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Volume Estimation of Standing *Shorea* sp. on UPM-JISE Rehabilitated Forest in Bintulu, Sarawak

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Abstract

This study was aimed to analyze the relationship between diameter at breast height, height, and volume of standing Shorea sp. and the relationship between age and volume of this species. The study was conducted at different ages of rehabilitated forest in Bintulu Sarawak, where the measurement was taken from tree stand year 1992 until 2003. The sampling plot of 20m x 20m was built for each age of stand. Ten standing Shorea sp. were randomly measured for sectionals (taper) from diameter at breast height until the free branches of the tree. The rest of the trees within the plot were only measured by diameter at breast height. All collected data were calculated to find basal area of each tree in meter square (m^2). The volume per plot was calculated using the Smalian's formula to find the taper volume of the Shorea sp. Statistical analysis was conducted to find the regression equation which could explain the relation between volume, diameter, and height of the tree. Result showed that there was a relationship between volume, diameter, and height of the tree, and also there was relationship between volume and age of the tree. Meanwhile, there was no relationship between taper of standing trees and age of trees. This means that volume taper of standing tree and age have no correlation.

Keywords: rehabilitated forest, volume estimation, basal area, taper, regression analysis

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Introduction

With the impending shortage of raw timber supply and the increasing area of degraded natural forest, forest rehabilitation is the key answer to overcome this problem. Rehabilitation of forest involves re-establishment of more intact canopy that is found in undisturbed forest (Lim 1992). Even though the potential of using indigenous tree species for forest plantation in Malaysia has been known since 1921 (Appanah and Weinland 1993), the species were never planted on a large scale. Instead, they were planted as part of experimental research or reforestation project.

Aiming to realize a sustainability developing society through ecological study, Japanese center for International Studies in Ecology (JISE) conducts practical research toward restoring and improving the environment related training programs and provides environmental information. JISE ecotour in Malaysia aimed to train and educate specialist, student and every other stakeholder for practical reforestation.

The UPM-JISE rehabilitation joint research project was held in 90 hectare Bukit Nyabau reserved forest for research and demonstration. It was started in 1991 and the species of trees that have been planted since then until now were including *Shorea* sp. such as *S. ovata, S. macrophylla, S. mecistopteryx,* and many other species such as *Dryobalanops beccarii*, *Parashorea parvifolia, Hopea beccariana, Durio carinatus, Eusideroxylon zwageri, Vatica cuspidate, Koompassia malaccensis, Callophyllum* sp., and *Dipterocarpus* sp. At the phase 4 plantation area, the earliest plot was in the year 1995 and the most recent plantation was in 2006. Then it was need to estimate the volume of standing *Shorea* sp. at phase 4 JISE-UPM rehabilitation project as one of indicators of the effectiveness of the rehabilitation project on this abandoned area.

Stem volume measurement is a laborious and time consuming task, even for felled trees. In modern forestry practice, one of the most common reasons for taking such measurements is to develop stem 'volume function' or 'taper function' for a particular tree species in a particular forest region. Stem volume functions allow estimation of the total stem volume of individual trees from simple measurement, which can be taken from the ground, usually diameter at breast height and total height (West 2003).

The objectives of this study were to analyze the relationship between diameter at breast height (dbh), height, and volume of standing *Shorea* sp. Also, to determine the relationship between age and volume of standing *Shorea* sp.

Method

A study on the estimation volume of standing trees was located at UPM-JISE Rehabilitated Forest, Bintulu and 5 km from the Bintulu town. It is located about 600 kilometers northeast of Kuching, latitude 03º12'N, longitude 113º02'E and 50 meters above sea level. The soil of the study area belongs to Nyalau and Bekenu series, which is well drained. The study was conducted on this rehabilitated area, where the plot established on the flat until undulating area and measurement was taken from tree stand year 1992 until 2003. The sampling plot of 20 m × 20 m was built for each age of stand.

The volume of the sample trees was determined on the standing tree. Diameters at breast height (dbh) of 10 trees per plot were taken and volume was determined by section wise measurements.

For small tree, height was measured directly with height poles. Height poles consist of section of light-weight materials (usually fiberglass) that can be extended to form a measuring stick of length equal to the height of tree being measured. Poles can be used quite efficiently for trees up to 12 m (Avery and Burkhart 2002).

The height accumulation concept was conceived and developed by Grosenbaugh (1948, 1954), who stated that the system can be applied by selecting tree diameters above breast height in diminishing arithmetic progression, say 1 or 2 in taper intervals, and estimating, recording, and accumulating tree height to each successive diameter. For a tree with small diameter, digital calliper was used to determine diameter in millimeter(mm). For older tree with big diameter, diameter tape was used to determine diameter in centimeter (cm).

Collected data was filled in the volume table. There are 2 types of table volume available. The first table is only for climbed trees (measured sectionals) and the other one is the table only for unclimbed trees. Ten trees in total on every plot were measured their diameters and heights at sectionals (taper). The rest of species left on every plot was measured only by their diameters at breast height (dbh) and total free branch height.

The volume was determined using the Smalian's formula as below (Husch 2003):

$$\text{Smalian's} = [(s1 + s2)/2] \times l \qquad [1]$$

where:
$s1$ = smallest diameter (cm)
$s2$ = biggest diameter (cm)
l = lenght (m)

Study parameter. Parameters in this study were:

1 Diameter at breast height (cm). Diameter at breast height is the diameter of the stem of a tree measured at breast height (4.5 ft or 1.37 m) from the ground. It is usually implied diameter outside bark of the tree.
2 Height (m). Height is the linear distance of an object normal to the surface of earth or some other horizontal datum plane. Total height is the distance along the axis of the tree stem between the ground and the tip of the tree.
3 Volume (m^3). Volume was calculated using the Smalian's formula. It is known as an important parameter for providing information necessary for making decision.

Data analysis. Regression and correlation analysis were carried out by SPSS to analyze relation between diameter, volume and height of the tree, also to calculate the percentage of volume regressed from basal area. Form factor was also estimated from regression equation, with diameter and height as independent variables. Combination of regression relation would be diameter at breast height versus volume, and diameter at breast height, and height versus volume.

Result and Discussion

Relationship between volume and diameter. According to Table 1, all regression has significant reading below 0.05. This indicates that there has been significant linear correlation between volume (logV) and diameter (logD).

The lowest coefficient determinant was the regression resulted on plot 1 (R^2 = 0.596), which means 59.6% of the total variation in logV can be explained by linear equation logV = -0.552 + 1.482logD. The highest coefficient determinant was the regression resulted on plot 5 (R^2= 1.000), which means 100% of the total variation in logV can be explained by linear relationship between logD and logV as described by regression equation logV = 0.259 + 1.989logD.

Table 1 Regression equation between volume and diameter of each plot

Plot	n	Regression equation	R^2	F	Signif.
1	10	logV = -0.552 + 1.482logD	0.596	11.78	0.009
2	10	logV = 0.381 + 2.086logD	0.972	275.26	0.000
3	10	logV = 0.75 + 2.342logD	0.927	101.01	0.000
4	10	logV = 1.138 + 2.671logD	0.878	57.82	0.000
5	10	logV = 0.259 + 1.989logD	1.000	15247.4	0.000
6	10	logV = 1.162 + 2.66logD	0.959	187.7	0.000

In activity, the estimation volume using trees diameters will be feasible with treat assumption that trees with the same diameters would give the same volume, in the same growth condition. According Loewenstein (1996), diameter distribution for small areas of uneven-aged forests may show considerably greater irregularity. From the regression analysis, the significant reading was less than 0.05. It shows that there has been a significant difference between diameter and volume of taper with the level of confident 95%. So, from this result, the independent variable (diameter) in regression equation has a relationship and correlates with the dependent variable (volume).

It was visible that value significant relationship between volume and diameter in regression equation for every species was big enough. The equation described about the relationship between basal area and merchantable bark using the sums of the integration methods. This indicated that the relation between diameter and volume was less correlated compared to the linear graph from other plot. Some were too small while others were too big.

Interrelationship between volume and diameter from chosen trees was adequate close, whereas regression equation which stated that relationship would be evident. Thus, regression equation achieved usable to calculate the real volume for all trees in other areas. However, they may not be representative of all trees in a stand plot.

Relationship between diameter, volume, and heights. According to Table 2, all regression has significant reading below 0.05. This indicates that there has been significant linear correlation between volume, diameter and height. The lowest coefficient determinant was the regression resulted on plot 1 (R^2 = 0.649), which mean 64.9% of the total variation in log V can be explained by linear equation logV = -0.852 + 1.407logD + 0.665logH. The highest coefficient determinant was the regression resulted on plot 5 (R^2 = 1.000), which mean 100% of the total variation in logV can be explained by linear relationship between logD and logV as described by regression equation logV = 0.321 + 1.997logD – 0.091logH.

Based on the relationship between volume, diameter and height, the significant value of all regression was between 0.000-0.026. This significant value also shows that there has been a significant different between diameter, height and the volume of taper. So, the independent variable (diameter and height) in regression equation has a relationship and correlates with dependent variable (volume).

Similarly, the regression equation in diameter and volume relationship, 100% of total variation in Y can be explained by the linear relationship. So regression equation logV = 0.321 + 1.997logD – 0.091logH, can be used to estimate the volume of the same species within the stand.

Based on calculation result, proved determination volume in field was compared only go through diameter, and then calculated based on diameter and height test. This result was clearer and more accurate.

The total volume of standing tree. According Table 3, the highest volume was plot 6. The total volume for plot 6 was 1.579 m^3 and the lowest total volume was plot 1 = 0.025 m^3.

This association was divided by two namely, association between age and taper volume which were calculated using the Smalian's formula and association between age and total volume of standing tree using regression equation. Between age and taper volume there has been less significant. This means that there has been no relationship between age and the volume of the tree. This was because each age stand has many different species that might vary in size.

The study on 8 and 16 feet softwood logs of 4-12 cm in diameter, calculated volume by Newton's, Smalian's, and Huber's formulas were compared with volumes determined by displacement (Husch 2003).

In this area many of trees have small diameters. For many species, upper-stem bark factors were not often same as lower stem bark factors. To account for this, it might need to develop multiple regression equations to predict upper-stem bark factors from such variables as tree age, tree dbh, height above ground, and diameter outside bark at cross sections for which bark factor is desired.

Table 2 Regression equation between diameter, volume, and heights of each plot

Plot	n	Regression equation	R^2	F	Signif.
1	10	logV = -0.852 + 1.407logD + 0.665logH	0.649	6.468	0.026
2	10	logV = -0.509 + 1.88logD + 0.455logH	0.978	154.9	0.000
3	10	logV = -0.461 + 1.814logD + 1.062logH	0.978	158.3	0.000
4	10	logV = 0.485 + 2.346logD + 0.555logH	0.891	28.67	0.000
5	10	logV = 0.321 + 1.997logD – 0.091logH	1.000	10817	0.000
6	10	logV = -0.227 + 2.172logD + 0.972logH	0.985	223.7	0.000

Table 3 The total volume of *Shorea* sp.

Plot	n	Regression equation	Total volume (m^3)
1	30	$V= 10^{-0.552}D^{1.482}$	0.025
2	30	$V= 10^{0.381}D^{2.086}$	0.044
3	30	$V= 10^{0.750}D^{2.342}$	0.143
4	30	$V= 10^{1.138}D^{2.671}$	0.141
5	30	$V= 10^{0.259}D^{1.989}$	0.371
6	30	$V= 10^{1.162}D^{2.660}$	1.579

Conclusion

The regression equation can find strong ties between volume with diameter and volume with diameter and height. Strength of relationship between volume with diameter and height was higher than strength of relationship between volume with diameter.

The regression equation generated from taper volume can be used to estimate the other standing trees within the same plot. Volume functions allow estimation for any trees through measurement only of diameters at breast height and total height. Furthermore, they allow estimation of stem volume between any two points on the stem.

Volume and taper functions have been developed for many of tree species. Measurement taken from two parameters, height and diameter showed more accurate volume value than using only diameter. However, practically taking two measurements need a lot of works. There has been not much different in coefficient determinant reading, so estimation using diameter was easier. Relationship between age and volume using Smalian's formula showed no correlation, so it mean that age can not be indicator for volume estimation.

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