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Crown model for Perhutani's Teak Plus from Clonal Seed Garden Aged 6 to 11 Years in Madiun Forest District, East Java, Indonesia

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ABSTRACT

Study of forest dynamics should cover tree crown beside stem diameter, tree height and tree volume. Tree crown plays an important role in photosynthesis proccess and eventually determines forest productivity. This research is aimed to propose lighted crown model and to estimate lighted crown volume for Perhutani's Teak Plus from clonal seed at 6 to 11 years in Madiun forest district. The lighted crown was modelled based on 480 dominant trees selected from 16 good-performing growth and easy access compartments. the model was modified from Pretzcsh's crown shape model. Parameters measurement for lighted crown model was total tree height, height at crown base, maximum crown radius, and height at maximum crown radius. the data were processed to find out the crown length and lighted crown length. Descriptive Statistics was used to obtain mathematical relationship between crown radius and crown lenght of lighted crown section. Furthemore, lighted crown volume was calculated by integration of obtained lighted crown model. The result showed that parabolic form was proposed to modelling the lighted crown. the model was as follows: *radius of lighted crown = constant*(lenght of lighted crown)$^{0.33}$*, with constant values were = 1.02, 1.19, 1.23, 1.28, 1.17 and 1.32 respectively for aged 6 to 11 years. the lighted crown volume was estimated using the following equation: *lighted crown volume = π*constant*(lenght of lighted crown)$^{1.66}$*, with constant values were 0.623, 0.853, 0.917, 0.994, 0.827 and 1.047 respectively for aged 6, 7, 8, 9, 10 and 11 years.

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INTRODUCTION

Forest dynamics for structure management is shown by stands development (stand structure) as a result of growth process and treatment imposed on trees in stand. Stand dynamics can be seen from the stem growth, tree height and tree crown development (Anonymous, 1993). The actual state of growth dynamics of teak stands in field do not always meet expectations. Teak stand dynamics is expected growth optimal for teak with a straight stem growth, large diameter and cylindrical, high branch free, light branching and free from pests and diseases. Teak stands management needs to include growth dynamics of stands in order these expectations can be achieved. Efforts to manage growth dynamics of teak is conducted by Perhutani not only in form of thinning, but also setting the spatial location of trees in stand.

Actually stand dynamics management does not only use diameter, height and volume, but also the dynamics of tree crown. Tree crown play an important role in trees productivity. Crown is place for physiology process with a combination of amount of solar radiation energy, especially photosynthesis, respiration, and transpiration. It leads to growth and development of trees. Solar energy is absorbed from the tip until entire leaf crown to produce crown volume (Grace, 1990; Wang and Jarvis, 1990). Energy absorption is directly affected by tree growth and growth dynamics.

Crown formation comes from local environmental factors and supply of existing resources in forest. Stand is mainly determined by inter- or intra-specific trees in forest stands. Crown structure is very important in feedback loop between the tree function, structure and environment pure stands (Day, 1985 in Bayer *et al*., 2013). Crown shape is determined by characteristics of branching pattern (angle and main branch length ratio with further branches), generally there are many topic widely studied, but more focused on studying the theoretical relationship between the trees architecture and adaptive strategies (e.g. to optimize interception

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production of light and photosynthesis). There rare little model is designed for measurement (Honda, 1971, Horn, 1971, Cannell, 1974 and Honda and Fisher, 1978 in Rautiainen and Stenberg, 2005). Crown size is an important variable because it serves as a good indicator for tree strength, photosynthesis and accumulation of all the factors affecting growth during development. Crown size is also a promising variable in several sizes competition (Daniel *et al*., 1987; Biging and Dobbertin, 1995 in Campo, 2009; Sadono, 2014b).

Crown shape has three important aspects, namely: to determine integration limits over the entire crown surface, to determine the area of crown projection on horizontal plane and calculating crown volume (Kuusk and Nilson, 2000; Rautiainen and Stenberg, 2005). Tree crown can be used to measure the stand density (Daniel *et al*., 1987). Stand density will affect the availability of tree growth space. Individual tree need space to grow their own trees for sunlight, water and other nutrients needed for growth. Individual trees in a stand will be limited by surrounding trees. It will have limited space to grow. These conditions stimulate the competition between trees. Bayer *et al*. (2013) explains the existence of competition in sun light between species that are affected by a neighbor in pure stands.

Observation of Assmann (1970) shows the crown is required as growth indicator. Furthermore, Assmann explained that to address issues regarding the space usage to grow of most excellent of a tree type, it needs to research the structure, size and shape of tree crown in relation to dimensions of crown, growing space needed and efficient increment. Crown measurements in field are not as easy as to measure height and diameter. It is necessary to build a model of crown, in addition to reducing constraints crown measurements in field; it can also gives information in studying the crown dynamics.

Tree crown provides an overview of potential growth and trees development. In addition, crown can also be useful to determine the level of trees competition, stand density, plant spacing determination and even grow room setup (Sadono, 2014b). These important is not everything can be applied such as headers usage to determine optimal growing space for a tree type. Especially from differences in age, because according to research Ishii and McDowell (2002) in Campo (2009), crown structure and morphology shows different changes with age, as a result of combined effects of branch growth and death. Based on exposure, this study aims to develop a crown model of lighted crown section of Perhutani's Teak Plus from Clones Seeds Garden at age 6 to 11 years of standing with good classification and predict the crown volume is exposed to light (lighted crown volume) Perhutani's Teak Plus come from Clones Seed Garden at age 6 to 11 years of standing with good classification.

MATERIAL AND METHODS

Study site:

This study was conducted on plots of Perhutani's Teak Plus from Clones Seeds Garden. These are combinations from PHT I and and PHT II. Both clones were planted in period 2002 to 2007. The study was conducted in September 2013 when plant oldest is 11 years old and youngest is 6 years old. Furthermore, selected plots selection of Perhutani's Teak Plus is based on growth percent, ring and height of plant. From plots with good criterion, the chosen plots are good accessibility and easiest route for measurement. Plots at each age have been two to three plots of plants as replications. Location of research plots can be seen in Table 1.

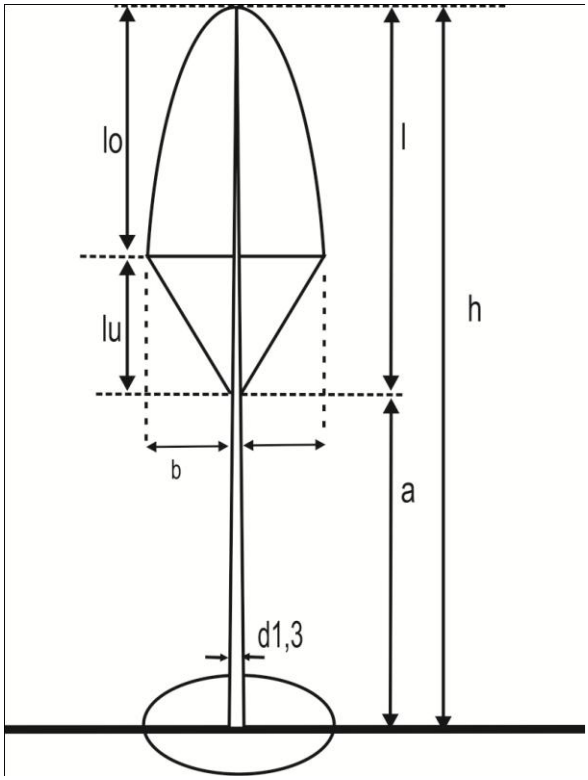
Table 1: Research location of KPH Madiun

Sub-Forest District	Forest Resort	Compartment number	Planting year	Age (years)
Dagangan	Sareng	83 a	2007	6
	Sareng	88 f	2007	6
	Tambak Merang	112 a	2007	6
	Tambak Merang	103 g	2003	10
	Panggung	62 e	2003	10
	Panggung	62 b	2002	11
Sampung	Sampung	92 b	2006	7
	Sampung	34 a	2005	8
	Sampung	76 a	2003	10
	Pohijo	89 b	2005	8
Bondrang	Sawo	118 d	2004	9
	Sawo	118 h	2002	11
	Sawo	121 d	2002	11
	Gunting	56 b	2005	8
Pulung	Setonggo	76 d	2006	7
Dungus	Kuwiran	144 f	2004	9

Sampling and Data Collection:

Samples for each plot were selected from 30 dominant trees to meet the assumption of a normal distribution (Sudjana, 2003). Dominant tree selection criteria are based on a healthy and grow well. Data collection for materials analysis are consisting of tree characteristics of data sample, i.e. the diameter at breast height (1.3 m), maximum crown diameter,

total tree height, crown and initial maximum crown height (Figure 1). Crown measurement is modeled in according to Bayer *et al*. (2013). Main objective is to understand, to predict and to maximize tree growth based on empirical relationship between space to tree growth, crown size and volume.



Keterangan :
d 1,3 : stem diameter
b : maximum crown radius
l : crown height
lo : height of lighted crown section
lu : height of shaded crown section
h : total tree height
a : height at crown base

Fig. 1: Measurement Design of Tree Samples, adopted from Burger (1939) in Assmann (1970) and crown shape model adopted from Pretzsch 2009 case 234).

Measurement of Tree Samples Characteristics:

Diameter is measured by diameter tape (phi band) at a height of 1.3 m (d1,3 m) from the ground. Tree height is measured from total tree height, crown and high initial to maximum crown height using Hypsometer Haga. Initial high is measured at lowest tree crown height, from ground level to lowest crown. Maximum crown height is measured from the base of tree to high indicating the width of crown diameter (Figure 1).

Crown diameter is measured from the outer crown projection on four sides of radius in four cardinal directions of north, west, south, and east (Ayhan (1973) in Foli *et al*., 2003; Sadono, 2014a). Measurements were taken 2 to 3 times to obtain accurate measurement results (Laar and Akca, 1997).

Based on research Fu *et al*. (2013), an important variable in tree crown modeling is the crown size. It usually indicates a long crown or crown width ratio. Crown width is a useful measure. It allows to predict tree growth. Crown width can also be used in ecological modeling to predict the crown light interception.

Data Analysis:

Data measurement of each sample consists of crown length, crown length exposed to light and shaded crown. Crown length is obtained from the difference between total tree heights with initial high crown. Header length exposed to light is obtained by reduction of total tree height with maximum crown height and crown length or shade is obtained from the difference between the maximum crown heights with initial high.

Model crown is assumed symmetry with same shape on both sides. Modeling crown crown shape is adopted from Pretzsch (2009, p. 234) by modifying the initial value of crown width equal to zero. Furthermore, model is limited to depict crown model and crown volume calculation exposed to light. Top crown top exposed to with paraboloid-shaped can be prepared with the following mathematical equation:

Rl = c * hld

where

hl: crown length exposed to light = lo (m)

Rl: crown radius of lighted crown section (m);

c and d: intercept and slope

Crown dimension is is included to clarify the description of measurement crown for each age. The dimensions include: crown ratio = l/h; crown factor (Crown Form Index) = l/2 * b; headline to gets light

on tree height = lo/h; Crown thickness index = 2 * b/l.

Crown volume of lighted crown section is obtained by integrating the equations derived from modeling with assumption that crown and lighted crown section of an object is rotate with radius perpendicular to y-axis, while the length of tree crown is perpendicular to x axis (Raharjo and Sadono, 2008).

Age is used to estimate the crown volume of lighted crown section by regression analysis. Model of crown volume of lighted crown section obtained by curve estimation. The model is statistically significant if the value of test statistics are in critical areas where H0 is rejected, otherwise called not significant when the value of test statistics are in an area where H0 is accepted (Ghozali, 2001). The best model is selected based on coefficient of determination and a high adjusted coefficient of determination, value of standard error of estimate are small, statistical F and t statistics are significant.

Result:

Tree and Crown Characteristics:

Samples trees are 480, consisting of 90, 60, 90, 60, 90 and 90 respectively for each of age of 6 years to 11 years in 16 plots of Perhutani's Teak Plus selected. Samples measurements samples in each age were analyzed with descriptive statistics for variable development at each age (Table 2a and Table 2b). General trend the average value of crown diameter, initial high, height maximum, total tree height, diameter maximum, length and lighted crown section are continues to increase in every age.

Table 2a: Average value of trees and crown characteristics at each age

No	Age (th)	Samples	Average								
			DBH (cm)	TAT (m)	TTM (m)	TPT (m)	DTM (m)	Rmaks (m)	l (m)	lo (m)	lu (m)
1	6	90	10,49	3,86	5,45	8,21	2,84	1,42	4,35	2,76	1,59
2	7	60	13,12	4,46	6,80	10,24	3,58	1,79	5,79	3,44	2,35
3	8	90	15,15	5,20	7,64	12,68	4,21	2,11	7,49	5,05	2,44
4	9	60	15,55	4,78	7,30	12,41	4,40	2,20	7,63	5,11	2,52
5	10	90	17,05	6,65	8,61	14,30	4,16	2,08	7,65	5,69	1,96
6	11	90	18,53	6,58	8,98	14,64	4,67	2,34	8,06	5,66	2,40

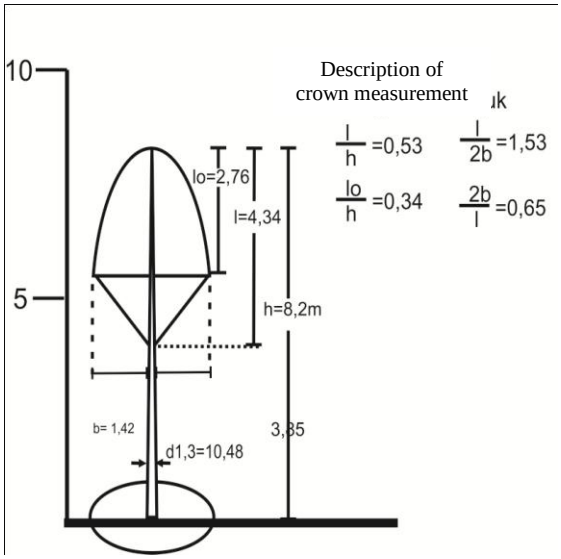
Table 2b: Standard deviation of trees and crown characteristics at each age

No	Age (th)	Samples	Deviation Standard								
			DBH (cm)	TAT (m)	TTM (m)	TPT (m)	DTM (m)	Rmaks (m)	l (m)	lo (m)	lu (m)
1	6	90	2,347	0,90	1,11	1,42	0,99	0,50	1,55	1,32	1,05
2	7	60	3,463	0,94	1,63	1,87	0,99	0,49	1,89	1,63	1,48
3	8	90	2,946	1,35	1,51	1,83	0,88	0,44	1,56	1,88	1,47
4	9	60	3,200	1,72	1,66	2,71	1,02	0,51	2,25	2,65	1,74
5	10	90	4,134	2,42	2,47	3,65	1,15	0,56	2,94	2,89	1,51
6	11	90	3,736	1,58	1,77	1,50	1,15	0,57	1,98	2,09	1,59

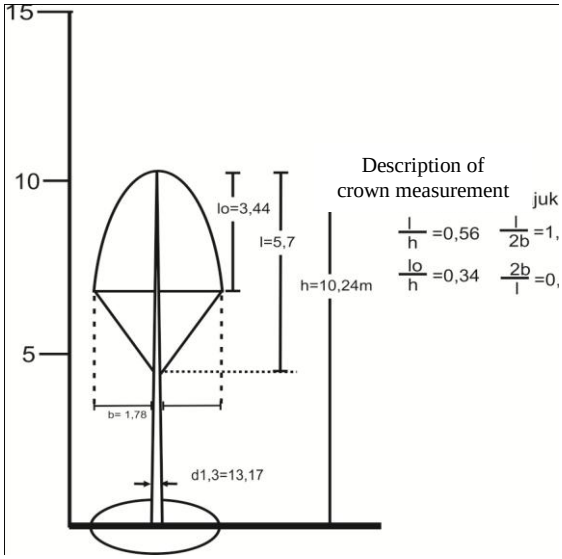
Description: DBH = diameter at 1.3 m above land; TAT = initial crown high; TTM = maximum crown height; TPT = total tree height; DTM = maximum crown diameter; Rmaks = radius of maximum crown; l = crown length; lo = header length is lighted crown section; lu = shaded crown length

Crown Shape Models:

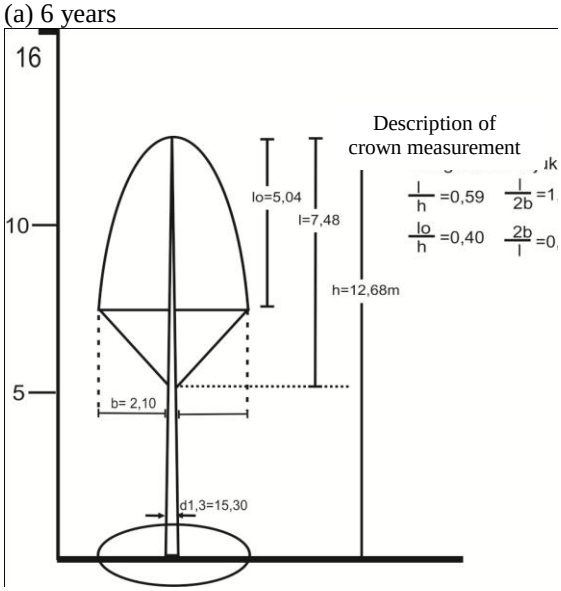
Visual observation result of Perhutani's Teak Plus crown and crown characteristics show that crown can be modeled to follow the crown shape models from Pretzsch (2009, p 234). Heading is divided into two parts, lighted crown section and part shade (shaded crown section). Headers are exposed to light while the paraboloid-shaped crown shaded linear shape with an early diameter is assumed 0. Crown model made is used to describe the crown measurement at age of 6 to 11 years. Description of crown in every age and dimensions can show clearly crown shape development (Figure 2).



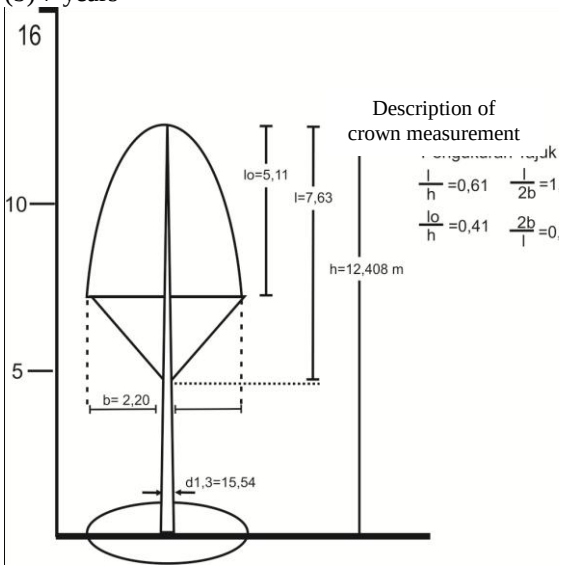
(a) 6 years



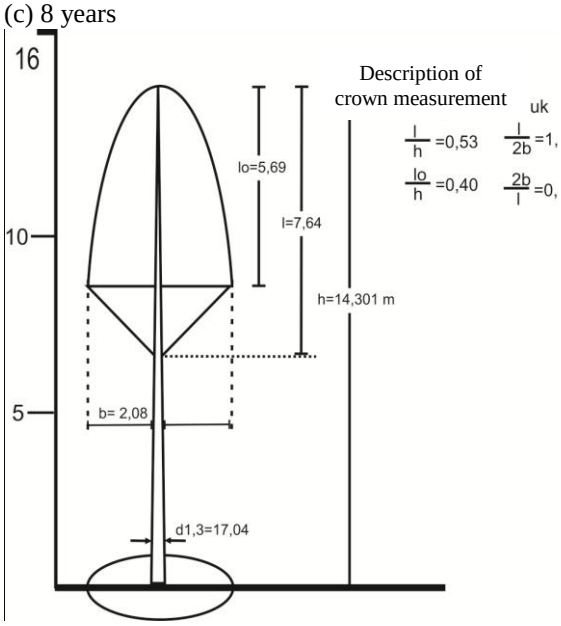
(b) 7 years



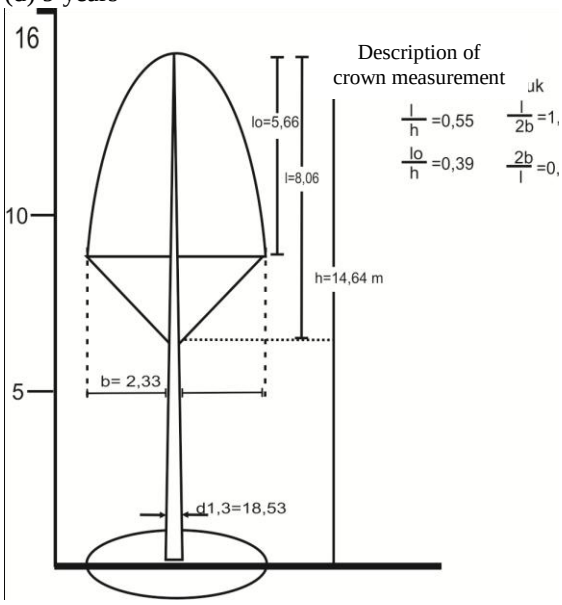
(c) 8 years



(d) 9 years



(e) 10 years



(f) 11 years

Fig. 2: Description and Dimensions crown shape at aged 6 to 11 years

Six figures above show that tree crown is dominated by crown. It is shown by crown ratio of more than 50%, while the proportion of lighted crown section is more than 25% of total tree height. Crown factor index ranged from 1.53 to 1.84. Generally, value of header factor increases along with tree age. Value for crown ratio ranges from 0.53 to 0.61. Crown ratio is proportional to thickness of headline index, where the increasing age, ratio of thickness and index of crown will also increase. Value comparison is needed to determine the effect of lighted crown section on whole tree and optimization of process of photosynthesis.

Lighted Crown Section Models:

Crown shape visualization in every age can be used to determine mathematical models. Determination of mathematical model is based on average value of crown characteristics measurement. Crown modeling of Pretzsch approach (2009) divides the crown in two models of linear equations (crown shaded section) and paraboloid (lighted crown section). This study only focuses to lighted crown section. Mathematical model only use paraboloid. Selected sample of average tree has a ratio between height and crown diameter of 1: 2. According to Corder (2000), a crown shape can be approximated by a paraboloid shape if it has a length and width ratio close to 1: 2 or with a number form 0.5. These paraboloid model equations used line or slope coefficient (d) of 0.33 (Pretzsch, 2009). However, this value is not addressed because of subject is a model tree crown. Results of crown modeling on age levels are presented in Table 3.

Table 3: Mathematical models of lighted crown section for Perhutani's Teak Plus from Clones Seeds Garden

No	Age (th)	Paraboloid			
		$Rl = c*hl^d$	c	d	Lo
1	6	Rl=1,02* hl^d	$(Rmaks/(lo^{0,33}))$	0,33	lo=0,64*l
2	7	Rl=1,19* hl^d	$(Rmaks/(lo^{0,33}))$	0,33	lo=0,59*l
3	8	Rl=1,23* hl^d	$(Rmaks/(lo^{0,33}))$	0,33	lo=0,67*l
4	9	Rl=1,28* hl^d	$(Rmaks/(lo^{0,33}))$	0,33	lo=0,67*l
5	10	Rl=1,17* hl^d	$(Rmaks/(lo^{0,33}))$	0,33	lo=0,74*l
6	11	Rl=1,32* hl^d	$(Rmaks/(lo^{0,33}))$	0,33	lo=0,70*l

Table 3 also compares the length of lighted crown section (lo) and header length (l). The values show that more than half of header length is a header section of lighted crown section. This shows that live crown is greater than the shaded crown. Amount of active crown indicates that tree crown requires a plentiful supply of nutrients for growth and crown photosynthesis becomes catcher light for production process. Greater nutrients provided makes the growth will be faster.

Crown Volume Estimation of Lighted Crown Section:

Crown volume of lighted crown section is one indicator of stand growth. It is able to give consideration to appropriate silvicultural measures for stands, mainly related to availability of space to grow. It has been assumed that crown shape is symmetry, so that crown volume of lighted crown section can be calculated by volume of rotate objects. Crown radius is perpendicular to y-axis and perpendicular to long editorial on x axis. Therefore, crown volume of lighted crown section can be obtained by integrating the equations derived from modeling of lighted crown section (Table 4).

Table 4: mathematical equation of crown volume of lighted crown section

No	Age (th)	Crown volume of lighted crown section
		$V = \pi(0{,}623 * hl^{1{,}66})$
1	6	$V = \pi(0{,}853 * hl^{1{,}66})$
2	7	$V = \pi(0{,}917 * hl^{1{,}66})$
3	8	$V = \pi(0{,}994 * hl^{1{,}66})$
4	9	$V = \pi(0{,}827 * hl^{1{,}66})$
5	10	$V = \pi(1{,}047 * hl^{1{,}66})$
6	11	

Above equation can obtains estimation of crown volume of lighted crown section at each age 6 to 11 years respectively 10.5653 m^3; 20.8365 m^3; 42.3296 m^3; 46.8301 m^3; 46.6000 m^3 and 58.4915 m^3. These figures show that crown volume increases along with age.

Modeling The Crown Volume of Lighted Crown Section:

Estimation the crown volume of lighted crown section is calculated from age. Curve estimation regression analysis is used to obtain best prediction of model similarities with age as independent variable. Age is one factor to describe the growth of forest stands through a massive increase over time in form of increment (RJ, 2013). The best model is selected if it meets the requirements for estimating crown volume. According to Marcelino (1960) and

Prodan (1965) in Susila (2012), in preparation of a model based on a regression equation using the variables of allowed standard error (Se) at maximum of 25%.

From model criteria acceptance, it is obtained results that S model is the best to estimate the crown volume of lighted crown section. S Model has a coefficient of determination of 0.9601 and adjusted coefficient of determination corrected $Radj^2$ of 0.9022. It means more than 90% volume variation of lighted crown section can be explained by age. It also has small standard error of 0.2046 compared with other significant models. F test is done by comparing the F value level of significance test used (0.05). Analysis of variance model shows S has a Sig. F < (0.05) which shows that proposed regression equation can be accepted as a predictor equation of crown volume of lighted crown section. For t-test, S model has the Significant smaller than the significance level (0.05) and statistically significant. Therefore the S model is used as a predictor models the lighted crown section with age and can be written as:

Crown volume of lighted crown section = $\boldsymbol{e^{(6,2063-22,1859/umur)}}$

Where e is natural numbers (2.71828).

Discussion:

Lighted Crown Models:

This model is a representation or abstraction of an object or actual situation. The model shows the directly or indirectly relationship, and reciprocity relation in terms of cause and effect. Cause is abstraction from reality, then the reality is less complex than reality itself (Suwarto, 2006). Furthermore, Suwarto explained that model is a simplification of a complex reality. Based on above definition, it can be understood that something is a function of model to simplify the description of reality characteristics in field. Development of model has aims to create various forms of prototype implementations that can be used as a reference for policy making and implementation in field.

Research on model of lighted crown section is to estimate crown volume of lighted crown section that not to be found yet. The research is still on relationship components of crown to growth and plants development. Each plant has different crown shape, it needs different approach to geometry. Generally, function of model crown is one variable to see tree growth, to determine the appropriate silvicultural treatments so that growth and development of tree can optimal and to understand structure and dynamics of forest stand.

Research results show that every age has its own crown model of lighted crown section. This indicates that at every age the shape and structure of crown there is a difference. Models obtained can describe the condition of circumstances at time of crown measurement. Crown models are represented in picture to see the development of crown at each age. In addition to revealing more information, crown models are also represented in form of equations. Therefore, we can estimate the magnitude of crown volume , crown volume particularly lighted crown section.

Crown Volume of Lighted Crown Section:

Estimation the crown volume of lighted crown section for Perhutani's Teak Plus is obtained by finding tape rotary volume, because the model used is a paraboloid crown. Crown volume plays an important role in metabolic processes, so that part of light crown development is closely related to it. Crown development of lighted crown section is influenced by many factors, including age, density and slope. Therefore, to see the crown development of Perhutani's Teak Plus at every age, it can be seen in Figure 3. The image is presented along with pictures all over the depiction of estimated crown volume of lighted crown section. It can seen and compared to Crown shape and crown volume of lighted crown section of Perhutani's Teak Plus from Clones Seeds Garden at age 6 to 11 years in KPH Madiun.

In addition to looking at Crown shape , it is used for volume estimation of lighted crown section, to see the availability of growing space for plants of Crown Projection Area (CPA), which is an area of maximum of crown diameter. This value is used as an indicator to see plant growth and needs of crown space. Area search of crown projection is useful to understand structure of forest, competition and production. Area of crown projection is calculated using the approach of circle area (Sadono, 2014a).

Crown development at age 6 to 11 years is increase, despite the fluctuation of crown element variables. Crown shape increase at age of 6 to 8 years. Crown is looked taller and larger. Meanwhile, at age of 9 years crown tends to widen the maximum crown diameter, it makes the crown becomes fuller. At age of 10 years crown become higher and longer. At age of 11 years, crown becomes highest crown and widest diameter. This shows that crown development is affected by age.

Volume estimation of lighted crown section is obtained not in massive volume, but still there is still an air cavity in it. Crown shape development of Perhutani's Teak Plus is affected by increase in volume estimation of lighted crown section at levels 6 to 11 years. Although the crown shape can not be represented as an ideal development and consistent form, but it can be seen that crown shape changes as evidenced by longer age of lighted crown section, the volume also increased.

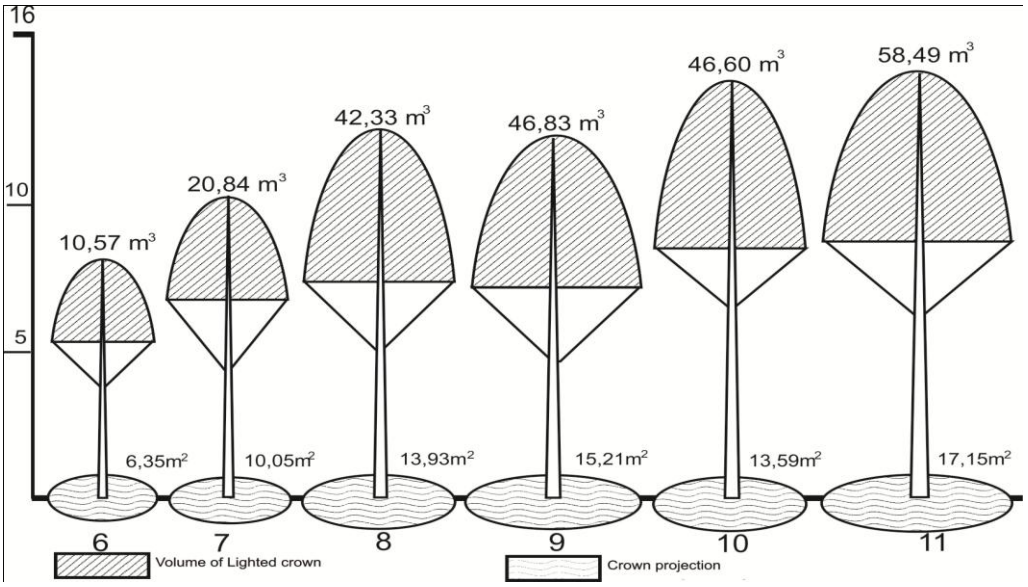


Fig. 3: Crown Depiction of Perhutani's Teak Plus at Age 6 to 11 Years Along with Estimated Volume Crown of lighted crown section and Crown Projection

Regression analysis only uses one independent variable, in this study is age. Significance level is set at 5%. This means that probability of correct decision is at 95% (1-α), or the wrong decision has probability of 5%. Best model is a model that gives the smallest prediction error. A small error rate will affect the accuracy of estimation results of of lighted crown section. Correlation coefficient close to 1 means that independent variables can explain or describe variables, has high coefficient of determination (R2) and adjusted coefficient of determination ($Radj^2$), small standard error values and significant value of F and t is less than 0.05, which gives a real effect for each variable. Based on results of research in KPH Madiun after estimation curve analysis to look at modeling and acceptance test the model, model obtained estimators crown volume exposed to best light is S model with the equation V crown formed is exposed to light = e (6.2063 to 22.1859/age. It means that crown volume of lighted crown section can be obtained only by looking at age. e value indicates the natural number with value of 2.71828.

Relationship Between Volume Crown of lighted crown section and diameter at breast height:

Diameter is one easiest tree parameters to be obtained/measured. But because the tapered shape of tree, diameter values obtained as every decision point on a stem diameter. Therefore, location of stem diameter measurements will become characteristic of a tree. It is based on DBH (diameter at breast height) as a measurement standard stem diameter. According Muhdin (2003), diameter at breast height is dimensional accuracy that most easily controlled. Therefore, it is often used as predictor variable dimensions of other trees.

The area of crown projection reflects how much tree needs space to grow, to get nutrients. greater projection, It means nutritional needs are also more and more. More age needs greater crown projection. Crown increase area is affected by age. However, at age of 9 years old, it has an area greater than the 10 years. This proves that competition at age of 9 small as evidenced by a small competition index in Sadono research (2014b) of 0.5 on same stand.

Relationship Between Age and Volume Assessment of lighted crown section:

Age is a variable with high correlation to growth, especially the diameter and volume of trees. More age is accompanied by diameter increase annually. Age affects volume development of lighted crown section. Relationship between age and volume estimation of lighted crown section at Perhutani's Teak Plus is obtained by looking at various models using curve estimation and then searching the best model using regression analysis. According to West (2009), regression analysis is one tool that can be used to analyze the data in context of natural and physical sciences. Regression analysis functionality to determine how the relationship between one variable with another and can assess the value of a variable from one or several other variables. Particularly since the 1960s, when computers became available, much regression analysis was introduced. Many scientists in field of forestry also developed a various volume equations for many types of trees in world and followed by other scientists (Cordero and Kanninen 2003; Akindele and LeMay 2006; Brandeis *et al*., 2006; Dieguez-Aranda *et al*., 2006b; Vallet *et al*., 2006 in West (2009).

supplies of nutrients, water and light for growth, 3) thinning activities that trigger lower plant growth thereby increasing competition.

Role of Crown Models in Stands Dynamics:

Stands of teak plantations will have dynamic growth. Stand dynamics is closely related to resources sharing both nutrients and light needed for growth (Sabarnudin *et al*., 2004). Stand dynamics will affect the development process and growth of Perhutani's Teak Plus, including in crown development.

Tree crown is one component that plays a role in stands dynamics, mainly on vertical space. Dynamics process will affect the shape and size of stem (Rudnicki *et al*., 2003). Competition over resources in light for photosynthesis and dry matter production of wood products is one crown dynamics on Perhutani's Teak Plus on vertical space. One thing that should be of concern is how to create a balance competition in vertical space of light resource. Moreover, nature plastic response of each individual trees also affect the individual's ability to makes a particular size of crown morphology (Rozendaal *et al*., 2006).

The shape and size of tree crown has an important relationship with growth of stands factors, such as plant spacing, wood quality control and need for maintenance (Daniel *et al*, 1987). Crown model of lighted crown section at Perhutani's Teak Plus has been prepared to become instrumental in formulation of strategies silvicultural considerations. Growing space arrangement can provide sufficient resources for the process of growth as one silvicultural strategy. Technical measurement of growing space arrangement is the determination of spacing in forest plantation development by utilizing crown trend model. Determination spacing of Perhutani's Teak Plus still not notice trend of crown development. It still based on site quality (bonita) and type of plants used.

Teak stands generally have basic properties of low crown density and high transparency of leaves (foliage transparency) because of teak leaves tend to be thin and little in each tree. These nature causes sunlight penetrate into trees crown at lower position level so that light resource requirements can be fulfilled. This is caused by positive correlation between the area of leaf with the amount of sunlight absorption (Campoe *et al*., 2013). Direction of leaves surface also affect the crown formation where broad leaf trees tend makes wider crown in horizontal direction (Kitajima *et al*., 2005). Crown volume of lighted crown section in this study may reflect both the nature, and also at Perhutani's Teak Plus.

Based on crown model depiction, the greater lighted crown section, so that crown volume is also bigger than the shaded crown. This was due to volume will determine the light size that can be absorbed by leaves for photosynthesis. These

According to Krajicek *et al*. (1961) in Shimano (1997), if a tree does not have a competition with neighbor's tree then there is a linear relationship between crown diameter and stem diameter. While Meng *et al*. (2007) revealed that stem diameter has a strong correlation with crown volume. It was also included in study Bechtold (2003) using a diameter as a predictor variable to determine the width or diameter of tree crown. Based on some study results, stem diameter or diameter at breast height (1.3 m) can be used as a predictor variable to predict volume of tree crown.

Based on above graph, it can be seen that there is a strong correlation between the crown volume of lighted crown section and diameter at breast height. This is shown on magnitude of determination coefficient. Correlation coefficient of 0.9722 indicates that crown volume of lighted crown section has a strong positive linear relation with diameter at breast height. Coefficient of determination of 0.9452 means that more than 94% diameter at breast height (1.3 m) can be explained by crown volume of lighted crown section. It can obtained with the diameter trendline equation = 0.1537 * crown volume of lighted crown section + 9.2002.

Relationship Between Crown Volume of lighted crown section and Branch-Free Stem:

Crown and stem growth has a close relationship. This is related to crown as a function of metabolic processes and stem is a result of metabolism. Tree photosynthesis ability is affected by leaf wide, while leaves wide of a tree can be controlled from the crown pruning. Davis and Johnson (1987) states that crown closely related to diameter at breast height. Branch-free stem volume is used as basis of Sudarman (2014) on same object for each age 6 to 11 years, respectively at 0.0296 m^3; 0.0545 m^3; 0.0800 m^3; 0.0847 m^3; 0.1323 m^3 dan 0.1497 m^3.

Jayanti (2010) mentions that relationship between the crown volume and branch-free stem volume is positive. This is also indicated by value of correlation coefficient of crown volume of lighted crown section and branch-free stem volume at 0.9123 and is positive. Magnitude of coefficient of determination was 0.8323. It means more than 83% of branch-free stem volume can be explained by exposure to light with a crown volume trendline branch-free stem volume = 0.0023 * crown volume of lighted crown section + 0.0021. Presentation means that there is a relationship between the volume of branch-free stem and crown volume exposed to light.

Factors affecting the volume change of lighted crown section and branch-free stem volume are: 1) effect of seasons change, dry season makes the trees shed their leaves to minimize absorption of sunlight for photosynthesis, 2) competition level between individual tree crown is shown on overlapping to get

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conditions consistent with opinion of Daniel *et al*. (1987) in Raharjo and Sadono (2008) which revealed that stand condition, bottom crown that receives relatively little light contributes to net photosynthesis process. Large crown volume will affect on tree growth due to crown size has a strong correlation with the trees growth (Jimenez *et al*, 2002). In addition, amount of sunlight absorbed by tree crown size generally has logarithmic trend to decide where the equation for the average amount of effective sunlight on certain crown size (Forrester & Albrecht, 2014)

Size and wide of crown relate to availability of growing space which will affect the tree development (Bohlman & Pacala, 2012). Growing space will affect on roots to get the nutrients that will be used to carry out metabolic processes, namely, photosynthesis. Crown condition and crown projection area can predict how much tree needs space to be able to carry out metabolic processes.

Conclusion:

Crown model of lighted crown section at Perhutani's Teak Plus from Clones Garden Seeds in KPH Madiun can be described in form a paraboloid. Lighted crown section is crown radius are exposed to light = c * (length of crown exposed to light) 0.33 with a value of c = 1.02; 1.19; 1.23; 1.28; 1.17 and 1.32 respectively for the age of 6, 7, 8, 9, 10 and 11 years.

Model of lighted crown section of Perhutani's Teak Plus from Clones Seeds Garden aged 6 to 11 years in KPH Madiun is: Volume headers = π * c * (length crown exposed to light) of 1.66, with a value of c respectively 0.623; 0.853; 0.917; 0.994; 0.827 and 1.047 for age 6, 7, 8, 9, 10 and 11 years in order to obtain estimated crown volume of 10.5653 m^3; 20.8365 m^3; 42.3296 m^3; 46.8301 m^3; 46.6000 m^3 dan 58.4915 m^3 respectively.

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