Advances inEnvironmental Biology, 11(5) May2017, Pages: 6-12

AENSI Journals

Advances inEnvironmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

Temporary Site Index for Two-Invented Teak Clones with Generative Regeneration in the State Forestland in East Java, Indonesia

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Received 8 January 2017; Accepted 28 April 2017; Available online 24 May 2017

ABSTRACT

Site quality is an important factor which influences growth and it must be taken into account in determining spacing arrangement of teak plantation. It can be used to identify stand productivity as well as to provide benefit from planning and implementation of forest activities. A model is needed to predict height growth of dominant trees and site index of perhutani's teak plantation which will be used as reference to forest management plans. This research is aimed at defining model for predicting height growth of dominant trees andthe quality of site index of perhutani's teak plus plantation. Dominant height was defined as height average of 30 dominant perhutani's teak plus trees in a compartement. Compartements were evaluated based on the height average of 30 dominant trees in the age of 6 to 13 years.50% of data based on the values approaching the mean were used to predict the height growth of dominant heights The dominant heights were analyzed using three candidates of dominant height models namely Schumacher, Chapman Richards and Wolf von Wulving. The proposed model was selected through the highest coefficient of determination (R^2).Schumacher equation model, in this case ,was selected as the proposed model for predicting height growth of dominant trees and site index.. The site classes were divided into three classes namely good, medium and poor based on the age of 13 years used as the reference age. Data were divided into three classes based on the dominant height of the reference age, they were Site Index 12 as a poor class, Site Index 14 as a medium class and Site Index 16 as a good class. This temporary site index proposed to classify perhutani's teak plus plantation was in the age of 6 to 13 years in the research area.

KEYWORDS:perhutani's teak plus plantation, growth model, dominant height, Site index, Two-Invented teak clones

INTRODUCTION

Teak is popular because of its attractiveness and durability. Sadono *et al*. [18] said that this wood has a very good quality with wonderful fiber and texture and has stable, strong, and durable characteristics, Therefore, it has been a target species in Plantation. In Java, Teak plantations cover 1.2 million hectares [2]. Teak is characterized by slow growing species, that becomes an opportunity and a challenge for teak plantations management in order to make innovation to increase productivity.

Perhutani is a state owned enterprise whose duty is to manage forests around Java Island. In this case, they have developed perhutani's teak plus or Jati Plus Perhutani (JPP) in order to improve the teak productivity and the quality conducted through tree breeding programs. The tree breeding programs are vegetative propagation (cuttings and tissue cultures) and generative (seed orchard clones). The two invented teak clones are known as PHT I and PHT II where these have superior and stable growth. The JPP is adaptive in various places as it is a result in a very strict selection process. The JPP can grow faster than conventional teak, both in poor and good sites. The level of Perhutani's teak plus uniformity is high,cylindrical and having straight trunk [13].

The plantation of JPP from seed orchard clones was started in 2002 conducted in wide scale around Perhutani regions and last planted in 2007. The implementation was combined with manipulation of environmental factors through application of intensive sylviculture. The plantation of JPP was expected to realize effective and efficient management and to increase productivity within 20 year-rotation period. However, the different altitudes in compartment as become problem in JPP Plantation.Moreover, the determining factors were different fromsite quality, plant maintenance and imbalancing fertilizing. These factors were also found to influence the growth rate [14].

Site is the main factor which influences the growth athough treatment maintenance has been done similarly. The plantation of JPP in different sites will also produce different qualities. Harbagung [7] explained that information about site quality becomes important parameter in forest management in order to determine silvicultural treatments. Therefore, a model is needed to predict height growth of dominant trees and site index for perhutani's teak plus plantation which can be used as reference for forest management plans. The model is used toassess site productivity [20]. Then, it can be used as reference for management planning of JPP.

This research is aimed to determine the prediction model of dominant tree height growth for perhutani's teak plus plantation, from which a site quality class model would be set. The model is expected to be applied on perhutani's teak plus plantation in Forest Planning Section (SPH) at Madiun, Saradan and Ngawi Forest Districts, East Java Perhutani Regional Division.

MATERIAL AND METHODS

Research area:

This research was conducted in 2013, 2014 and 2015 inthe Forest Planning Section (SPH) Madiun, Saradan and Ngawi Forest Districts, East Java Perhutani. Samples were selected by taking 30 dominant trees of Perhutani's teak plus with a good quality from clonal seed orchard in each compartment which was aged around 6 to 13 years. To meet the assumption of normal distribution, samples were taken from 30 dominant trees in each compartment.

Material data:

The material data were from dominant heights of perhutani's teak plus plantation from clonal seed orchard. The total numbers of compartment were 147. All compartments were established by selecting 30 dominant trees in each compartment which was aged around 6 to 13 years. The minimum number of compartment was three compartments in each age and each forest district. Table 1 shows research site for the year of 2013, 2014 and 2015.

Table 1: Perhutani's teak plus compartments for study site measured in 2013, 2014 and 2015

Year of measurement	Age (years)	Number Compartment in Forest District of		
		Madiun	Saradan	Ngawi
2013	6	83a, 92, 112a	121, 104g, 136c	53b, 54c, 56k
	7	76d, 92b	50a, 165a, 136a	44d, 44a, 47g
	8	65b, 89b, 34a	133a, 152g, 6b	103a
	9	118d, 114f	92b, 2b	151g, 3i
	10	62e, 103g, 76a	77c	151h
	11	118h, 121d, 62b	123a	-
	12	-	-	-
	13	-	-	-
2014	6	-	-	-
	7	112a, 60c, 59a	152g, 98b, 100a	51d, 3c, 50b
	8	72c, 70d, 92b	106b, 152a, 160g	4h, 4b, 7b
	9	34a, 72b, 74d	152b, 152c, 102a	-
	10	100k, 118d, 114c	2b, 93b	151g, 3i
	11	123b, 76a, 74c	77c	151h
	12	117d, 121f, 117k	123a	156b
	13	-	-	-
2015	6	69a, 67d, 103c	16d, 67a	-
	7	26, 2b, 3a	121c, 6b	73c, 174k
	8	228a,145b, 79a, 69e, 100a	100a, 89b, 104g	45b, 48f, 64g
	9	92a, 78c, 152b	160b, 114d, 81a	47h, 49d, 65g, 65h2
	10	34a, 74d, 80a	94b, 6c, 96d	22h, 175g, 143a, 135e
	11	118d, 296b, 90g	2b, 93c, 84a	2b
	12	76a, 123b, 82a	71c, 93d, 96a	167e
	13	121f, 101i, 117k	16a, 91a, 123a	45a, 47a, 52d, 72b

Data analysis

Dominant Height:

Dominant height is usually defined as the average height of a specific number of the largest diameter or tallest trees for a unit area, it is useful to measure the site quality because it is little affected by variation in stand density or by most thinning regimes [10]. However, Yevide *et al*. [24] used another definition, site index as the mean quadratic diameter at reference age wherethe guide curve method has been used. Dominant height in this research is defined as the average of 30 dominant trees of perhutani's teak plus plantation per compartment [11]. The dominant height is characterized by trees that are healthy, straight and cylindrical. Height measurement used was haga hypsometer.Dominant height samples were taken by calculating the average of each compartment and age. Samples were analysed using non linear regression in SPSS 20 software. Normality distribution of dominant height was analysed using boxplot.To predict height growth ofdominant heights, 50% of data were used based on the values of approaching mean. It was expected that the result obtained would be more representative.

The three elements of modeling dominant height were selected as a modeling form, a modeling data structure, and statistical procedures used to estimate model parameters [22]. Many growth model equations had been applied to construct site index model, such as Chapman Richards, Johnson Schumacher and log logistic models. Variations of those models have probably been the most commonly used for site index modeling [4,15]. These different methods can have important implications on the resulted site index equation [16,22].

The three non linear models were respectively adjusted by adopting the dominant height and the age as dependent and independent variables. Table 2 shows the dominant height models proposed for teak plus plantation. Guiding models had been generated since the dominant height was equal to the site index and the reference age. Reference age was 13 years as the oldest age of perhutani's teak plus plantation. The site class curve was drawn up using mean of the guiding model. This model was obtained using the model selected by the highest coefficient of determination (R^2) as the statistical criterion.

Table 2: Candidates Model of Dominant height growth for teak plus plantation

Name of candidate model	Equation	Regression coefficient
Schumacher *in* Clutter *et al.*[3]	$H = ae^{b/t}$	a,b
Chapman-Richards *in* Clutter *et al*. [3]	$H = a(1 - e^{-kt})^{(1/(1-b)}$	a,k,b
Chairil Anwar [1]	Ln H = $a+b\frac{1}{\sqrt[3]{t}}$	a, b

Where:

H = dominant height
t = age
a, b, k = regression coefficient

Site Index:

Site index is commonly used to measure site quality, it is defined as dominant height of stand at site index age [10]. Determination of the site index can be done in two ways, indirect and direct site evaluations [3,18]. Indirect site evaluation is determined by parameter of soil, climate, and vegetation types. While, direct site evaluation is determined by tree height, total production and standing stock. This research used direct site evaluation using dominant tree height as site index. The direct site evaluation is commonly used for site index modeling by considering efficiency. Dominant height has close correlation with forest yield that is related to volume [12,4,9,17]. It is also influenced by other factors such as stand density and thinning [3,18]. Site index classification is defined as dominant height because all of the environmental factors are being reflected by the height growth.

This research used direct site evaluation using dominant tree height as site index. In this case, the oldest age of perhutani's teak plus plantation was 13 years when data were collected from the rotation period set at 20 years. For that reason, the reference age used was 13 years. Dominant height model was used to divide data into three classes (good, medium and poor).Classification of the site index was based on the dominant height mean ofthe reference age. Classification value is based on the mean and it was arranged into site index table which attached the top height in certain age and site class [6]. Based on the guiding model, construction site index curve and site classifications(good, medium and poor) would be set.

RESULTS AND DISCUSSION

Measurement of height refers to Laiho *et al*. [11] using the samples of 30 dominant trees in each compartment. Site index was constructed by collecting the sample of 30 dominant trees from each compartment in the age of 6 to 13 years. Data from 2013, 2014 and 2015 were compiled. Total compartment was 147 compartments. Samples were calculated by averaging the dominant heightsfrom each compartment and age. In order to find out the normality distribution and the outlier, through the use of SPSS 20, the samples were analyzed using descriptive analysis and boxplot. Figure 1 shows the result in boxplot and scatterplot.

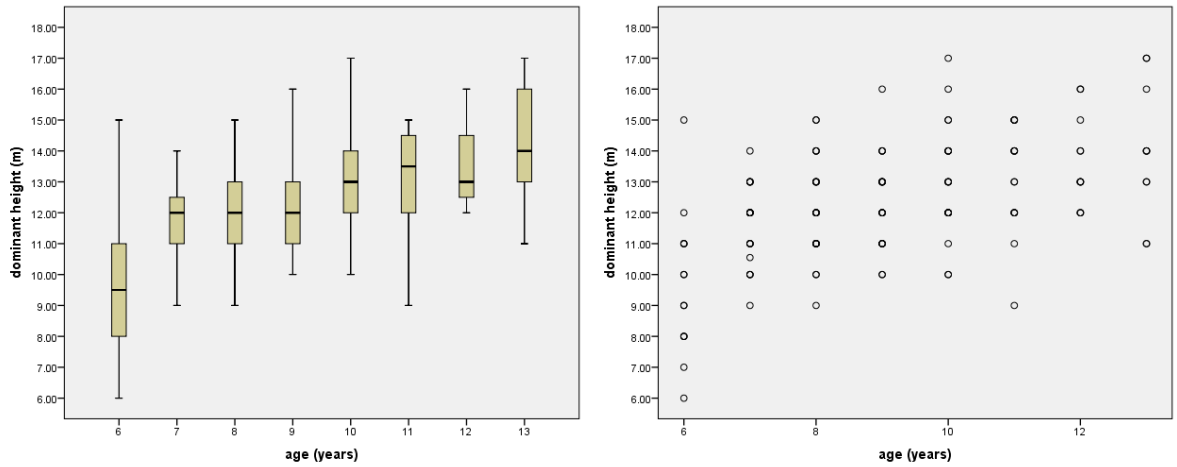

Fig. 1: Dominant height data distribution for perhutani's teak plus in the form of (a) boxplot, (b) scatterplot.

Boxplot and scatterplot show dominant heights mainly close to normal distribution. Growth of dominant heights increased with age, except in the age of 6 years. Table 3 shows statistics of dominant height over the ages.

Table 3: Descriptive Statistics of dominant height over ages

Age (years)	Number of compartments	Mean of dominant height (m)	Std. Deviation	Minimum	Maximum
6	14	9.642	2.307	8.310	10.975
7	24	11.689	1.212	11.177	12.201
8	27	12.074	1.517	11.473	12.674
9	22	12.318	1.460	11.670	12.965
10	22	13.000	1.772	12.213	13.786
11	16	13.125	1.707	12.214	14.035
12	12	13.583	1.443	12.666	14.500
13	10	14.000	2.160	12.454	15.545

Dominant heights were selected by considering 50% of each age for analysis to which it was based on the values of approaching mean. It was expected that the result obtained would be more representative. Table 4 shows the statistical criterion of candidate models for the dominant height modeling based on the coefficient of determination (R^2).

Table 4: Paramaterization of candidate models for dominant height growth

model name	equation	Number of compartments	R^2	parameter	value
Schumacher	$H = ae^{b/t}$	74	0.532	a	16.524
				b	2.649
Chapman-Richards	$H = a(1 - e^{-kt})^{(1/(1-b))}$	74	0.530	a	70.011
				k	0.149
				b	-0.573
Chairil Anwar	Ln H = $a+b\frac{1}{\sqrt[3]{t}}$	74	0.529	a	3.509
				b	1.941

Compared to Chapman Richards and Wolf von Wulfing models, Schumacher model presents the proposed model based onthe highest coefficient of determination (R^2). The Schumacher model was selected for drawing the site index curve. This curve of dominant heights is shown in Figure 2.

Schumacher model is the proposed model used in this research in order to predict the dominant height growth of Perhutani's teak plus plantation. It is similar with the result in Friday's [5]research, which used Schumacher and Log-log models for teak in the Limestone hill, Poerto Rico. The Schumacher model has constant approach for height with increasing age, while the log-log model does not approach the limit. In contrast, Sajjaduzzaman *et al.*[19] suggested that the Chapman Richards model was found to be the most suitable model for teak in Bangladesh. Furthermore, Tewari *et al.* [21] roposed equation from Korf model to predict the dominant height of teak in India. Anwar also [1] invented equation model for predicting teak bonita in Central Java from Wolf von Wulfingtable [23], but the results show that the model performance have the lowest coefficient of determination (R^2) for predicting dominant height of Perhutani's teak plus plantation. The different objects of height probability influence the result. Wolf von Wulfing [23] used height of conventional

teak characterized by slow growing species and this research used height of Perhutani's teak plus characterized by fast growing species.

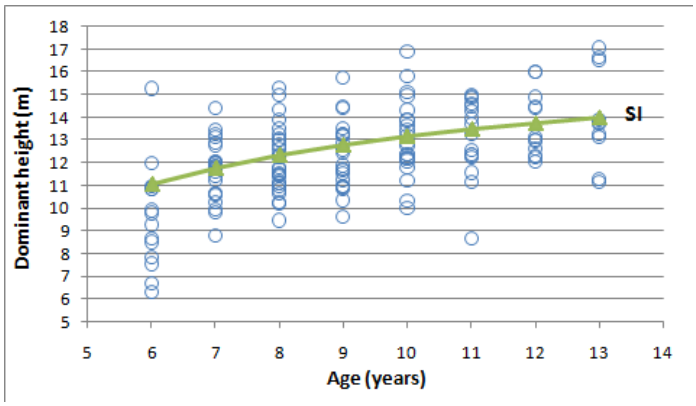

Fig. 2: Guiding curve for perhutani's teak plus

Figure 2 shows the guiding curve that was drawn using Schumacher model. Dominant height scattered is mainly close to the guiding curve site index. On the contrary, for the age of 6 years, most of the dominant heights are scattered below the guiding curve site index. Based on Schumacher site index equation model, the dominant heights were divided into three classes that belong to the age of 13 years as the reference age. The use of reference age should be the same as the rotation period [8]. However, there was not yet plantation in the age of 20 years that could be used as the rotation period. Hence, the selected reference age in this research was 13 years as the oldest age. Graph site index curve class is shown in Figure 3. Dominant heights for the age of 13 years were 11 m as the minimum height and 17 m as maximum height. Furthermore, mean of the dominant height for the age of 13 years was 14 m. Dominant heights were divided into three classes based on the reference age. The limit of the dominant height is 14 m. The equation for the class division is as follow:

Class limit $=14 \text{ X } \frac{16.524*\text{EXP}(2.649/13)}{16.524*\text{EXP}(2.649/\text{age})}$

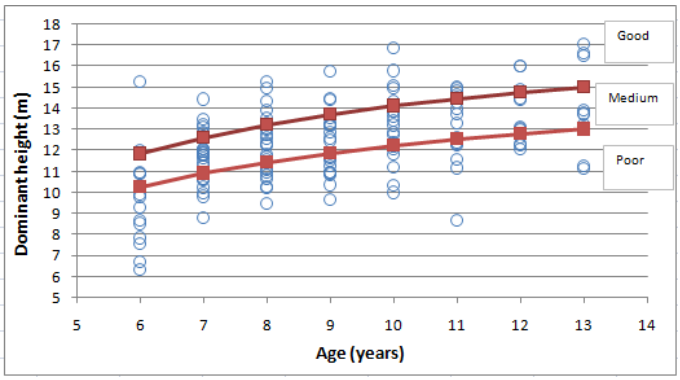

Fig. 3: Site index curve class for perhutani's teak plus

Based on the guiding curve as the limit, the site class was divided into three parts (Site Index 16 as a good class, Site Index 14 as a medium class and Site Index 12 as a poor class).Site Index 16 was the dominant heights that were located above the curve of Site Index 14. Site Index 13 was dominant heights that were located under the curve of Site Index 14. Table 5 presents the values of site class limit of Schumacher guiding model.

Table 5: Dominant height limits of each site class for perhutani's teak plus

Age (years)	dominant height (m) for site quality class		
	SI 12	SI 14	SI 16
6	>9.460	9.460-12.614	<12.614
7	>10.076	10.076-13.086	<13.435
8	>10.565	10.565-14.086	<14.086
9	>10.960	10.960-14.614	<14.614
10	>11.288	11.288-15.051	<15.051
11	>11.563	11.563-15.418	<15.418
12	>11.797	11.797-15.730	<15.730
13	>12.000	12.000-14.000	<14.000

Table 5 shows that the class limit increased with age. However, for the age of 7 and 8 years, they are different, the class limit for the age of 7 years is higher than the age of 8 years and the class limit for the age of 8 years is lower than the age of 8 years.

Reliable growth model is essential for effective long term planning and decision making. This is important in intensively managed forest plantations and is important to evaluate alternative planting densities, thinning regimes and rotation lengths [21]. The forest height growth is directly related to the site characteristics and the forest productivity, as well as the improvement of stand growth that represents better productivity estimation [4].

Conclusions:

Three candidate models were analysed using non linear regression and fitted to the data in dominant height growth. Eventhough all models presented similar performance, the highest coefficient of determination (R^2) went to Schumacher model. Schumacher model was the proposed modelused for predicting the dominant height growth and the site index forPerhutani's teak plus plantation in the Forest Planning Section (SPH) at Madiun, Saradan and Ngawi Forest Districts, East Java Perhutani. Based on the data, Schumacher site index equation model has produced site index class for perhutani's teak plus plantation for the age of 6 to 13 years. The site index class was divided into three classes, they were Site Index 16 as a good class, Site Index 14 as a medium class and Site Index 12 as a poor class.

ACKNOWLEDGEMENTS

The authors are grateful to Gadjah Mada University for financial support and to Perum Perhutani East Java Region Division for permission to conduct this research. Next acknowledgement is addressed to the management and the staff of Madiun, Saradan, and Ngawi Forest Districts that facilitated this research with the measurement in the field. Thank to Wieke Herningtyas for preparing the manuscript and helping in the aspect of data analysis, and to the measurement team for good cooperation and hard work during data collection period in the field as well as for anonymous reviewers for the valuable comment and suggestions to help to improve this manuscript.

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