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Preliminary Dominant Height Growth Model and Site Quality Class of Perhutani's Teak Plus from Clonal Seed Orchards in Madiun, Saradan and Ngawi Forest District, East Java, Indonesia

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ABSTRACT

Background: site quality index is as one of crucial factors that must be taken into account in a success of teak plantation and can be used to identify stand productivity as well as provide beneficial information regarding planning, implementation of forest activities. **Objective:** this research goals were to define model to predict height growth of dominant trees and to propose site quality class of Perhutani's teak plus from clonal seed orchard which was originated from mixture of clon number PHT I and PHT II. **Methodology:** dominant height of 6 to 12 years old were average of 30 measured dominant trees selected from good-performing growth and easy access compartments. The obtained dominant height for every age was analyzed by box-plot and explored their 75th and 25th percentiles. Curve estimation on regression analysis was applied to model these for two percentiles values. The two-proposed model were eventually used to classify site quality based on dominant height into three classes, i.e. good, medium and poor for the highest 25%, around 50% of median and the lowest 25% respectively. **Results:** the S-curve was best fitted to predict dominant height growth both 75th and 25th percentiles values. The obtainedmodel were $H_{dom,75} = exp\ [2.925\text{-}3.026/age]$ and $H_{dom,25} = exp\ [2.933\text{-}4.526/age]$ for 75th and 25th percentile respectively. The coeffisien determination and standard error of the estimate values were 0.695 and 0.065 for 75th percentile, and 0.864 and 0.059 for 25th percentile. Sites with dominant height above the 75th model were classified into good site quality, in between 75th and 25th models weremedium site quality and below the 25th model were poor site quality. **Conclusion:** the S-curve model was able to predict dominant height of Perhutani's teak plus plantation from mixture of clone number PHT I and PHT II. The model was proposed to classify site quality into good, medium and poor clases. This temporary site quality class should be taken into account to respond the urgent need for reference and prediction of production of Perhutani's teak plus in the study area.

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INTRODUCTION

Teak (Tectona grandis Lf) is one of luxury timber forest product with high demand in market. It is because teak wood has a very good quality with wonderful fiber and texture and having stable, strong, and durable characteristics. This Indonesia wood type with management widely applied in Java is experiencing higher market demand. This could become an opportunity and a challenge for teak plantations management. As one actor, Perhutani teak forest management in Java is compelled to make a breakthrough to increase teak productivity.

Perhutani has developed superior products such as Perhutani's Teak Plus. Perhutani's Teak Plus was produced by Perhutani through tree breeding programs, either through vegetative propagation (cuttings and tissue culture) or generative (seed orchard clones). Perhutani's Teak Plus clones with superior growth and stable clone was known as PHT I and PHT II. Advantages of Perhutani's Teak Plus is adaptive properties in various places because it comes from a very strict selection process. Perhutani's Teak Plus can grow faster than normal teak, both on skinny land and arable land. Perhutani's Teak Plus uniformity level is high, trunk is straight and cylindrical (Perhutani, 2013). The mixture of these clones have been propagated and planted generatively on a wide scale in Perhutani region for period 2002 to 2007.

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There are many factors to limit the success of teak plantation establishment. One of them is site quality index. As an initial step in forest management planning, site quality measurements play an important role (Parthama *et al*. 1999). Place to grow is a major factor to affect plant growth teak. Simon (2007) emphasized the importance of measuring the quality of a plant growing in forest management for purpose of: 1) to identify the productivity of stands and 2) to present an overview of plan and implementation of forestry techniques. Teak stands with a good quality can be obtained through proper management by performing plant maintenance. One of these maintenance activities is thinning. Generally, thinning in Perhutani system is based on table stand. Table stands are arranged based on quality of place to grow.

Perhutani has experienced problems to maintain stand for Perhutani's Teak Plus in relation to thinning. It is about how to thin intensity and how much maintenance is required to obtain desired results. This constraint is caused by unavailability of reference and stand growth predictions of Perhutani's Teak Plus. Thinning stands maintenance actions need a model to infer the dominant tree height growth and site quality index of Perhutani's Teak Plus stand that can be used as a reference for forest management plans. This study is aimed to determine the model prediction of dominant tree height growth and to make the site quality class for Perhutani's Teak Plus.

MATERIAL AND METHODS

Study area:

This study was conducted on plot of Perhutani's Teak Plus (JPP) in Forest Planning Section (SPH) at Madiun, Regional Division of East Java Perhutani, precisely in Forest Management Unit (FMU) Saradan, Madison, and Ngawi (Figure 1). Perhutani's Teak Plus Plots is made from plants seeds derived from clones Garden Seeds. It is a combination of Clones PHT I and II. Locations selection is based on crop plots: 1) good growth based on following criteria: a. percent of higher plants, b. larger diameter average, c. higher tree height average, and 2) easy access location.

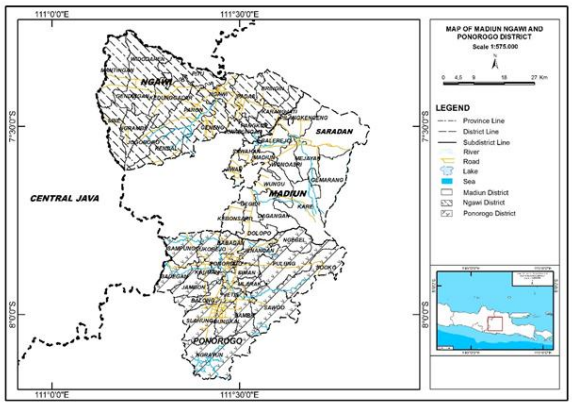

Fig. 1: Administrative area Map of FMU in Madiun, Saradan, and Ngawi.

This study was conducted at 2013 and 2014. JPP plants with a clone's combination of PHT I and II were conducted in 2002 to 2007. Therefore, plant plots for 2013 have 6 to 11 years old and in 2014 have 7 to 12 years old. Every year there has representatives and their repetitive was cultivated in each FMU. But in 2014, KPH Ngawi does not found crop plots that can be selected as representative. Table 1a shows study site for 2013 and Table 1b shows study site for 2014.

Table 1a: Perhutani's Teak Plus plot for study site for 2013.

Forest District	Sub-forest District	Compartment Number	Age (years)
Madiun	Dagangan	83a	6
	Sampung	92	6
	Dagangan	112a	6
	Pulung	76d	7
	Sampung	92b	7
	Bondrang	65b	8
	Sampung	89b	8
	Sampung	34a	8
	Bondrang	118d	9
	Pulung	114f	9
	Dagangan	62e	10
	Dagangan	103g	10
	Sampung	76a	10
	Bondrang	118h	11

	Bondrang	121d	11
	Dagangan	62b	11
Saradan	Rejuno	131	6
	Rejuno	104g	6
	Wilangan Selatan	136c	6
	Kedungbrubus	50a	7
	Notopuro	165a	7
	Wilangan Selatan	136a	7
	Rejuno	133a	8
	Tulung	152g	8
	Wilangan Utara	6b	8
	Wilangan Utara	93b	9
	Kedungbrubus	2b	9
	Notopuro	77c	10
	Tulung	123a	11
Ngawi	Kedunggalar	53b	6
	Kedunggalar	54c	6
	Kedunggalar	56k	6
	Kedunggalar	44d	7
	Kedunggalar	44a	7
	Kedunggalar	47g	7
	Watutinatah	103a	8
	Pandean	151g	9
	Payak	3i	9
	Pandean	151h	10

Table 1b: Perhutani's Teak Plus plot for study site for 2014

Forest District	Sub-forest District	Compartment Number	Age (years)
Madiun	Dagangan	112a	7
	Dagangan	60c	7
	Dagangan	59a	7
	Sampung	72c	8
	Sampung	70d	8
	Sampung	92b	8
	Sampung	34a	9
	Sampung	72b	9
	Sampung	74d	9
	Dagangan	100k	10
	Bondrang	118d	10
	Dagangan	114c	10
	Bondrang	123b	11
	Sampung	76a	11
	Sampung	74c	11
	Bondrang	117d	12
	Bondrang	121f	12
	Bondrang	117k	12
Saradan	Tulung	152g	7
	Tulung	98b	7
	Wilangan Utara	100a	7
	Tulung	106b	8
	Tulung	152a	8
	Pajaran	160g	8
	Notopuro	152b	9
	Notopuro	152c	9
	Notopuro	102a	9
	Wilangan Utara	2b	10
	Wilangan Utara	93b	10
	Notopuro	77c	11
	Tulung	123a	12
Ngawi	Kedunggalar	51d	7
	Kedunggalar	3c	7
	Kedunggalar	50b	7
	Walikukun	4h	8
	Walikukun	4b	8
	Walikukun	7b	8
	Pandean	151g	10
	Payak	3i	10
	Pandean	151h	11
	Pandean	150b	12

Material Data:

Dominant trees stand was decided from JPP plants plot that chosen as study site observations. The dominant tree is characterized by trees with: a. grows healthily and straight, b. rods with large-diameter and cylindrical, c. high free branches and cylindrical canopy. Samples are 30 dominant trees to meet the assumption of normal distribution. Tree characteristics were measured by: a. stem diameter (130 cm from soil surface using a diameter tape), and b. total height of tree (using Hypsometer Haga). Average heights of 30 total dominant trees sample are referred to as dominant height (Hdom). Furthermore, dominant height is used as main material in this study (Table 2).

Table 2: Statistics of dominan height over ages.

Age (years)	Number of observation	Mean of dominan height (m)	Std. Deviation	Minimum	Maximum
6	8	9.8828	1.58926	7.53	11.99
7	17	11.2204	1.16272	8.78	13.23
8	16	12.4490	1.48063	10.27	15.28
9	12	12.2173	1.37435	9.63	14.50
10	12	13.0644	1.88238	9.99	16.90
11	9	13.5256	1.52519	11.00	14.98
12	4	12.5200	0.46569	12.05	13.12

Data analysis:

Dominant height growth models:

Site's index of Perhutani generally is used to determine the improvement (top height). It is an average of one hundred high-dominant trees scattered evenly in one hectare area. This improvement concept is implemented by Perhutani in conventional teak plants in form of tables from Wolf von Wülfing (Wülfing, 1932). But the improvement is not as estimates of average height. It is a size function of sampling unit. Sampling is often used to measure the number of trees per unit area and choosing a fixed proportion of trees per unit area. Elevator does not implement because the average height of Perhutani's Teak Plus are higher than stand growth from Wolf von Wüolfing table. On theoretical side, Wolf von Wülfing table reserved for conventional teak plants and not for excellent genetic as JPPl. To overcome this obstacle, dominant height is used as growth.

Modeling principles to project stands growth high from time to time basically are remains same regardless of high definition usage. High modeling presentation will refer to dominant height without giving precise definition on how the term was applied in various analyzes. Plantations age on site index estimation can be defined as the total age from planting.

Normality distribution of dominant height for each age is tested by box-plot. The dominant height data were analyzed using descriptive statistics to find the value of 75^{th} and 25^{th} percentile. Value of each percentile in each age modeling is analyzed by regression analysis based estimation curve choice. The next model selection is based on following criteria: a. high determination coefficient, b. low standard error estimate, c. significant F test and d. significant t test.

Site quality class:

Determination of site index can be done in 2 ways, direct and indirect site evaluation. Indirect site evaluation is determined by parameters of soil, climate, and vegetation types. Direct site evaluation is determined from tree height, total production and standing stock. This study directly uses dominant tree height as site index. Site index with parameter of tree height is determined by age. Reference from David *et al*. (2015) is commonly used for cycle life of fast growth species (Sadono *et al*. 2014). Wolf von Wülfing table is used by Perhutani for teak plantations. Site index is determined by 80 years old as reference (Wülfing, 1932). In case of Perhutani's Teak Plus the oldest age only 12 years when data collected from rotation which is set at 20 years. To overcome this reference age, first step uses term of site quality class.

Modeling the dominant height is used to divide dominant height data into three classes (good, average and poor). For high class is proposed top 25%, it is site with dominant height above the dominant model of 75^{th} percentile. Medium class is 50% around median dominant height; dominant height of the site is located between 75^{th} to 25^{th} percentiles. Lowest class is 25% lowest, dominant height of the site is located under lowest 25^{th} percentile.

RESULT AND DISCUSSION

Department of Forestry (1992) explains that height is another parameter after the diameter with significant importance to estimate dimensions of stand. Height measurement is determination of perpendicular distance of a few objects from the earth surface or some other flat surface to normal direction of base plane. Widodo (1989) states that, together with age, high average of dominant and codominant trees are very good to show the level of site quality (site quality index), with provision that average growth of tree height was not affected by silvicultural treatments . Character of dominant trees can be seen from a height and canopy where the

canopy has an important role in tree growth (Sadono, 2015).

Model improvement and site index curves have been developed for some tropical species such as *T. grandis* (Malende and Retrieval, 1990; Nunifu and Murchison, 1999; Bermejo *et al*. 2004), *Cupressus lusitanica* (Teshome and Petty, 2000) and *Azadirachta indica* (Tewari, 1992). Particularly in area of forest management, Indonesia have been developed breeding of teak tree named Perhutani's Teak Plus which still require intensive management. One management efforts is to create a growth model and site quality index.

Calculation of site quality class in this study was conducted by measuring height (Laiho *et al*. 2014) and diameter of 30 samples dominant of Perhutani's Teak Plus on plots which have been determined for 6 to 12 years old in SPH Madiun of Perhutani Regional Division at Java region. Dominant tree of Perhutani's Teak Plus dominant tree is calculated from average height for each plot as dominant height. Dominant height and age data is used to analyze descriptive statistical. Descriptive analysis shows two (2) outliers, i.e. the measurement year 2014 for plots 100a number 102A for 7 and 9 years old at KPH Saradan. After that, scatter distribution of dominant Perhutani's Teak Plus in form of plots and box-plot (Figure 2). Data distribution results show that dominant height growth continues to increase along with age, except at 12 years old. At that age only there are four dominant height data and availability of crop plots in field is very limited.

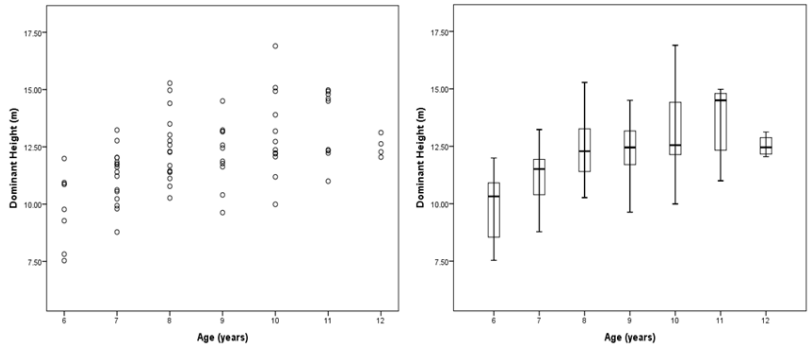

Fig. 2: Distribution data of dominant height for Perhutani's Teak Plus in form of (a) scatter plot and (b) a box-plot.

Box-plot graph shows that most of dominant height data is close to normal distribution, although the amounts of data for each age are still relatively few. Furthermore, Descriptive Statistics is done to analyze data for each age with a dominant height to find 75^{th} and 25^{th} percentile (Table 3). Second percentile value is intended to divide the height distribution of dominant height into three parts, namely: a. 25% above the 75^{th} percentile, b. 50% is located between the 75^{th} and 25^{th} percentile, c. 25% below 25^{th} percentile. The two percentile values at 6 to 12 years old were modeled by regression analysis at estimation curve choice.

Table 3: Dominant height value of 75^{th} and 25^{th} percentile from various ages.

Age (years)	Dominant height (m)	
	75^{th} percentile	25^{th} ppercentile
6	10.9225	8.1808
7	11.9808	10.3100
8	13.3800	11.4000
9	13.1700	11.6300
10	14.6725	12.1025
11	14.8600	12.2800
12	12.9975	12.1075

Based on regression analysis, 75^{th} percentile values have best equation of S curve with R^2 value of 0.695 and standard error of estimate of 0.065. S equation is chosen to model the dominant height of 75^{th} percentile because it has a high value of R^2 and lower standard error values than other equations that equally significant in F test and t test. Both Growth and Exponential Equation generate equal R^2 value and standard error of estimate, respectively for 0.555 and 0.079. Furthermore, model for dominant height of 75^{th} percentile can be written with formula of $H_{dom,75} = exp\ [2.925\text{-}3.026/age]$.

Best equation from regression analysis to make model of dominant height at 25^{th} percentile is also S-curve with a R^2 value of 0.864 and having a standard error of estimate at 0.059. S curve produces higher R^2 and standard error of estimate is lower than other equations that equally significant in F test and t test, namely Exponential and Growth equation. Both equations have same value of R^2 of 0.710 and equal

standard error of estimate at 0.086. Models of dominant height for 25th percentile can be expressed by formula: $H_{dom,25} = exp\ [2.933\text{-}4.526/age]$.. Calegario *et al*. (2005) use exponential equation to relate age and diameter growth. Curve estimation results for both percentiles values are presented in Figure 3.

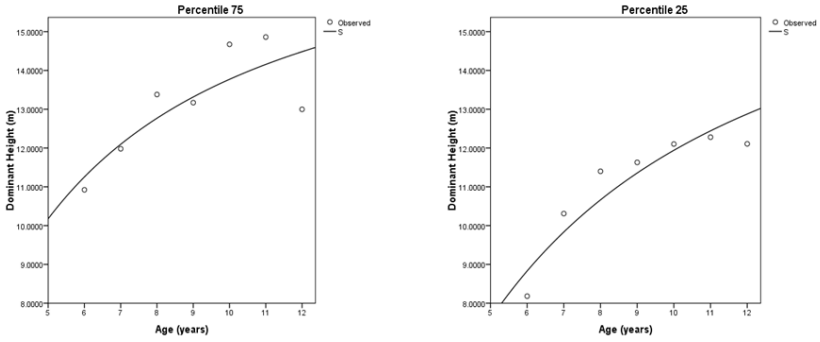

Fig. 3: S curve for 75th percentile (left) and 25th percentile (right).

Both models were used to divide the dominant height data into three parts, namely top 25%, medium 50% and bottom 25%. Upper part is for site with good classification for growth site quality, namely area with prediction higher dominant height that than 75th percentile for equal age. At center area is reserved for medium growth quality, area between 75th and 25th percentiles for equal age. Bottom area designated as poor growth quality, an area of dominant height at lower than prediction of 25th percentile for equal age. The division can be seen graphically in Figure 4 and numerical values are presented in Table 4.

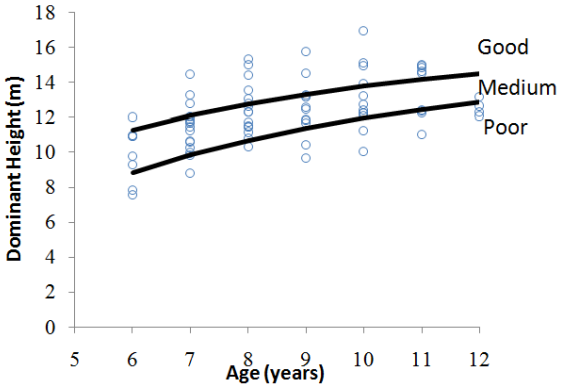

Fig. 4: Graph the division dominant height for growth quality.

Table 4: Site quality class based on dominant height models of 75th and 25th percentiles.

Age (years)	dominant height (m) for site quality class		
	Good	Medium	Poor
6	> 11.24	8.84 – 11.24	< 8.84
7	> 12.08	9.85 - 12.08	< 9.85
8	> 12.76	10.68 - 12.76	< 10.68
9	> 13.30	11.37 - 13.30	< 11.37
10	> 13.76	11.96 - 13.76	< 11.96
11	> 14.14	12.46 – 14.14	< 12.46
12	> 14.47	12.89 –14.47	< 12.89

Site quality will affect the trees growth. Trees growth at right land will provide greater results than trees growth at less suitable land. Above graph shows that site quality class that produces the best high growth predominantly found in upper class. Dominant height for medium growth is located at medium class, whereas for dominant of low growth is located at bottom. Growth level of teak tree is strongly influenced by local climatic factors as humidity (Upadhyay *et al*. 2005; Scolforo *et al*., 2013; González *et al* Venegas- . 2015). Genetic factors will also affect on oak growth but it is not flexible to environment (Hansen *et al*. 2015). In addition, stands growth can also hindered by other

factors as forest fires. According Wibowo *et al*. (2013), forest fires do not turn off the teak but will inhibit the growth with a diameter of about 1-2 cm / year at 4 years old. Quality classification of teak site using dominant height and age provide site quality evaluation methods that comfortable and consistent, because of all the environmental factors is reflected interactively in high growth, which will also relate to volume (Sadono *et al*. 2014).

Clutter *et al*. (1983) explains that site quality can be measured by direct and indirect methods. Efficiency and practicality of direct method based on dominant height can makes this method most widely used to predict the trees production (Perin *et al*. 2013). It is because these variables are strongly correlated with forest products and also slightly influenced by other factors, such as density and thinning (Adame *et al*. 2006; Berges *et al*. 2005; Bravo-Oviedo and Montero 2005; Dieguez-Aranda *et al* . 2005; González *et al*. 2005; Calama *et al*. 2003; Niinemets and Lukjanova 2003; Clutter *et al*. 1983).

Site index model is a convenient and effective tool to determine forest management practices to predict the productivity of timber, timber volume, rate of forest growth potential and initial and subsequent thinning time. Diameter and high ratio can make site quality index to illustrate the trees productivity (Sánchez-González *et al*. 2005). Thinning will affect the density of teak trees to affect the growth (Kang *et al*., 2014). Site index is indispensable input parameters in growth model and growth prediction of biomass models (Chaturvedi & Raghubanshi, 2015). It has been used in studies to estimate the growth and yield of timber volume and basal area (Clutter, 1963; Johnstone, 1976; Singh, 1979; Sharma, 1979).

Conclusion:

S curve can be used to makes model the dominant height of 75^{th} and 25^{th} percentile. Both models are proposed to determine site quality class of Perhutani's Teak Plus in area KPH of Madiun, Ngawi and Saradan to become three classes, namely good, medium and poor. Quality classes of growth site are calculated to answer the urgent needs based on reference and prediction of wood production of Perhutani's Teak Plus.

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