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Tree diameters and planting distance as the most important factors for the liberation of tree competitors in silvicultural systems of TPTJ

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Abstract: Maintenance of forest plants intensively under the selective cutting and line planting system (TPTJ) will accelerate the growth of plant species. Widening the line planting improves the penetrating light, thus increasing growth rate of the plants. The purpose of this study was to determine the relationship between stem diameter and distance of competitor tree to forest plant, as well as stem diameter and canopy diameter as a basis for the liberation of competitor trees on the TPTJ system. Regression analysis showed that the competitor trees diameter and distance can be used as one technique of vertical liberation with equation correlation for both variables is $X = 3.567 - 0797dbh + 0.121dbh^2 - 0.004dbh^3$. The approach of liberation using correlation between stem diameter and canopy diameter can not be used as a vertical liberation technique with equation correlation between the two variables is $Cda = 2.535 - 0.031dbh + 0.050dbh^2 - 0.002dbh^3$. The study revealed that saplings with diameter (dbh) 5−9 cm located at 1−2.5 m of subplots must be slashed down. For sapling with diameter (dbh) ≥10 cm dbh located at 3−5 m of the center of planting line must be girdled.

Keywords: Selective Cutting and Line Planting System, Forest Productivities, Widening of Line Planting, Vertical Liberation, Maintenance of Plants

1. Introduction

Forests play important roles for human as they offer a wide range of both wood and intangible benefits, all of which have a value but only some of which are currently expressed in monetary terms. However, the rate of deforestation continues to increase significantly, thus the future direction of forestry development should be focused on its rehabilitation, especially the management of logged over forest areas and the development of plantation forests by promoting the principles of forest sustainability.

As the Indonesia population have increased significantly it will have a severe impact on the demand for timbers and additional lands to establish the infrastructures necessary to support the growing, thus they will cause the deforestation of its tropical rain forests. Therefore, the implementation of forests rehabilitation requires a large input, such as strong need and incentive for methods and innovative technology. The increasing demand for wood can be met with the increasing timber productivity by sustainable forest management. Ministry of Forestry issued a policy in exploitation activities to be carried out by holders of license for utilization of timber forest products (*Izin Usaha Pemanfaatan Hasil Hutan Kayu*-IUPHHK) is a system of silviculture in forest logging to obtain sustainable yield.

Silvicultural system of selective cutting and line planting system (TPTJ) is one of the methods for forest management to improve forest productivity through planting the pathway system [1]. Line planting is (width 3 m) while the distance between line planting is (width 20 m) are made alternately. In this system, plant maintenance in the line planting can increase the productivity of trees, then it is necessary widening of line planting in order to increase the penetrating light to support plant growth.

Widening the distance of line planting is a method usually practiced under the silvicultural system TPTJ. The implementation of TPTJ system was initiated by making a strip/line planting three meters wide, planting line gradually widening until it reaches 6−7 m by the end of 3rd year. This method proved to be successful to increase the forest tree productivity, however, such methods has also disadvantages as widening the distance of line planting requires qualified human resources for systematic practices. Such drawbacks will be minimized by the liberation of the vertical planting based relationship tree trunk diameter and distance tree competitors. A study to determine the best liberation treatment for TPTJ tree is really required.

The objectives of this study were to determine the relationship between stem diameter and distance of competitor trees, as well as stem diameter and canopy diameter as a basis for the liberation treatment of competitor plants on the selective cutting system row.

2. Methods

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2.1. Period and Study Area Description

The study was carried out from April to May 2013. The study area was located at the production forest of PT. Suka Jaya Makmur, West Kalimantan. The objects of the study were plant growth at several ages namely, of 6 years (Annual Working Plan [AWP] 2006), to 5 years (AWP 2007), 4 years (AWP 2008), 3 years (AWP 2009), and 2 years (AWP 2010).

2.2. Location of Plot Establishment

Several plots, i.e. size 100 m × 100 m for plant growth of 6 years (AWP 2006), 5 years (AWP 2007), 4 years (AWP 2008), 3 years (AWP 2009), and of 2 years (AWP 2010) for observation were established along the transect. Several plots, i.e. size 20 m × 20 m for observation at tree level, *circular area* (r = 5 m) and *inner circle* (r = 2.5 m). Method for data collection used the modified of transects line and plot establishment by [2] as shown in Figure 1.

Measurement of inner circle was carried out for sapling with stem diameter of 5−9 cm and the tree distance within line planting is 2.5 m. Whereas for the circular area measurement will be implemented for pole with diameter 10−19 cm and trees with diameter ≥20 cm and its the tree distance within line planting is 5 m. Measurement of the tree distance within line planting of *Meranti* (Dipterocarp species) with its plant competitors in the plot is done by using a tape meter, and the height the diameter of the trees measured is 1.3 m above ground level.

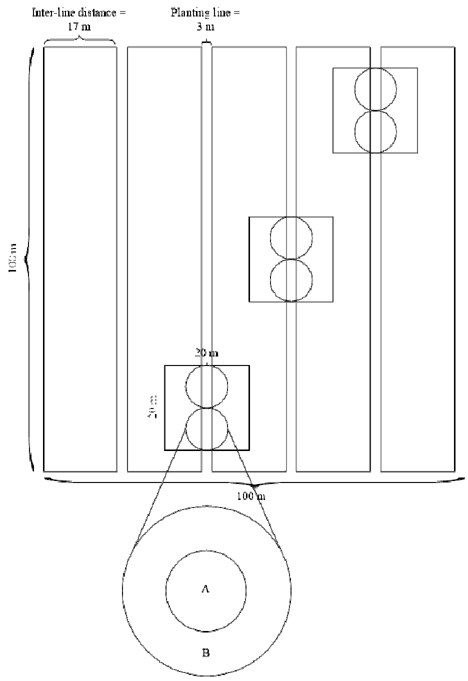

Figure 1. *Observation plot. A = inner circle (r = 2.5 m) for forest stand and trees; B = circular area (r = 5 m) for forest stand*

2.3. Basal Area

The diameter of tree is used as the growth rate of basal area (basal area). It is one of the important factors to assess the tree growth and on subplots [3]. The growth of basal area per hectare was calculated based on the different number of living trees in a plot throughout basal area due to the vegetation cover change. Formulation to calculate the value of basal area per hectare is as shown in Equation 1.

$$BA = \tfrac{1}{4}\pi d^2 \qquad (1)$$

Note:
BA = basal area (m^2/ha)
d = diameter at breast height (dbh)

2.4. Measurement of Canopy Closure

The canopy closure was calculated based on the percentage of the image of sky reflected in the mirror with specific ranks. Fully open (100%) was ranked into 4th, 75% opened was ranked into 3rd rank, 50% opened was rank into 2nd rank, 25% opened was rank into 1st rank, and when sky produced no image it was rank into 0. All data were summed up to be the value of certain point. Average value in each plot is calculated with the Equation 2.

$$T_i = \frac{t_1+t_2+t_3+\cdots+t_n}{N} \qquad (2)$$

Note:
T_i = canopy openness
t_n = the value/weight at each measurement point
N = number of measurement points

The percentage of canopy closure (T) at each location is based on the Equation 3. For this study measurement was carried out before and after logging.

$$t = 100 - T_i \tag{3}$$

2.5. Measurement Canopy Diameter

Canopy diameter is the average value of the length and width of the respective tree canopies. The diameter of the canopy was calculated based on the two methods, namely length of canopy (CdWd-Crown Diameter Width) and the width of the canopy (CD90-Crown Diameter at 90°). The length of canopy (crown diameter width) is the measurement of widest distance along the canopy azimuth, and the width of tree canopy (crown diameter at 90°) is the shortest distance between the azimuth with 90° of back azimuth canopy of crown diameter width. The measurement of the canopy diameter was up to 10 cm accuracy [3].

2.6. Observations and Analysis

2.6.1. Regression Analysis

Regression equations were used to describe the relationship between tree distance and diameter of the tree is as shown in Equation 4 [4].

$$X = \alpha_0 + \alpha_1 dbh + \alpha_2 dbh^2 + \alpha_3 dbh^3 \tag{4}$$

Note:
dbh = diameter at breast height (cm)
X = tree distance within line planting (m)
α_0 = constant
$\alpha_1, \alpha_2, \alpha_3$ = regression coefficient

Regression equations to describe the relationship between canopy diameter and tree diameter is as shown in Equation 5 [5].

$$Cda = \alpha_0 + \alpha_1 dbh + \alpha_2 dbh^2 + \alpha_3 dbh^3 \tag{5}$$

Note:
dbh = canopy diameter (m)
Cda = tree distance within line planting (m)
α_0 = constant
$\alpha_1, \alpha_2, \alpha_3$ = regression coefficient

Relationships level based on [6] is presented at the following Table 1.

Table 1. *Guidelines for The Interpretation of The Correlation Coefficient*

Interval Coefficients	Relationships
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Medium
0.60–0.799	Strong
0.80–1.000	Very strong

Source: Statistika untuk penelitian (Sugiyono 2011)

3. Result and Discussion

3.1. Plot of Study

The basal area (BA) appeared in every Annual Planning Program were different or fluctuating. The highest BA was in 2007, it was 20.51 m^2/ha, while the lowest was in 2010 it was 4.78 m^2/ha. In 2010 only one type of plant species was obtained, it was *bangkirai*, thus 2010 was the smallest BA among Annual Planning Programs presented. In addition, the status of the plots before logging, as well as its logging intensity was factors that affect the amount of residual stands in the basal area. Moreover, reductions of total number commercial trees of > 20 cm diameter were very high due to the relatively high intensity of logging. The highly destruction of forests left only few residual trees. This is consistent with the statement of [7] which stated that important factors to describe forest stands are age, composition, structure, and a place to grow or its geographical areas. Based on these results, the intensity of girdling process for trees liberation should be reduced as the coverage of BA in each Annual Planning Program were small, they were not match with the required standard of basal areas of tropical forests. This program was implemented to minimize the damage and reduce basal areas.

3.2. Canopy Closure

The most important conditions for success of line planting are light control. Light intensity for forest floor is very important, for the germination and growth of seedlings. The intensity of light entering the bottom of this canopy will also affect the microclimate beneath. The light intensity is directly influence the growth of forest plants through the process of photosynthesis, the mechanism of opening and closing of stomata, chlorophyll synthesis, and cell differentiation are expressed with increasing height, diameter, leaf size, leaf and stem structure. In TPTJ silvicultural system, the most critical treatment is improvement of light conditions of the seedlings and saplings by liberating competitor trees for canopy opening. The important component for the growth of *meranti* is light. This is supported by a study conducted by [8] and [9] that enhancing light availability induces advance regeneration and change coverage in the understory, even the species richness of understory layer. The observation of the percentage of canopy cover before and after logging can be seen in Figure 2.

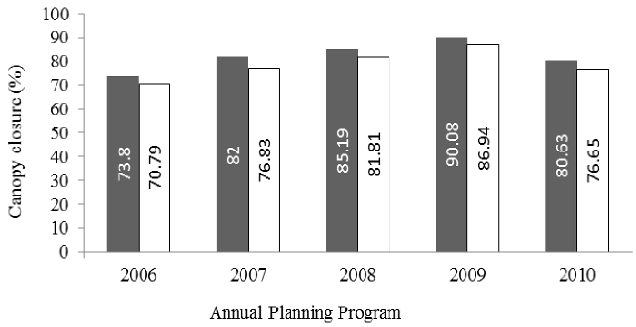

Figure 2. *Canopy cover before (■) and after logging (□)*

In general the percentage of canopy cover prior to harvesting was greater than after logging (Figure 2). It can be concluded that a decline in canopy cover after logging occurred in 2006, it was 3.01%, and the highest was in 2007, it was 5.71%. According to the Annual Report of 2006-2009, the canopy cover was increased significantly on 2006, and it was due to the fact that intensive maintenance was performed that year. On the 2010 the canopy cover was decreased, this was due to the fact that land preparation was started that year, thus, there were more open spaces compared to other areas stated in the 2007-2009 Annual Report. According [10] the percentage of canopy closure does affect the growth of trees in line planting, therefore, other method to conserve forest stands by girdling or slashing tree competitors for light intensities for maximum growth rate of trees is really required.

According to [1], managing the production of natural forest as applied in the TPTJ system by thinning of *meranti* and slashing down of competitor trees at line planting intensively for 1 year old plants led to increasing the residual organic matter thus it increased the accumulation of organic matter in line planting, and it is very important in the practice of intensive TPTI. It seems that this system give impression that it will probably create considerable effect on vegetation, soil quality, and finally on plant growth. In addition, reducing the forest canopy cover decreases the canopy interception and increases the net rainfall in the forest floor, which is important ecological factor for the trees grow.

Therefore, widening intensive line planting by performing both vertical and horizontal liberation are really required as they will help reduce the competition between trees in line planting with weeds. This statement is closely related to the statement by [4] which explains that the growth of red *meranti* (*Shorea leprosula*) planted at the open space in logged areas and get sufficient sunlight, their growth rate is better than those which are planted at shaded areas with less sunshine.

3.3. Relationship of Tree Diameter and Planting Distance

Equation (4) $X = 3.567 - 0.797dbh + 0.121dbh^2 - 0.004dbh^3$ is a cubic equation, and based on this equation the coefficient of determination (R^2) was obtained, and it was 63.4%. This coefficient of determination shows the variance of planting distance of trees competitors was 63.4% can be explained by the variance that occurs in tree diameter variable, or 63.4% of competitors tree distance is determined by the size of the diameter of the stem, and the remaining 36.6% of the variance explained by the others variable. Based on Table 1, the cubic equation that produces the coefficient of determination (R^2) is 63.4% had a strong relationship, meaning that the variable diameter of the stem has a strong relationship to the level of the variable tree distance competitors. Based on the test model fit (sequential analysis of variance) Equation (1) can be used as a basis for determining the vertical liberation treatment, because the model has a p-value (0.000) <5 %.

Figure 3 describes the distribution of tree diameter wih the distance of competitor trees. The trees of the (x,y) coordinates under the curve be vertically reduced [2]. According to the research results the vertical reduction will be performed on trees with 5−9 cm dbh and located 1−2.5 m from the center of subplot, except for the trees located at > 2.5 m from the center of subplot. Tree stands at the level of 3−5 m from the center of the plots with 10−19 cm dbh had not been reduced but had been girdled.

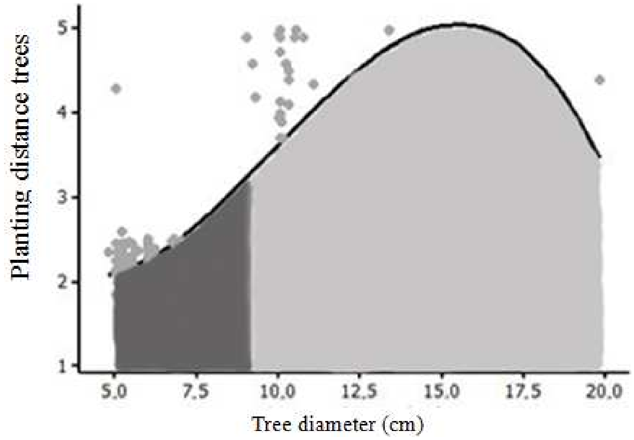

Figure 3. *Distribution of data on stem diameter and planting distance tree. Felled (■)girdled (□)*

Out of the 106 sapling available, 68 of those with diameter of 5−9 cm should be liberated by verticallyvertical clearance, thus, 38 individuals have to be maintained. Ten poles with diameter between 10−19 cm were to be verticaly cut down by girdling and 22 individuals will be left untreated.

3.4. Relationship of Tree Diameter and Canopy Diameter

Equation (5) $Cda = 2.54 - 0.031dbh + 0.050dbh^2 - 0.002dbh^3$ is a cubic equation to produce the coefficient of determination (R^2). In the present study coefficient 39.6% was resulted, which explains that the diameter of the stem or canopy was 39.6%, whereas the remaining coefficient of determination of 60.4% means that 60.4% of diameter stem was determined by other other variants. Table 1 shows that for the cubic equation with 39.6%, it means that the coefficient of determination (R^2) has low level of relationship. This explains that the diameter of the stem has lower relationship with the diameter of the canopy. Further study on sequential analysis of variance, it was revealed that Equation (2) cannot be used as a basic factor to determine the vertical liberation treatment. As the p-value (0.222) > 5%.

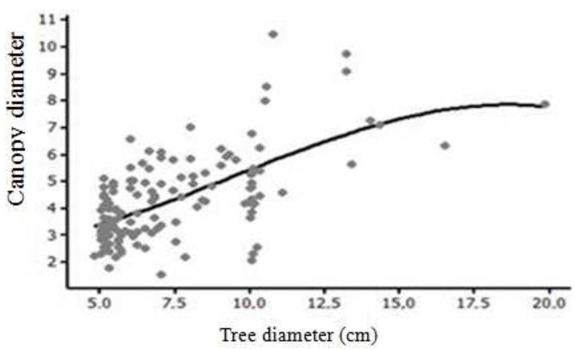

Figure 4. *Relationships of stem and canopy diameter*

4. Conclusion

It is concluded that the equation $X = 3.567 - 0.797dbh + 0.121dbh^2 - 0.004dbh^3$ can be used as the basis in determining the liberation treatment in TPTJ system. This system allows to cut trees with diameter at breast height of 5–9 cm within a 1–2.5 m from the center of subplots, but should not be performed if they are >2.5 m from the center of subplot. At the level of the tree stands that located at 3–5 m from the center the girdling process will be utilized.

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