the selective cutting system (Tebang Pilih Tanam Indonesia/TPTI) and a system combining selective cutting and strip planting (Tebang Pilih Tanam Jalur/TPTJ) [8]. In these systems, the diameter limit of commercial trees allowed to be harvested is greater than 40 cm and the cutting cycle is 30 years [8]. Enrichment planting is conducted for the TPTI system if the regeneration of the residual stand is low [8]. Moreover,

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enrichment planting of the TPTJ system will be undertaken with strip planting where the number of seedling planted in the area is 100-200 seedling/ha [8].

It has been reported elsewhere that TPTI residual stands contained various species but that the growth of small trees (dipterocarps) was delayed due to their reduced access to light [9]. Other reports have indicated that TPTI operations damaged more than 50% of the trees, affecting the structure and composition of the logged over area (LOA) [10, 11, 12]. Moreover the increasing intensity of harvesting creates a large canopy opening and allows vine invasion [9]. The tree density of commercial trees in the LOA both in TPTI and TPTJ is low when compared to the non-commercial species in the forest, especially when harvesting intensity has been high [13]. Today, a large area of Indonesia's tropical rainforest has become LOA. The rate of forest degradation in Indonesia has declined from 1,914,000 ha year⁻¹ (1990-2000), but is still at a very high rate 498,000 ha year⁻¹ (2000-2010) [14].

Deforestation and degradation of the tropical rainforest is also caused by land conversion to forest plantations, both legal and illegal logging, and other land uses such as palm oil plantations, mining, etc. The results of deforestation and degradation are an increase in the loss of biodiversity at both species and genetic levels. Deforestation and degradation will also result in the loss of a large carbon sink, forest function in hydrology, and non timber forest products.

In natural tropical rainforest, the mean annual diameter increment (MADI) of trees is as low as 0.22 cm years⁻¹ and MADI of dipterocarps is 0.34-0.40 cm years⁻¹ [13]. In one example, in the 2-4 years after harvesting, the MADI of the entire stand decreased to 0.18 cm year⁻¹, and MADI of dipterocarps also decreased to 0.29 cm years⁻¹ [9]. The data indicated that the timber stock increment in the LOA is not sufficient to achieve sustainability with a 30 year rotation if it is not manipulated to increase the productivity and regeneration.

One of the techniques to increase commercial tree stock and productivity of LOA in tropical rainforest is enrichment planting using indigenous and valuable species, such as dipterocarps. Enrichment planting in tropical rainforest will have two main advantages: improving the sustainability of timber production and conserving the dipterocarp species. Research on enrichment planting in the tropical rainforest has been instigated to improve over-logged forests [13, 15, 16]. Some species of dipterocarps identified as being useful for rehabilitation of the LOA were *Shorea leprosula*, *S. parvifolia*, *S. johorensis* and *S. platyclados* for which MADI was 1.16-1.3 cm. years⁻¹ [13, 17, 18]. However, very little information regarding silviculture treatment to rehabilitate LOA in tropical rainforest has been produced.

In this paper we focus on developing silviculture techniques to improve productivity and survival rates of *Shorea* species. The aim of the study is to test spacing, fertilizer dosage and the best species to support large scale dipterocarp plantations and rehabilitate LOA tropical rainforest.

2. Methods

2.1. Experiment site

The research was conducted in Sari Bumi Kusuma (SBK) forest company concession, Central Kalimantan (00°36'-01°10' S and 111°39'-112°25' E). The silviculture system which was used to manage forests in the concession was TPTI and TPTJ, where the diameter limit allowed to be harvested was greater than 40 cm [5]. The climate type is type A (on the Schmit and Ferguson climate classification) where mean annual rainfall was 3,730 mm year⁻¹ and the number of rainy days varied from 95 to 112 days.

2.2. Seed collection

Flowering and fruiting of dipterocarps is irregular with interval of 3-5 years and the seed is categorized as recalcitrant seed with less than one month viability after collection. The seeds of five dipterocarp species, *S. leprosula*, *S. platyclados*, *S. parvifolia*, *S. virescens* and *S. johorensis*, were collected during a mass flowering event from January to February 2005 in the whole of the concession area. As fallen fruit is eaten by animals, the fresh fruit was collected every day from the same collection sites. The fruit was sent to a nursery of SBK to be germinated and cultivated for 8 to 12 months in the nursery.

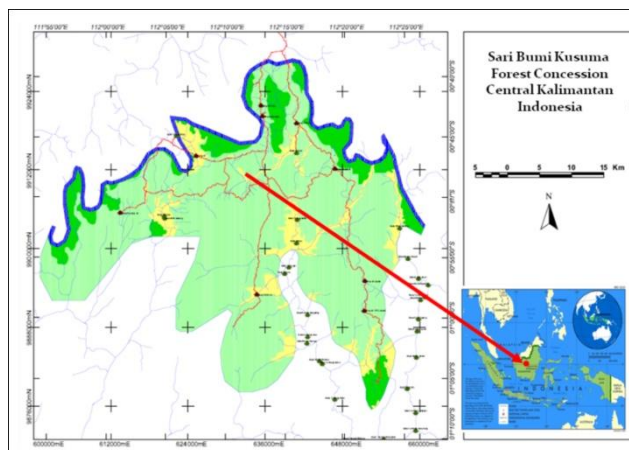


Figure 1 Location of the research site, Sari Bumi Kusuma forest company concession, Central Kalimantan, Indonesia

2.3. Site preparation and planting

An experiment was carried out in a 5.7 ha artificial gap formed in an LOA tropical rainforest. The gap was created from January to March 2006. Site preparation was done via clear cutting to ensure all of the treatments would be exposed to the same light and microclimate conditions. Clear cutting was also effective to control competing vegetation. Planting holes were approximately 40 x 40 x 30

cm. Site preparation and planting time was from February to April 2006.

2.4. Experimental design

Experimental plots were set in split-split plot arrangement with 4 replications. The main plot factor was two levels of tree spacing i.e. 6x2 m and 6x4 m. The sub plot factor was two levels of dosage of NPK fertilizer applied to the planting holes, 0 and 100 g per tree. The sub-sub plot factor was 5 species of Genus *Shorea*, i.e. *Shorea leprosula*, *S. platyclados*, *S. parvifolia*, *S. virescens* and *S. johorensis*. Each sub-sub plot contained 30 trees (3x10 trees). The growth was monitored for the inner 8 trees excluding 22 border trees every 6 to 12 months. Total tree height (H) and stem diameter at breast height (D) was measured. The data was analyzed by Analysis of Variance (ANOVA) using the software SAS 9.0.

3. Result and Discussion

3.1. Survival Rate

The mortality rate of the dipterocarps was high in the first year and slowed down until the third year. Between the third and sixth year, the mortality rate rose again. At 6.5 years after planting, the survival rates of *S. johorensis*, *S. leprosula*, *S. parvifolia*, *S. platyclados* and *S. virescens* were 86.7%, 84.4%, 72.9%, 65% and 55.5%, respectively (Fig 2.)

Survival rates of *S. leprosula* over 2 years in South Kalimantan and 3 years in East Kalimantan were reported to be 60% and 74% respectively [19, 20]. The survival rate of *S. johorensis* and *S. parvifolia* at 2 years old in a species trial at Kintap, South Kalimantan, were 51% and 48% respectively [21]. Compared to these reports, our experiment showed higher survival rates.

increases [23,24, 25]. Among dipterocarps, *S. johorensis* and *S. leprosula* were more resistant to direct sunlight than the other dipterocarps [26] and normally showed high survival in open planting where trees suffered high heat stress in the early plantation establishment [26].

3.2 Growth of Diameter and Height of Trees

The results of statistical analysis using ANOVA for the height (H) and diameter (D) of 6.5 years old trees showed a significant interaction effect between spacing and dosage (F=18.49, p<0.0056) for D. The interaction effects on H of spacing x dosage (F=7.58, p<0.033) and the effect of species treatment (F=3.19, p<0.021) were also significant. While the other treatments were not significant at a significance level $\alpha=0.05$ for either height or diameter variables (Table 1).

Table 1 Analysis of variance on silviculture treatments (spacing, dosage and dipterocarps species)

Source	DF	Mean Square		Pr > F	
		Diameter	High	Diameter	High
Blok	3	2.16	3.30		
Spacing	1	24.35	2.82	0.411 ns	0.103 ns
Error a	3	26.93	0.52		
dosage	1	0.27	0.036	0.699 ns	0.766 ns
Interaction between dosage and spacing	1	30.51	2.78	0.00561**	0.0331*
Error b	6	1.65	0.37		
Species	4	1.09	4.94	0.862 ns	0.021*
Interaction between Species and spacing	4	6.82	1.67	0.109 ns	0.376 ns
Interaction between Species and dosage	4	0.89	0.98	0.901 ns	0.641 ns
Interaction between Species, spacing and dosage	4	4.66	1.77	0.260 ns	0.347 ns
Error c	48	3.41	1.55		
Total	79				

Note: ns= non significant; * = significant at 0.05 level of probability; ** = significant at 0.01 level of probability

3.3. Species effect

Species effects were significant only in height growth (Table 1 and Figure 4). *S. leprosula* performed the best both in diameter and height growth with 14.45 cm (2.2 cm year⁻¹ of mean annual diameter increment: MADI) and 8.63 m (1.32 m year⁻¹ of mean annual height increment: MAHI), respectively, at 6.5 yrs old.

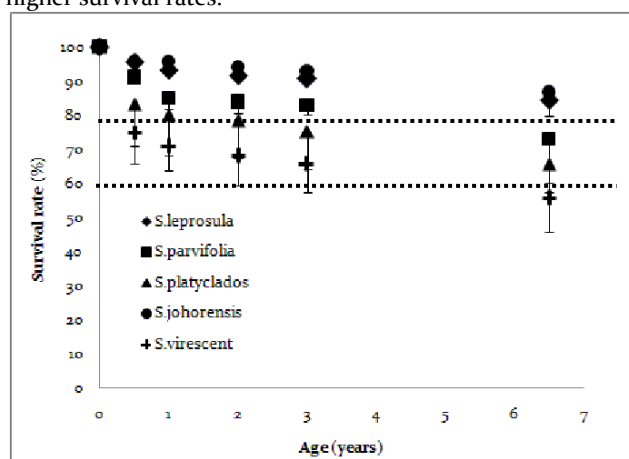


Figure 2 Survival rate of dipterocarps up to 6.5 years after plantation

The results indicated that the performance of the five species varied widely dependent on the ecological traits of the species [22]. In general dipterocarps need 30-50% of shading for the first one and a half years. After this, tolerance to light or demand for light subsequently

D and H of *S.parvifolia* at 6.5 years old were 14.07 cm (MADI= 2.16 cmyear⁻¹ of) and 7.97 m (MAHI = 1.22 m year⁻¹), respectively. *S.parvifolia* can be found on clay soil on hills below 800 m above sea level and is considered a fast grower [4].

D and H of *S.johorensis* at 6.5 years old were 13.79 cm (2.12 cm.year⁻¹ of MADI) and 7.65 m (1.17 m year⁻¹ of MADI), respectively. It has natural distribution range in Peninsular Malaysia, Sumatra and Borneo. It grows best on sites of well-drained alluvium and undulating soil up to 600 m above sea level [4].

The growth performance of the three species, *S.johorensis* and *S.leprosula*, and *S. parvifolia*, were better than the growth rate reported by other sources. Adjers et al. [13] reported that at 2 years after planting of *S.johorensis* and *S.leprosula*, heights were less than 2.5 m. Appanah and Weinland [25] reported that the growth of *S. leprosura* and *S. parvifolia* at Kepong, Peninsula Malaysia, was 0.75-1.2 cm year⁻¹ and 1.2 cm year⁻¹ in MADI for first 30 years, respectively.

S.johorensis was reported to exhibit slow growth in the line planting system (3 m planting strip width) where the survival rate and MADI at 2 years were less than 70% and 0.6 cm year⁻¹, possibly because the species was sensitive to excess light and/or high temperature [13]. This result was contradictory to our result, in which *S.johorensis* in the open area had 93% survival and 2.51 cm year⁻¹ MADI at 6.5 years old. The quite high survival and growth in the present study may be due to better land preparation techniques, whereby in this study horizon-A was added to across the whole plantation and the upper soil layer in the research location remained continuously moist.

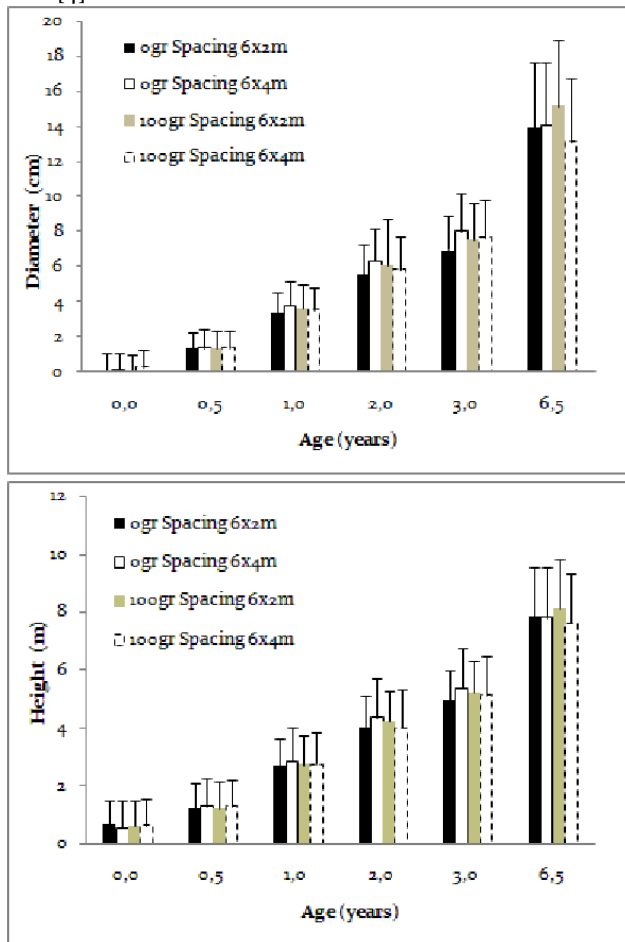


Figure 3 The spacing and fertilizer dosage of NPK did not affect growth significantly at diameter and height variables.

D and H of *S.platyclados* at 6.5 years old were 14.35 cm (2.20 cm.year⁻¹ of MADI) and 7.93 m (1.22 m. year⁻¹ of MAHI), respectively. This species has widely spread in lower mountain forest usually between 700 to 1,300 m above sea level, in peninsular Malaysia, occasionally down to 200 m in valley bottoms near mountains. By contrast, in Borneo the species grows down to 70 m above sea level.

The growth of *S.virescent* on height and diameter were 2.12 cm.year⁻¹ and 1.07 m year⁻¹ respectively (Fig 4). *S.virescent* has a narrow distribution range and can be found on flat and undulating land with fertile clay loams and hills 800 m above sea level.

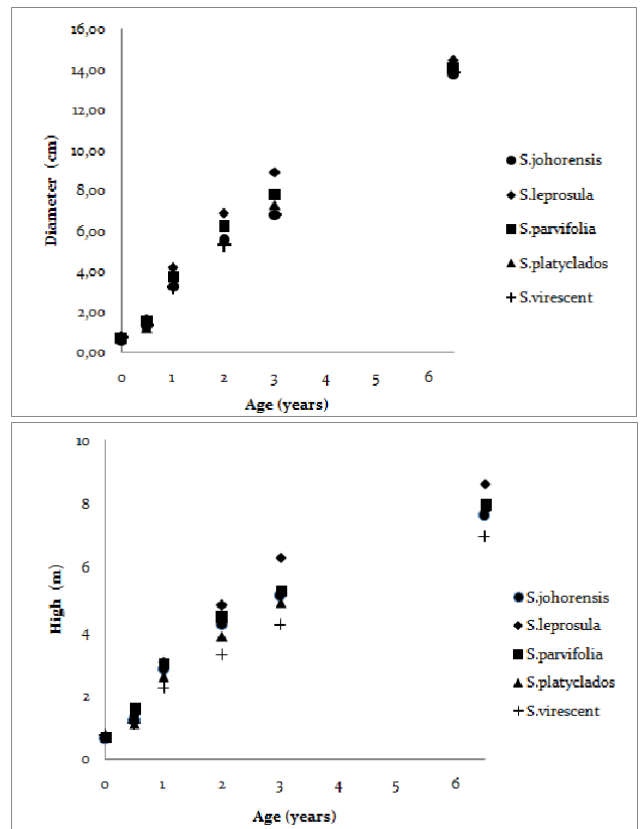


Figure 4 (a) The D growth of 5 dipterocarps species; (b) The H growth of 5 dipterocarps species

3.4 Perspectives online planting for enrichment of LOA

Enrichment of LOA by line planting started in Indonesia from 1997 as a standard silvicultural method as TPTJ. In this method, planting strips of 3 m width are made at 20 m intervals in LOA and Shorea trees are planted with 2.5 or 5 m spacing. This method causes very limited disturbance to the existing LOA ecosystem [26, 27]. The planting strip openings occupy less than 15% of land area and trees - especially dipterocarp and protected trees species i.e. *Eusideroxylon zwageri*, *Garcinia* sp., *Durio dulcis*; *Sindora wallichii*, *Tengkawang*, *Dyera* sp. etc. [28, 29] are not cut even if the trees are located in planting strips. On the other hand, TPTJ causes soil compaction and a decrease in infiltration capacity in the early establishment of plantation. Moreover, infiltration in the TPTJ system after 10 years was similar to that of virgin forest, indicating that TPTJ would increase productivity of timber without negative impact on infiltration [30]. The TPTJ system also had a positive impact on the prevalence of 17 carnivore species, including three species listed as Endangered (Flat-headed Cat *Prionailurus planiceps*, Bay Cat *Pardofelis badia* and Otter Civet *Cynogale bennettii*) and six as Vulnerable (Banded Civet *Hemigalus derbyanus*, Hose's Civet *Diplogale hosei*, Binturong *Arctictis binturong*, Sunda Clouded Leopard *Neofelis diardi*, Marbled Cat *Pardofelis marmorata* and Sun Bear *Helarctos malayanus*) which appear on The IUCN Red List of Threatened Species [31].

For species growth, increasing available light to the forest floor by creation of planting strips will increase sunflecks in the forest floor where the planted Shorea trees grow. Diffuse light intensity is very low [32] and contribution to undergrowth trees is low. Sunflecks consist of high intensity in the red light spectrum composed of uniform spectral energy between 400-800 nm, while open sunlight has a peak at 450 nm with gradual decline towards the red light spectral region [32]. Sunflecks yield sufficient energy to promote growth of plants in understory layers in the forest [33]. Gap creation for line planting in LOA can increase the occurrence of sunflecks and is expected to increase the survival rate and growth of planted dipterocarps.

Based on our survival and growth performance test, *S. johorensis*, *S. leprosula* and *S. parvifolia* exhibited the best performance in open areas. These species could be recommended as the main species for rehabilitation of tropical rainforest. These species are considered to be among the more light-demanding species of the genus *Shorea*, exhibited high tolerance to open conditions and have potential to be planted in degraded tropical rainforest [34].

Apanah and Weinland [25] suggested that to obtain optimum growth, especially in line planting, the over-story in the planting strip must be removed [25]. This suggestion was in line with our result where *S. johorensis*, *S. leprosula*, and *S. parvifolia* are shown to grow well in open sites and benefit from the removal of over-story trees. Removal of over-story trees before planting is likely to have other

advantages, including: (1) decreasing damage of planted trees and (2) improving quality of opening area to support of seedling [21].

Selection of species is also important to get success in large scale dipterocarp plantations because each species of dipterocarp has different growth performance and micro-climate requirement [5]. Choosing species of dipterocarps - especially of light-demanding dipterocarp species with TPTJ is very important to improve productivity of LOA, forest ecological services provision and forest sustainable management (FSC). Sist *et al.* [35] reported that because the MADI of the remaining dipterocarp stands of LOA was less than 0.4 cm year⁻¹ [13], in order to maintain sustainability of forest management in Indonesia, the rotation of cutting cycles was varied from 40-90 years [35]. This option is not good from the economic aspect so the TPTJ system with appropriate silviculture techniques may be used to reduce the cutting cycle (to around 25 years) [8], preventing dipterocarps from extinction and also increasing forest productivity in the future.

4. Conclusion

In order to have successful large scale plantations of dipterocarps in the secondary tropical rainforest it is very important to choose species that have good growth and also high survival rates. In Indonesia, *S. johorensis*, *S. leprosula*, and *S. parvifolia* can be chosen as indigenous species to rehabilitate the LOA of tropical rainforest. The diameter and height growth were more than 2 cm.year⁻¹ and 1 m.year⁻¹ respectively and the survival rate was more than 70% for selected dipterocarp species. On the other hand, with regards to the silviculture technique, a combination of 100 gr of NPK fertilizer and spacing of 6x2 m, was shown to be the best treatment to improve the growth of selected dipterocarps.

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