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Potentialities of line planting technique in rehabilitation of logged over area referred to species diversity, growth and soil quality

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ABSTRACT

Pamoengkas P (2010) Potentialities of line planting technique in rehabilitation of logged over area referred to species diversity, growth and soil quality. Biodiversitas 11: 34-39. Human interventions in the utilization of tropical forest resources are experiencing unanticipated consequences. The selective logging practices generally cause considerable damage to vegetation and the soil surface. It is supposed that soil condition and vegetation growth rate is deteriorated and reduced. Therefore, scientist strongly argue that the only way to achieve sustainability of Indonesian natural forest will require that the production natural forest is managed through methods that are acceptable from the perspective of environment as well as timber production. This means that there will be a strong need and incentive for methods and innovative technology. For more than two decades, tropical rainforest in Indonesia have been managed intensively under the Indonesian selective cutting (TPI) and later on by the Indonesian selective cutting and replanting (TPTI) and then, selective cutting and line planting (TPTJ) system. TPTJ, as one example of selective cutting, recently become a proper alternative should be taken into consideration in the management of production natural forest in Indonesia by planting dipterocarp species in line. In this system, planting line (width 3 m) and intermediate line (width 17 m) are made alternately. The initial width of line is 3 m and to be expanded until 10 m within 5 years to introduce more light. The objective of this research was to assess growth and soil quality of TPTJ system. The object of research was TPTJ plot of various ages from 1 year to 7 years. For achieving the objective, 14 sample plots measuring 200 m x 200 m each, were laid out at research plots. The result showed that growth respond of *Shorea leprosula* toward the width of planting line was better comparing to *Shorea parvifolia*, but generally from this growth assessment it seems that individual tree has a successfully performance. In terms of soil quality, it was seen that planting line establishment of 3 m and more, does not cause soil properties decrease in the whole plots.

Key words: selective logging, production forest, selective cutting and line planting, dipterocarp species, growth, soil quality.

INTRODUCTION

Tropical rainforest is drawing much attention nowadays, primarily due to threats to its future sustainability is getting worse. Tropical forests generally have faster growth due to considerable amount of solar energy absorption, as well as important role in maintaining the balance of global carbon. In Indonesia the principal causes of natural forest destruction is commercial timber harvesting, especially dipterocarp species. The decrease and degradation of tropical forests affect not only the production of timber but also environment. The loss of biological diversity threaten the sustainable and development of forests ecosystem in the future. Maintaining biodiversity has become a global concern and requires the implementation of sustainable management practices at a range of spatial scale (production forests). The ecological importance of a species is very different and can have a direct effect on the community structure, and thus on overall biological diversity. For example, a dipterocarp species which support an endemic invertebrate fauna of hundred species evidently make a greater contribution to the maintenance of global biological diversity (Schulte 1996). In relation to this, rehabilitation of degraded dipterocarps forests is most urgent matter from the viewpoints of both compensation or enrichment of ecosystems (for maintaining and the preservation of species population) and sustainable forests management. It is estimated that the growth and regeneration rate of dipterocarp species has decreased in the logged-over forest. Many of logged-over forests still contain enough residual dipterocarp trees, to give rise to a sufficient supply of ephemeral seedling stock. As a consequence of repeated selective cutting, residual dipterocarp trees are scarce or of lack high-valued timber. An additional source of valuable timber could be obtained by planting dipterocarps in line. Enrichment planting is applied to add natural regeneration where this is insufficient. The best known enrichment planting is line planting which has a number of variants throughout the tropics (Lamprecht 1989). The application in Indonesia, line enrichment planting means planting under the forest canopy.

The common practice of high valued timber species, such as meranti, is planted in irregularly pattern as in TPTI system. This kind of traditional methods resulted in low growth performance. It is indicated by mean of annual increment diameter in permanent sample plot of less than 1 cm year^{-1}. One of the problems in enrichment planting with dipterocarps is that most species are adapted to narrow ecological niches, which prohibits successful establishment of most dipterocarps on planting. The most important conditions for success of line planting are light control, species choice and tending intensively (Weidelt 1996). The most critical treatment is improvement of light conditions of the seedlings and saplings by release cutting or canopy opening. The growth of South East Asian dipterocarp forests varies from 8 m^3 ha^{-1} $year^{-1}$ (Appanah and Weinland 1993) to 17 m3 $ha^{-1}year^{-1}$ (Evans 1982). Based on the findings, the new planting technique (line planting) is implemented to accelerate growth of dipterocarps species.

In the management of production forest, its productivity becomes a criterion which should be considered. Productivity itself depends on site quality and the developed silvicultural technique. The main challenge in rehabilitation of logged over production forest is creating growth site condition which is suitable for growth of dipterocarp species. For the purpose of increasing productivity of logged over natural production forest, the application of selective cutting and line planting System (TPTJ) which afterwards change into the so called ”intensive TPTI” (intensive Indonesian selective cutting and planting) or ”SILIN” (intensive silviculture) is one alternative which should be considered in managing production natural forest by planting dipterocarp species in line. In this system, after selective cutting is practiced, alternate line of 3 m wide for planting and 17 m wide for conservation as intermediate line are made. The initial 3 m width of planting line will be expanded to 10 m within 5 years, to allow more lights to penetrate. It seems that this system give impression that it will probably create considerable effect on vegetation, soil quality, and finally on plant growth.

Soil quality constitutes a complete description of specific condition of the soil for carrying out its function (Karlen et al. 1997). For this purpose, study on the change of soil quality, which up to now is rarely discussed, is very important in the practice of intensive TPTI. Information on soil quality which constitutes a sensitive indicator can be used to answer several questions related to probable decrease in forest productivity and amount of carbon stored in forest soil. Besides that, information on soil quality will help in investigating several key components of forest ecosystem, such as productivity and sustainability of forest management system, soil and water conservation, and contribution of forest area on global carbon cycle (O'Neill and Arnacher 2004). Therefore, soil quality is an important aspect in relation with issue of sustainability and environment (Lal 1998).

The objective of this research is to analyze vegetation aspects, plant growth at several ages of one to seven years, and condition of soil quality at age of one to five years.

MATERIALS AND METHODS

Study area description

The research was conducted from June through August 2007 in Seruyan Forest Cluster, Central Kalimantan which included in The study was conducted in PT. Sari Bumi Kusuma forest concession. The elevation is approximately 175-276 m above sea level. The area is originally covered with typical Mixed Dipterocarp Forests in which dominated by dipterocarpaceae species. The mean annual temperature is 25-28^{o}C, while the mean rainfall is 3000 mm year $^{-1}$. The soils in study site are dominated by Ultisol (Yellow-red Podsolic).

Experimental design

Vegetation collection was done in seven different ages of plantation, namely 1 to 7 years old. Method for data collection used combination of transects line and plot establishment (Moore and Chapman 1986). Several plots, i.e. size 20 m x 20 m for observation at tree level, size 10 m x 10 m for pole level, size 5 m x 5 m for sapling, and 2 m x 2 m for seedling, were established along the transect. Each transect line has 20 m width and 200 m length. Within one plot, there were two transects line. To ease the placement of observation plots, the sample units (plots) should possess similarity in terms of soil properties and slope (0-8%). Plots were installed at seven different ages, i.e. 1, 2, 3, 4, 5, 6, and 7 years old of plantation by using purposive sampling methods. The total sample plot was 7 plots x 2 replications are 14 plots. The each sample plot unit measuring of 200 m x 200 m or 4 ha, thus the totally area was 56 ha (Figure 1). The data collected in this research were primary data on diameter and height growth of *Shorea leprosula* and *Shorea parvifolia* at the ages of 1, 2, 3, 4, 5, 6, and 7 years, and soil data taken from depth of 0-10 cm and 10-20 cm, in the planting and intermediate line. The planting distance is 2.5 m x 20 m (200 plants ha^{-1}). Within one sample plot, there were 3 planting line which serve as observation plots for diameter and height of *S. leprosula* and *S. parvifolia*, whereas soil sample was taken as composite sample. Through this false time series study (pseudo plots), there would be obtained some ideas concerning several indications of growth recovery.

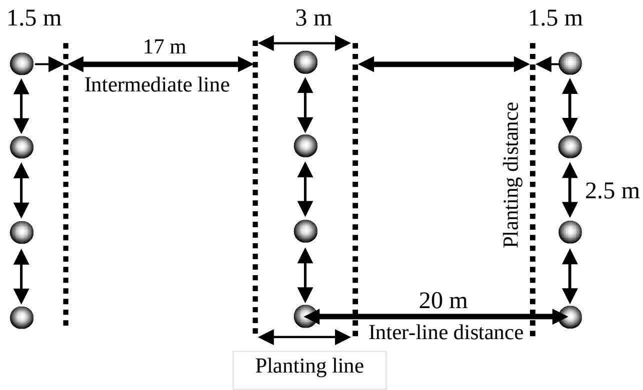

Figure 1. Lay-out of TPTI intensive (TPTJ) implementation

Data analysis

Statistical analysis. Vegetation data will be analyzed to find out species density and species composition in a certain plantation plot. From the above vegetation data, average of the stand height and diameter were calculated. On the other hand, data of soil physical, soil chemical and soil biological are analyzed by using Mann-Whitney test to compare median value of planting line and intermediate line.

Analytical network process. The soil quality evaluation was obtained by clustering the result of weight count of every soil quality indicator. Some of soil parameters used was bulk density, soil aggregate stability, C–organic, N–total and C–mic. The mentioned weight value is found by using Analytical Network Process (Saaty 1996). The final value of soil quality is the results of multiplication between weighted value and score value.

RESULTS AND DISCUSSION

Species composition

The species composition was clustered into dipterocarpaceae and non-dipterocarpaceae. The mentioned group species can be seen in Table 1.

Table 1. Species composition and density in each study plot

Stand (age)	Species density (N/ha)			
	Tree	Pole	Sapling	Seedling
1	108 (13%)	90 (11%)	1040 (11%)	5250 (12%)
2	103 (25%)	115 (26%)	1160 (29%)	12000 (11%)
3	115 (10%)	175 (3 %)	940 (9%)	4875 (15%)
4	160 (24%)	64 (19%)	336 (19%)	3300 (94%)
5	154 (19%)	80 (15%)	464 (45%)	4700 (15%)
6	141 (28%)	100 (26%)	384 (58%)	6800 (60%)
7	115 (13%)	144 (39%)	400 (44%)	3400 (64%)

Note: Figures in the brackets showed percentage of dipterocarp species.

In general, it can be said that the number of species per ha in all level is fluctuating, there is no increase tendency or consistent decrease starting from plot of 1 year to 7 years. As regards with contribution of dipterocarp species towards the total number of species in all level, it showed that non dipterocarp species is the largest except for seedling in plot of 4, 6, and 7 years old, and sapling in plot of 6 years. Some tree species of dipterocarpaceae family which is classified commercial found in the plot among others are *S. leprosula, Shorea laevis, Shorea johorensis*, etc. In general sense, the total of regeneration and tree level in all research plots classified over average if it is referred to the regulation of Indonesian selective cutting and replanting system (TPTI). In our study, as resulting from selective cutting of the overstorey is expected to create numerous canopy openings, and increased light availability and changed the species composition. This finding in line with the research conducted by Griffis et al. (2001), and Angers et al. (2005) who stated that enhancing light availability induces advance regeneration and change coverage in the understorey, even the species richness of e layer.

The results showed that the proportion of dipterocarps species in all plots study is smaller compared to non dipetrocarp species. Referring to the contribution tree level of dipterocarp species in primary forests which reaches 18.4% (not presented), it appears that the value of dipterocarp species in plot study were still accepted. In the plots of primary forest are found as many as 38 species per ha for tree level. The same finding is also reported by Mauricio (1991) in Philippines who recorded 31 species per ha. An average, the total number of species found in the plot study were 35 species per ha.

In average, the total seedling from dipterocarp species was relatively balanced compared to non dipterocarp. This was caused that dipterocarps species had trouble for competition with other species to dense crown condition. This species is very sensitive towards light so that have preference towards certain micro condition.

Based on the regeneration observation in seedling level, selective cutting and line planting system apparently gave stimulus as indicated by density in plantation plots. In the case of sapling regeneration, it appears that the recruited seedling which already existed before, has not reached the sapling stage may be due to increasing competition. It is recommended *Potentialities of line planting* that in all plots should be subjected to some silvicultural treatment, such as liberation to give better growing space for dipterocarps species by reducing competition. In relation to biodiversity, Matthews et al. (2000) stated that forest ecosystems, which can be defined by presence of tree canopies that cover more than 10% of a site have not escaped the loss of biodiversity. Thus, the application of line planting system on management of logged-over forest caused on acceptable level changes on vegetation aspect.

Growth respond

Data of diameter and height growth of *S. leprosula* and *S. parvifolia* at ages of 1 to 7 years can be seen in Table 2. The diameters of two dipterocarps species, i.e. *S. parvifolia*, and *S. leprosula* were measured in planting line, which have different width, as consequences of increasing width of planting line according to increasing age of plantations.

Table 2. Growth performances for species planted in study plot

Species	Stand age (yr)	MAI diameter (cm yr^{-1})	MAI height (cm yr^{-1})
Shorea leprosula	1	0.78 (n= 356)	249.73 (n=356)
	2	1.57 (n=158)	154.53 (n=158)
	3	2.09 (n=162)	175.10 (n=162)
	4	2.07 (n= 55)	166.35 (n= 55)
	5	2.08 (n= 15)	168.89 (n= 15)
	6	2.08 (n=12)	173.13 (n= 12)
	7	2.19 (n= 84)	175.11 (n= 84)
Shorea parvifolia	1	0.70 (n= 15)	209.00 (n=15)
	2	1.17 (n= 6)	125.00 (n=6)
	3	2.30 (n= 17)	165.49 (n= 17)
	4	1.85 (n= 10)	136.25 (n = 10)
	5	1.35 (n=9)	148.00 (n=9)
	6	1.48 (n=9)	137.50 (n=9)
	7	1.60 (n=12)	133.81(n=12)

Table 2 showed the growth performance of line planting. In general, it can be said that the growth of *S. leprosula* was better than *S. parvifolia*, though some trees failed to survive due to natural causes. At seven year of age, *S. leprosula* showed the greatest of Mean Annual Increment (MAI) in diameter of 2.19 cm year^{-1}, followed by age 3, 6, 5, 4, 2, 1 year at 2.09 cm, 2.08 cm, 2.08 cm, 2.07 cm, 1.57 cm, and 0.78 cm respectively. One can say that there was a consistent increase in diameter growth, with increasing age of plants. *S. leprosula* seems to be benefited slightly from more open canopy (Weidelt and Banaag 1982). This finding was confirmed in this study. The results showed the importance of a sufficient amount of overhead light when planting *S. leprosula*. Mean Annual Increment in diameter of *S. parvifolia* was 0.70 cm to 2.30 cm per year. Generally, from this growth, it seems that individual tree has a successfully growth performances in terms of diameter and height. We recommend opening up the canopy along the line before planting. Lamprecht (1989) stated that the greater the width the better the light conditions. It seems that generalization when planting dipterocarps are dangerous. Dipterocarp species have various requirements for light in the planting line.

At the present, line planting method is applied for enrichment planting under the TPTJ system in Indonesia. This system has been successfully implemented in 6 forest concessions model and now is being expanded to more than 20 concessions managing mostly large proportion of logged-over dipterocarp forests. The success of line planting depends on light penetration. Therefore, the most critical treatment is improvement of light conditions by release cutting or canopy opening. Light deficiency is the main factor causing death of plants. Light conditions are related to the line width and stand height. The line width changes depending on the light requirements of the species planted, for example, relatively light demanding species such as *S. leprosula* and *S. parvifolia*. Consequently, the planting line is expanded to introduce more light (Weidelt, 1996). Hence, direction of line, width, and maintenance method of line planting are important for its success. Appanah and Weinland (1993) emphasized the importance of removal of the overstorey in line planting.

Dipterocarp seedlings are naturally adapted to germinate and establish in the forest understorey where it is dark and moist. Complete removal of the canopy may lead to high mortality of the dipterocarp seedlings, while removing too little may suppress growth. Using the line planting has advantage, among others, a wider range of dipterocarps species can be used and consequently, mortality due to heat and water stress will be reduced.

In relation to our results, Dupuy and Chazdon (2008) suggested that the choice of management system for these secondary forests can strongly influence the direction and rate of succession. Management systems that mimic natural canopy gaps could enhance tree species diversity and favor the regeneration of shade tolerant species, potentially accelerating convergence of secondary stand to old-growth forest composition.

The difference of soil properties between planting line and intermediate line

To find out whether there is a difference soil physical, chemical and biological property between planting line and intermediate line in every age is done with. Statistical test Mann-Whitney (Table 3) was used to asses soil physical, chemical and biological properties between planting line.

Table 3. Median of soil physical, chemical and biological properties in all plot studied

Soil	4 years		3 years		2 years		1 year	
properties	PL	IL	PL	IL	PL	IL	PL	IL
Agregat stb	70.50$^{a)}$	73.13^{a}	73.98^{a}	74.70^{a}	75.61^{a}	69.33^{a}	67.13^{a}	69.82^{a}
C-org	1.02^{a}	0.85^{a}	1.37^{a}	0.86^{a}	1.13^{a}	1.25^{a}	0.92^{a}	1.59^{a}
N-total	0.09^{a}	0.08^{a}	0.12^{a}	0.08^{a}	0.10^{a}	0.11^{a}	0.09^{a}	0.12^{a}
C-mic	917.40^{a}	973.30^{a}	880.20^{a}	541.70^{a}	933.40^{a}	867.40^{a}	746.00^{a}	721.50^{a}

Note: Number followed by the same letter at the same row showed that there were no significant differences at α level of 0.5%, PL = Planting Line, IL = Intermediate Line

C organic in all research plots including low category, namely in the range between 0.85% to 1.59% and included low for N – total namely between 0.08 to 0.12% with variability between plots is relative small. The changing responses of soil C – organic and N – tot is extremely influenced by biotic factor vegetation, abiotic (temperature and moisture) and management (Parton et al. 1987 in Handayani and Prawito 1998). Further was added by Gregorich et al. (1997) that soil organic matter level caused by two reasons first decomposition process increased due to environmental changes (soil moisture, aeration and soil temperature). Both C and N input is low due to the decrease of organic residue input in an ecosystem. Other possible cause is composition species as important actor for C – organic formation in which each species has difference in carbon of land C – organic input. Handayani (2004) stated that the lower level of total C and N may have resulted from a combination of lower C inputs because of less biomass C returned and greater C losses because of aggregate disruption. The trends toward lower of total C and N in disturbed land is probably caused by the breakdown of aggregates (Gupta and Germida 1988; Blair et al. 1995), and greater organic matter oxidation following deforestation (Handayani et al. 2001)

The above opinions are met with field finding. As observed, in general sense soil C – organic in the whole research plots can be classified low. The low of C – organic and N – total in the related primary forest were due to increasing of decomposition processes in which implicates to C and N pool decrease. Other possibility low C – organic and N – tot is indigenous value from the primary forest ecosystem or in other words soil organic matter in the primary forest governed by environmental condition.

The actual condition of land closure which began to dense was assumed to affect microorganism activities result in C – mic content was high in plots of 3 years old and 4 years old. The behavior of C – mic is in complex which is affected by soil temperature, soil moisture, pH, texture and microbial activities The results showed no difference in soil physical properties tested namely aggregate stability in the planting line and intermediate line,. and oil chemical properties, namely C- organic and N-total, . The same also observed in C-mic. Based on statistical test assessment, soil physical, chemical or land biological properties in 1 year plants (3 m width) did not differ with condition in intermediate line. The same conclusion was obtained in 2 years old plant (4 m width planting line), 3 years old plant (6 m width), 4 years old plant (10 m width). In other words that establishment of planting line did not affect soil properties decrease in the whole plots studied. Assumption or perception that planting line establishment in silviculture system will change soil properties was not proved.

Nutrient leaching had not occurred in the planting line due to the fact that planting line was still shaded by meranti plants and there was still accumulation of fresh organic matter which resists the leaching process.

Soil quality value

Soil quality value in each plot evaluated through threshold soil quality is depicted in Table 4. The soil quality indicator used to decide soil quality value is bulk density, aggregate stability, C-organic, N-total and C-mic. Due to there is a dependent influence inter soil quality indicator mentioned so determination of soil quality value in the research plots were done by analytic network process (ANP).

Table 4. Category of soil quality value

Value of soil quality	Category
8-10	Very good
6-7.9	Good
4-5.9	Moderate
2-3.9	Low
0-1.9	Very low

Final value of soil quality was obtained by multiplication between scoring value (0-10) as a result of laboratory analysis with weighted value. The final weighted value of C-mic is bigger compared with other Indicators. C-mic gives biggest contribution (0.302) towards soil quality as compared to other indicators, such as bulk density (0.075), aggregate stability (0.121), C-organic (0.268), and N-total (0.234). This indicates that C-mic plays an important role in deciding soil quality. The soil quality value which obtained from multiplication between scoring value and weighted value, can be seen in Table 5.

Table 5. The final soil quality value in each study plot

Plot	Soil quality value	Category
Primary forest	4.707	Moderate
4 years	3.937	Low
3 years	4.205	Moderate
2 years	4.130	Moderate
1 year	4.055	Moderate

Table 5 showed that soil quality in the whole plots is in category low to medium. The soil quality conditions in the area of TPTJ of 3, 2 and 1 year old exist in medium class, and followed by 4 years old at 4.205, 4.130, 4.055, and 3.937 respectively. The value of soil quality in plantation of 4 years old were lower compared to the others plot because of less N-total and C-organic level at 0.08% and 0.97% respectively. These proved that lower level of total N and C-organic in the ecosystem of 3 years old plantation may have resulted from the combination of lower C inputs because of less biomass returned or faster decomposition processes. In other words, silviculture practices should be directed into site improvement such as creating micro climate in planting line, to allow more lights to penetrate and to increase decomposition processes.

Soil quality is a critical component of sustainable agriculture, while in term soil quality is relatively new, it is well known that soils vary in quality and that soil quality changes in response to their use and management (Handayani 2001). Type of land use is sustainable only when soil quality is maintained or improved. In this case, a quantitative assessment of the changes in soil quality provides a measure of sustainable management. Carter (2002) stated that a major component of sustainable land use is to sustain and improve the quality of the soil resource base. Monitoring is important, but the usefulness of the data will only be realized if it is used in management decisions to correct or improve the quality of the soil resource.

Increasing forest productivity that maintaining soil quality has been a continuing and fundamental management issue for forest soil researchers. Line planting system so called intensive silviculture, allowing foresters to use intensive management practices that increase productivity above native levels while avoiding activities that degrade soil quality (Carter and Foster 2006). This is clearly demonstrated by this research shows growth and soil quality tends to recover after planting, implying that forest productivity increased both by shortening the rotation and increasing carrying capacity (Burger 2009).

Logged-over forest invariably decrease soil organic matter content and open nutrient cycles (Olson et al. 2000). In turns, soil productivity decreases. The successes of line planting system using intensive silviculture in dipterocarps plantations have increased diameter growth by around 2 cm per year depending on the site. In relation to this, Fox et al. (2007) stated that practice on soil treatment, fertilization, and weed control have increased pine plantation productivity by 5-10 m^3 ha^{-1} $year^{-1}$. This increased productivity has been achieved by understanding forest response to each forest practices as well as the cumulative effects of intensive silviculture.

CONCLUSIONS

In general, plant growth of *S. leprosula* was better than that of *S. parvifolia*. Diameter and height growth of *S. leprosula* showed positive respond, whereas for *S. parvifolia* this condition was not favorable. The overview of the line planting indicates the plantations following this technique have good growth performance that leads to an increase in resource base. The salient criteria of line planting under TPTJ system considers that to be followed by the forest managers to make it sustainable. Establishment of planting line does not cause soil properties decrease in the whole study plots so that perception that planting line establishment in TPTJ system will cause changes towards soil properties is not proved. Status of soil quality in primary forest and planting area was in the categories of ranging from low (3.937) to moderate (4.707). The soil quality improvement occurred in the area of TPTJ while soil quality status at 4 years old TPTJ included in the low category.

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