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VOLUME ESTIMATION OF STANDING SHOREA SP. AT UPM-JISE REHABILITATION PROJECT, BUKIT NYABAU BINTULU

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VOLUME ESTIMATION OF STANDING *Shorea* sp. AT UPM-JISE REHABILITATION PROJECT, BUKIT NYABAU BINTULU

BY

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A Project Report Submitted in Partial Fulfillment of the Requirement for the Degree of Bachelor of Bioindustry Sciences in the Faculty of Agriculture and Food Sciences
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Dedicated to my beloved family:

Respected father Mokhsen Abdullah, mother Rohana Said, brothers Izhar Az-zuari, Luqman Al-hakim, Mohd Kamel, Khalid Al-walid, Mohd Fakhrul Razi and little sister Aliya Adiba.

ABSTRACT

This study is to analyze the relationship between diameter at breast height (dbh), height, and volume of standing *Shorea* sp. and the relationship between age and volume of this species. The study was conducted at phase 2 and 4, UPM –JISE joint rehabilitation project, Bukit Nyabau Forest where the measurement was taken from tree stand year 1992 until 2003. There were three stages involved in this research, first stage was building a one sampling plot of 20 × 20m (0.04 ha) for each age of stand. Then second stage was the measurement and data collection within each plot. Ten standing *Shorea* sp. were randomly measured sectionals (taper) 20cm up and down from diameter at breast height (dbh) for 1995-2003 stand while 2m sectionals for 1992 stand. The rest of the trees within the plot were only measured by dbh. All the collected data was calculated to find basal area of each tree in meter square (m^2) and volume sectionals in meter cubic (m^3). The volume was calculated using the Smalian's formula to find the taper volume of ten *Shorea* sp. Regression analysis was conducted to find the regression equation which could explain relation between volume, diameter, and height of the tree. Result showed that there has been a relationship between the volume diameter and height of a tree. By using the regression equation we could find the whole volume of a tree by only measure a dbh on the ground. Another relation was between volume taper of standing tree and age where there was no significant different between them. This means that volume taper of standing tree and ages were not correlated. While as for relationship between regression volume and age shows significance different, which means they both were correlated to each other.

ABSTRAK

Kajian ini adalah untuk menganalisis perkaitan antara diameter (dbh), tinggi, dan juga isipadu dirian pokok *Shorea* sp. serta perkaitan antara umur dan isipadu bagi spesies ini. Kajian telah dijalankan di fasa 2 dan 4 hutan projek pemuliharaan kerjasama UPM-JISE, Bukit Nyabau di mana pengukuran dilakukan dari dirian tahun 1992 hingga 2003. Terdapat tiga peringkat dalam penyelidikan ini iaitu pertama membuat plot persampelan 20×20m (0.04 ha) bagi setiap dirian umur. Kemudian yang kedua ialah pengukuran dan pengumpulan data. Di dalam setiap plot, sepuluh dirian *Shorea* sp.dipilih secara rawak dan telah diukur bahagian demi bahagian (taper) bagi setiap 20cm atas dan bawah diameter paras dada (dbh) bagi dirian tahun 1995-2003, manakala pengukuran bahagian setiap 2m bagi dirian tahun 1992. Selebihnya hanya di ukur diameter paras dada (dbh) sahaja. Semua data terkumpul dikira untuk mendapatkan luas bidang dasar dalam meter persegi (m^2) dan isipadu taper dalam meter kubik (m^3). Isipadu pokok telah dikira dengan menggunakan formula Smalian's untuk mendapatkan isipadu taper bagi sepuluh spesies *Shorea* sp. Analisis regresi telah dilakukan untuk mendapatkan persamaan regresi di mana ia boleh menerangkan perkaitan antara volume diameter dan tinggi pokok. Hasil menunjukkan terdapat perkaitan antara isipadu dan diameter pokok. Dengan hanya menggunaakan persamaan regresi kita boleh mencari keseluruhan isipadu pokok dengan hanya mengira melalui diameter pada paras dada sahaja. Perkaitan yang lain adalah antara umur dan jumlah isipadu dirian pokok di mana ia menunjukkan tiada hubungkait antaranya. Maka umur dan jumlah isipadu taper dirian pokok tidak mempunyai perkaitan. Manakala bagi hubungan antara isipadu regressi dan umur menunjukkan signifikansi di mana kedua-duanya mempunyai perkaitan.

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I certify that this research project report entitled "Volume Estimation of Standing *Shorea* sp. at UPM-JISE Rehabilitation Project, Bukit Nyabau Bintulu" has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Bioindustry Science in the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Campus.

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LIST OF TABLES

LIST OF FIGURE

TABLE OF CONTENTS

LIST OF ABBREVIATION

dbh	Diameter at breast height
JISE	Japanese Center for International studies in Ecology
Σ	Sum
β_0	Population Y-intercept.
β_1	Population slope
b_0	Y-intercept
b_1	Slope
r^2	Coefficient determinant

CHAPTER 1

INTRODUCTION

1.1 Background

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 (Mohamad Azani, 1998). 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 & 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) conduct 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 *Shorea ovata*, *Shorea macrophylla*, *Shorea 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 four plantation area, earliest plot was in the year 1995 and the most recent plantation was in 2006.

Shorea is a genus of 360 species of mainly rainforest trees is the family Dipterocarp. They are native to Southeast Asia, from Northern India to Malaysia, Indonesia and the Philippines. With the observed annual volume increment of 8–17 m^3 ha^{-1} $year^{-1}$ and current high prices of red meranti timber, planting of dipterocarps is much more profitable than the commonly applied practice to convert low-volume forests into plantations of fast-growing exotic tree species (Adjers *et.al*., 1994). Then it's need to estimate the volume of standing *Shorea* sp. at phase four JISE-UPM rehabilitation project as one of indicators of the effectiveness of the rehabilitation project on this abandoned area.

1.2 Problem statement

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).

1.3 Objectives

The objectives of this study are

1) To analyze the relationship between diameter at breast height (dbh), height and volume of standing *Shorea* sp.
2) To determine the relationship between age and volume of standing *Shorea* sp.

CHAPTER 2

LITERATURE REVIEW

2.1 Stand parameters

A stand is a group of trees that occupy a given area and that has some common characteristics or combination of characteristics, such as origin, species composition, size or age that set it apart from other group of trees. Stand structure can also be described using species composition, diameter distribution, height contribution, and crown classes (Oliver and Larson, 1996). For example, stand might be composed of a single species or a mixture of species.

The most important stand parameters characterizing structure include age, species composition, diameter and basal area, height and crown closure, density and stocking, volume, weight and site quality (Husch *et.al.,* 2003).

2.1.1 Age

The trees in an even age stand thus belong to a single age class. If stand, such as plantation, is absolutely even-aged, a count of the annual rings of a single tree will give the age. Younger trees should not be given the same weight as the larger because older trees is make up the major part of basal area or volume of the stand (Husch *et.al.*, 2004).

2.1.2 Diameter

Diameter is used to compute cross-sectional area and summed to yield an estimate of basal area. The total basal area of all trees or specified classes of trees, per unit area is a useful characteristic of forest stand. For example, basal area is related directly to a stand volume and biomass, and is a good measure of stand density and competition. Stand basal area can be calculated from the measurements of the diameter at breast height (dbh) of all trees (Husch *et.al.,* 2003).

2.1.3 Height

Height is another widely used stand parameter. Height is an important factor in determining individual and total stand volumes. Height is widely used as a measure of site quality and stand productivity. For an even age stand, the variation in heights is typically less than variation in diameter (Husch *et.al.,* 2003).

2.1.4 Site quality

Knowledge of growth responses of forest trees to factor of the environment is important to forest management. The relationship of the growth of the forest trees to their environment, or, as it commonly referred to, their site is difficult to measure. The environmental factors of the site can be group as edaphic, climatic, topographic, and competitive. The element in topographic factor is altitude, slope angle or position and length (Husch *et.al.,* 2003). For the slope factor, whether tree grow in flat area or steep terrain area.

2.1.5 Stand density

Stand density is a qualitative measure of stocking expressed either absolutely in terms of number of trees, basal area, or volume per unit area or relative to some standard condition. It also a measure of degree of crowding of tree within stocked areas commonly expressed by various growing space, ratios, e.g., height or spacing.

Predictions of stand development depend largely on ecological concepts. Qualitative silviculture applies principles, concepts and models from population ecology and biometrics to asses and makes prediction relating to various aspects of stand development. It also relates how density influences stand structure, canopy dynamics and production efficiency (Jack and Long, 1996).

Measures of stand density and forest stocking are both used to depict the degree to which a given site is being utilized by the growing trees or simply to indicate the quantity of wood on an area. However, a distinction usually made between the two terms. Gingrich (1967) describe the distinction in this way: "Stand density is a quantitative measurement of a stand in terms of square feet of basal area, number of trees or volume per acre. It reflects the degree of crowding of stems within the area. Stocking, on the other hand, is a relative term used to describe the adequacy of a given stand density in meeting the management objective. Thus, a stand with density 0f 70 square feet of basal area per acre may be classified as overstocked, or under stocked, depending on what density is considered desirable."

2.2 Measuring tree diameter

Tree trunk diameters are measured at breast height (dbh), define as a tree 4 ½ feet above ground on uphill side of the tree. If a tree forks below breast height, each trunk is treated as a separate tree. Dbh can be measured with a tree caliper, a Biltmore stick, a tree diameter tape, or a flexible measuring tape (e.g., cloth or steel) (Heiligmann & Bratkovich,).

2.3 Height determination

Direct height measurement involves simply holding a vertical measuring pole directly alongside the tree stem. With a telescoping set of pole segments, this device can be purchase readily. The aluminium or fiberglass pole has constant length about 1.5 to 2 m. These pole devices are effective to heights of about 12 to15m.

According to West (2004), when using these devices care must be taken to ensure the pole is raised to coincide exactly with the tip of the tree. This requires a team of two to measure heights, one to hold the measuring pole and the other to sight when the tip of the tree is reached.

2.4 Tree volume determination.

Direct volume determinations of parts of trees are usually made on sample trees to obtain basic data for the development of relationships between the various dimensions of a tree and its volume. Relationships of this type are used to estimate the volumes of other standing trees. In the past, sample-tree measurements were often taken on trees cut in harvesting operations. Volume relationships developed from such measurements may lead to bias because they may not be the representative of all trees in a stand. Preferably, measurements should be taken on a representative sample of all standing trees (Husch *et.al.*, 2003).

2.4.1 Estimation of tree volume

Tree volume can be estimated from previously established relationships between certain tree dimensions and tree volume. Diameter, height and form are the independent variables that are commonly used to determine the values of the independent variables-tree volume (Husch *et.al.*, 2003).

Guofan et al. (2006) suggest that diameter distribution and mean height of stand is obtained by sampling, but the stem form factor is either obtained from tables or the form factor is estimated from regression equation, with diameter and height as independent variables.

2.4.2 Sectional measurement of standing trees.

Standing trees could be climbed and measured sectionals (measuring both diameter over-bark and bark thickness) to determine their stem wood volumes. However, this is dangerous and labor-intensive work which is rarely used today. Tree volume and taper functions are available now for many forest tree species in many parts of the world to provide (usually quite precise) estimates of their wood volume from measurements of them which can be made easily from the ground (West, 2003).

2.4.3 Determination of volume by formula.

There are four types of calculation to determine volume. Type one is using cylinder volume determination, two is using Smalian's formula, three is using Huber's formula and lastly is using Prismodial or Newton's formula. Smalian's and Huber's formula is calculating the paraboloid form of solid while Newton's formula is calculating the neiloid form of solid.

If a tree can be climbed, then its volume can be estimated by measuring the length and mid-sectional diameter of girth in exactly the same manner as when the tree has been felled. Even if only the lower part can be climbed, the volume of this part can be estimated using Huber's formula and the volume of the reminder estimated either using Smalian's formula or by employing the model of a cone. The most valuable log usually is the butt log and in a plantation grown tree 40cm dbh and 25 m tall, 80% of the bole volume is contained in the lowest 10 m. Therefore the error introduced by the assumption of a cone for the form of the unclimbed upper part of the tree may not be serious (Philip, 2005).

When Huber's formula is used for part of the bole and Smalian's formula for the reminder, then extreme care is needed to ensure that the cross-sectional area at the top of the last log measured by Huber's formula (that is the base of the first log measured by Smalian's formula) is observed. Smalian's formula is rarely used for the butt section of a standing tree because of the difficulty in estimating the cross-section at or near ground level and because it is less accurate than Huber's-particularly over the butt flare (Philip, 2005).

2.5 Form

The form of main stem of tree has been the subject of many studies and methods of expression in the forest measurement. The stimulus for studying form is its relation to the cubic volume of the tree. The form of the main trees varies due to differences in the rates of diminution in diameter, known as taper, which varies with species, dbh, and age of trees and with sites, is the fundamental reason for variation in volume.

In a definitive study, Larson (1963) discussed the biological concept of stem form by a comprehensive review of the literature. Prodan (1965) presented a detailed summary of European approaches to the description of stem form, which was updated in Prodan et al. (1997). Form factors, form quotation, form point, and taper tables, curves, and formulas can express stem form. In all cases the ultimate objective is to utilize the expressions in the estimation of tree cubic volume.

2.5.1 Form factors

A form factors is the ratio of tree volume of a geometrical solid, such as cylinder, a cone, or a cone frustum, that has the same diameter and height as a tree. (The diameter of the geometrical solid is taken at its base; the diameter of tree is taken at breast height.) A form factor is different from other measures of form in that it can be calculated only after the volume of the tree is known. The formula of form factor f was as below:

$$F = V / V_{gs}$$

Where F= form factor

V= volume of tree

V= volume of geometrical solid of same diameter and height

It was recognized that there are many variations in form and that a tree rarely was of the exact form of these solids. Thus the form factor was conceived as a method of coordinating form and volume. The cylindrical form factor f_c, was the most commonly used (Husch *et.al.*, 2003).

CHAPTER 3

METHODLOGY

3.1 Study area

Study area is located at Phase 2 and 4; UPM-JISE rehabilitated forest project, Bukit Nyabau, Bintulu.

3.2 Sampling method

Methodology was carried out by systematic sampling with random start. Standing tree measurement was taken in 2003, 2001, 1999, 1997, 1995, and 1992 stand. Every plantation block (4, 6, 8, 10, 12, and 15 years) were having 1 plot. The width of every plot was 0.04 hectare or $400m^2$. The measurement was taken inside the area of 20×20m per block.

3.3 Volume estimation method

3.3.1 Sample selection

The volume of the sample trees is determined on the standing tree. The selected n samples trees will be measure. About 10 trees from *Shorea* sp will be climb per plot then; their diameter at breast height (dbh) and volume are determined by section wise measurements.

3.3.2 Height measurement

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.

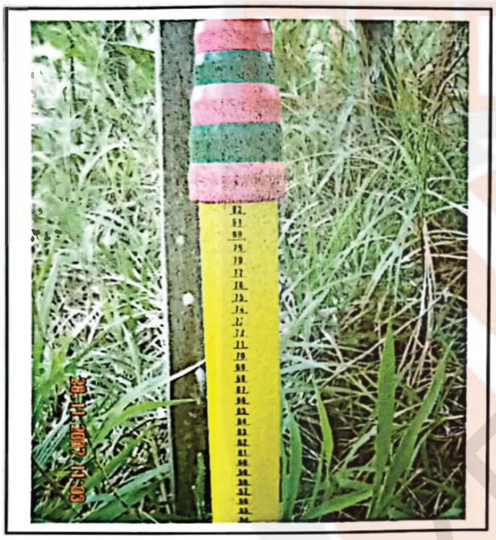

Figure 1: measurement pole

Two people were required to measure trees efficiently with height poles. One person stands at the base of the tree and extend the pole by adding sections at the bottom of the pole (or pulling interior sections out of the base section of the pole) while guiding the tip of the pole along the tree bole until the tip is even with the top of the tree. The second person in the crew serves as an observer to help align the pole tip with the top of the tree and as a recorder of the measurement (Avery and Burkhart, 2002).

For the tree height above 12 m, haga altimeter was use to measure total height of standing tree especially in an older plot.

Figure 2: Haga altimeter

3.3.3 Taper diameter measurement

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 a small diameter, digital calliper was use to determine diameter in millimetre (mm). For older tree with big diameter, diameter tape was use to determine diameter in centimetre (cm).

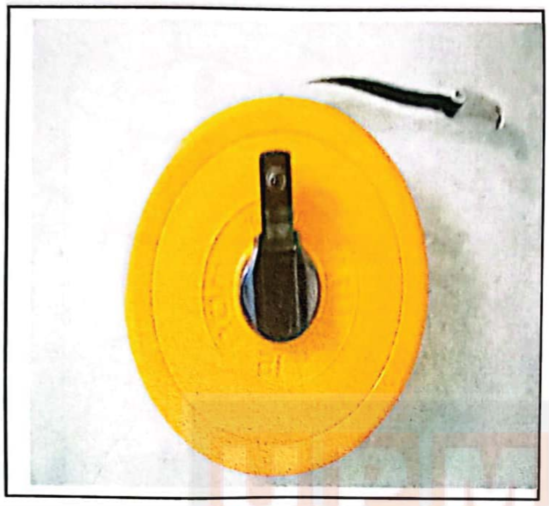

Figure 3: Measuring tape

Figure 4: Digital calliper

Because of the tree is still young at stand 1995-2003 and the height were less than 12 m, the height of every taper is taken for about 20cm above and down dbh level. But trees in stand 1992 were measured for every 2m sectionals. Next page shows the diagram of taper measurement:

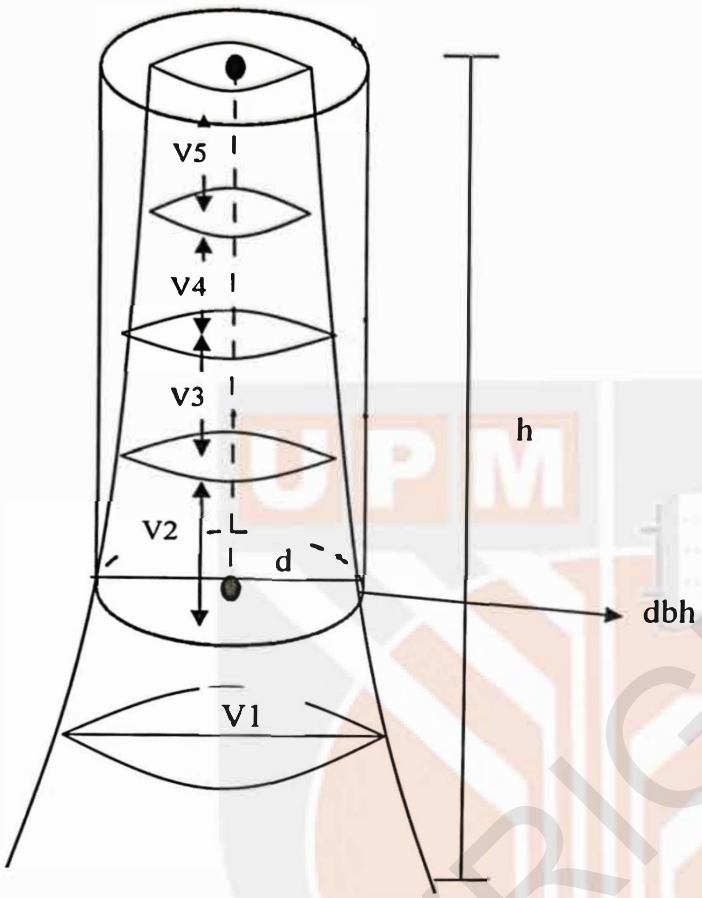

Figure 5: Taper measurement diagram.

3.3.4 Basal area determination (m^2)

Basal area (BA) = $1/4 \pi D^2$

$= 1/4\ (3.142) \times (dbh/200)^2$

Where;

D = diameter in cm

3.4 Data collection

Data was collected by filling the table volume. There were 2 types of table volume which was one table for climbed trees (measured sectionals) and another one was table for unclimbed trees. Total ten standing *Shorea* sp. trees on every plot were measured diameter and height at sectionals (taper). The rest of the *Shorea* sp. on every plot were measured only diameter at breast height (dbh) and total free branch height.

3.5 Determination of taper volume

The volume was determined using the Smalian's formula as below;

Smalian's = $[(s1 + s2)/ 2] \times l$

Where;

$s1$ is the sectional area at the thick end in square units,

$s2$ is the sectional area at the thin end in square units,

l is the length of the log or height of the solid in linear units.

3.6 Study parameter.

3.6.1. Diameter at breast height (cm)

Was the diameter of the stem of a tree measured at breast height (4.5 ft or 1.37 m) from the ground usually implies diameter outside bark.

3.6.2 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.

3.6.3 Volume (m^3)

Calculate by formula such as Smalian's, Huber's, and Newton's as an important parameter for providing information necessary for making decision.

3.7 Data analysis.

Statistical analysis of data was carried out using SPSS statistical package program. One-way Analysis Of Variance (ANOVA) has been used to determine whether there is significant difference in volume estimation between different ages of *Shorea* sp. plantation. Regression and correlation analysis was carried out to analyze relation between diameter, volume and height of *Shorea* sp. tree.

Percent of volume regressed from basal area also calculated. Form factor also estimated from regression equation, with diameter and height as independent variables. Combination of regression relation would be

1. Diameter at breast height (dbh) Vs Volume
2. Diameter at breast height (dbh), height Vs Volume

3. Volume of standing tree Vs Age.

3.7.1 Relationship between volume and diameter:

The relationship between volume and diameter (dbh) was analysed on every plot. This relation was approached using the function below:

$$V = aD^b$$

Where:

V= volume of free branches stem

D= diameter

The equation to analyse the relationship between volume and diameter using the single logarithmatic regression was:

$$\text{Log } V = b_0 + b_1 \log D + E$$

Where:

D= diameter

b_0= Y-intercept

b_1= slope

E= error

b_0 and b1 were sample statistics used to estimate the population parameter β0 and β1. b_0 and b_1 can be determine using the equation:

$$b0 = \frac{(\sum Y)(\sum X^2) - (\sum X)(\sum XY)}{n(\sum X^2) - (\sum X)^2}$$

$$b1 = \frac{N(\sum XY) - (\sum X)(\sum Y)}{n(\sum X^2) - (\sum X)^2}$$

The logarithmatic regression above can be explained as the equation below:

$$Y = a + bX + e$$

Definition:

A relationship between X (called the independent variable, or predictor variable) and Y (called the dependent variable).

Where; Y = value of logV

X = value of logD

a = value of b_0 (the Y- intercept represent constant)

b = value of b_1 (the slope)

The coefficient of determination is the amount of the variation in Y that is explained by the regression line. It computed as

$$r^2 = \frac{\text{Explained variation}}{\text{Total variation}}$$

3.7.2 Relationship between volume, diameter and height

$V = aD^bH^c$

$Y = a + bX_1 + cX_2 + e$

$Y = \log V$

$X_1 = \log D$

$X_2 = \log H$

A, b, & c= Value of B0, B1 & B2

e= error

CHAPTER 4

RESULT

4.1 Measurement result of volume taper

Table 1 shows taper volume for each plot from the 4, 6, 8, 10, 12, and 15 years old stand. There have a number of 10 standing *Shorea sp* trees measured sectionals using Smalian's formula and expressed by meter cubic (m^3). Plot 1 shows the lowest total volume per every single tree while plot 6 had the highest total volume per tree.

Table 1: Taper volume for each plot

Number of tree	Taper Volume (m^3)					
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
1	0.000732	0.002784	0.002677	0.002057	0.002879	0.09181
2	0.001036	0.005514	0.003325	0.001656	0.004477	0.012
3	0.001374	0.002701	0.004777	0.00353	0.01197	0.075
4	0.000915	0.001615	0.01385	0.00247	0.0321	0.01377
5	0.0001224	0.001718	0.004275	0.004552	0.008375	0.02637
6	0.00116	0.00478	0.008195	0.00275	0.004016	0.0305
7	0.000753	0.000652	0.001595	0.007275	0.028	0.03534
8	0.001702	0.002355	0.002805	0.01494	0.0163	0.05513
9	0.001755	0.001262	0.004793	0.003107	0.007735	0.02543
10	0.000835	0.003616	0.1265	0.003496	0.00804	0.2863

4.2 Relationship between volume and diameter

According to Table 2, all regression has significant reading below 0.05. This indicate that there has significant linear correlation between volume (log V) and diameter (log D). The lowest coefficient determinant was the regression resulted on plot 1 (4 year): r^2= 0. 596, which means 59.6% of the total variation in log V can be explained by linear equation LogV= -0.552 + 1.482logD. While another 40.4% remain unexplained. The highest coefficient determinant was the regression resulted on plot 5 (12 year): r^2= 1, which means 100% of the total variation in log V can be explained by linear relationship between log D and log V as described by regression equation LogV= 0.259 + 1.989logD.

Table 2: Regression equation between volume and diameter of each plot

Plot	n	Regression equation	r^2	F	Significant
1	10	LogV= -0.552 + 1.482logD	0.596	11.78	0.009
2	10	LogV= 0.381 + 2.086logD	0.972	275.257	0.000
3	10	LogV= 0.75 + 2.342logD	0.927	101.012	0.000
4	10	LogV= 1.138 + 2.671logD	0.878	57.819	0.000
5	10	LogV= 0.259 + 1.989logD	1	15247.439	0.000
6	10	LogV= 1.162 + 2.66logD	0.959	187.704	0.000

4.2.1 Regression analysis

The regression analysis shows the relationship between volume and diameter from each stand (4, 6, 8, 10, 12 and 15 years). Regression equation was generated from regression analysis using SPSS statistical package program. From the analysis, the value of b_0 and b_1 was obtained and they give the regression equation for each stand. Diameter value was inserted into the equation to determined volume of regression where it shows straight line in a graph. Volume from regression was compared with volume using Smalian's formula that has been measured sectionals manually. Figure 6 to 11 shows regression graph which explained the relationship between volume and diameter.

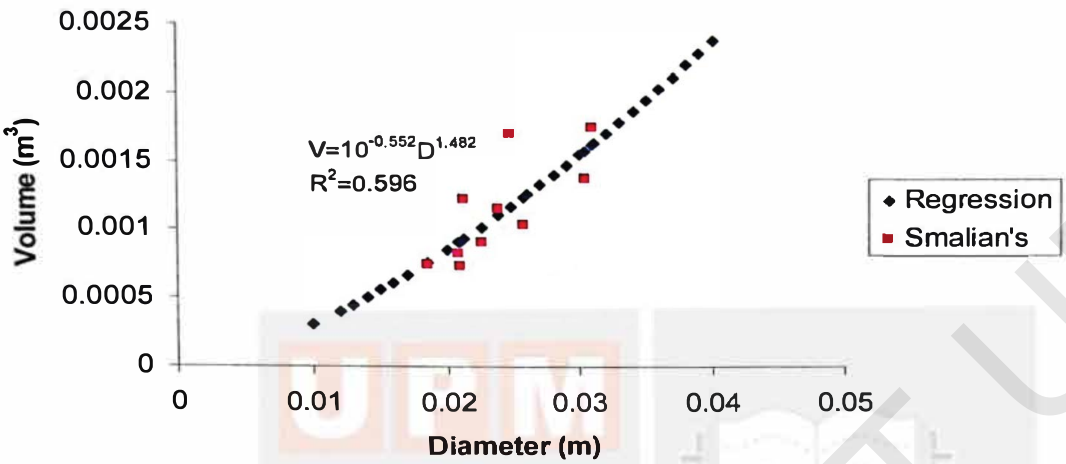

Figure 6: Scatter plot data collected from tree diameter and volume on plot 1 (tree age: 4 year).

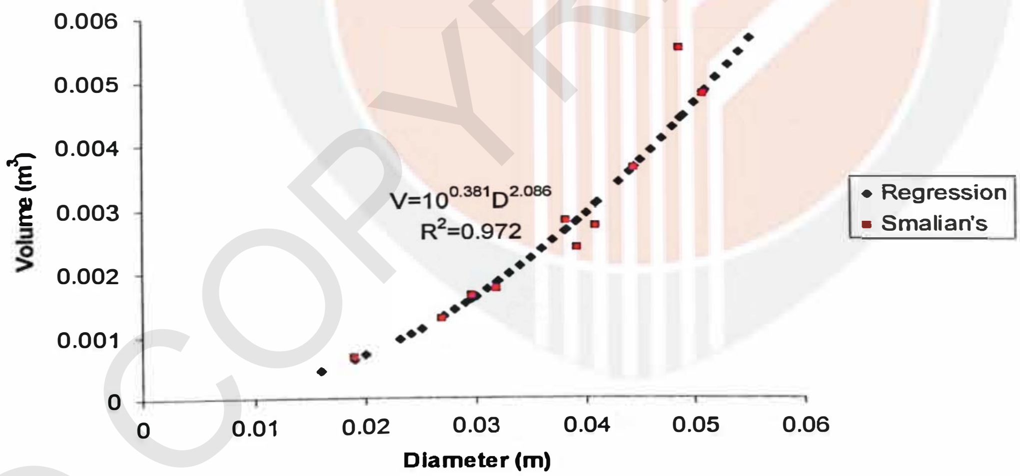

Figure 7: Scatter plot data collected from tree diameter and volume on plot 2 (tree age: 6 years).

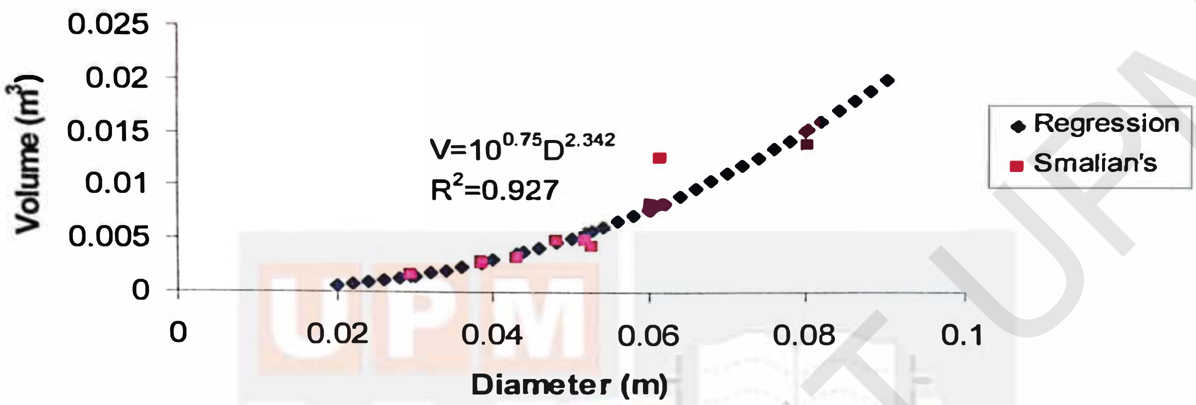

Figure 8: Scatter plot data collected from tree diameter and volume on plot 3 (tree age: 8 years).

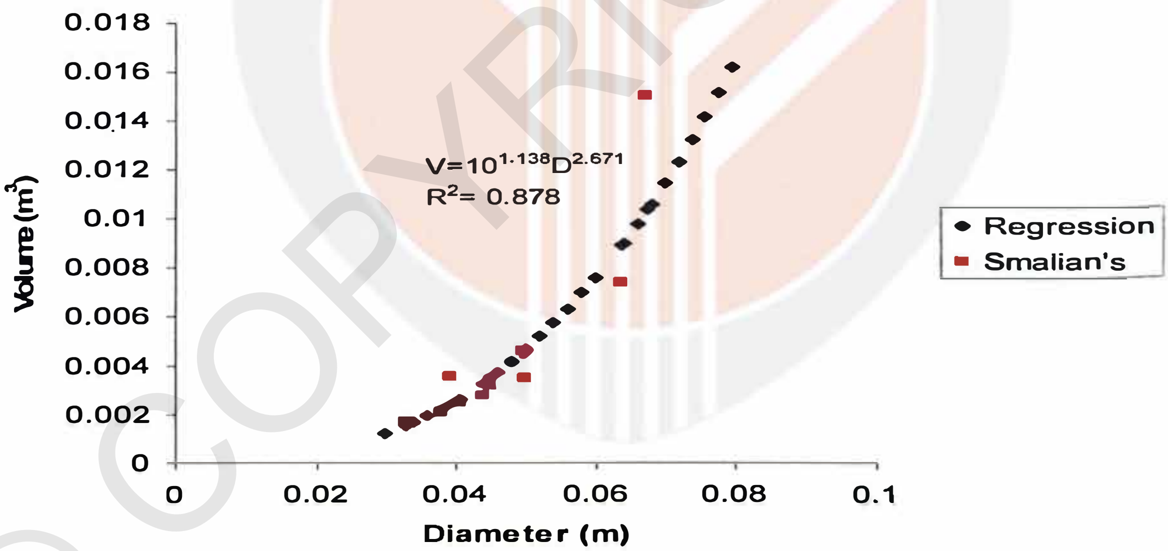

Figure 9: Scatter plot data collected from tree diameter and volume on plot 4 (tree age: 10 year).

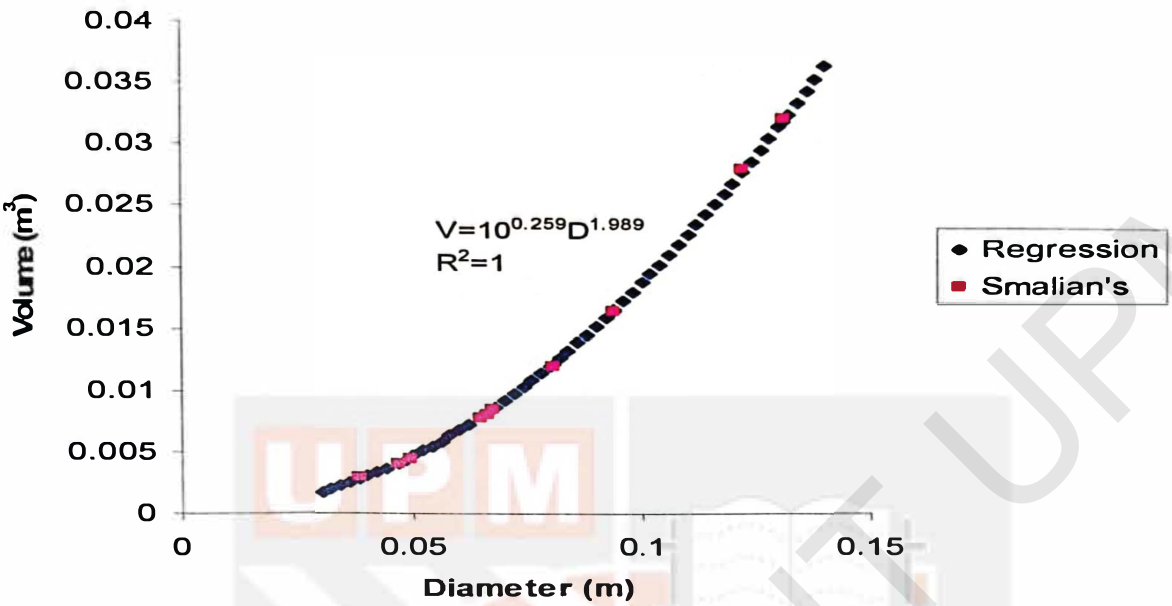

Figure 10: Scatter plot data collected from tree diameter and volume on plot 5 (tree age: 12 year)

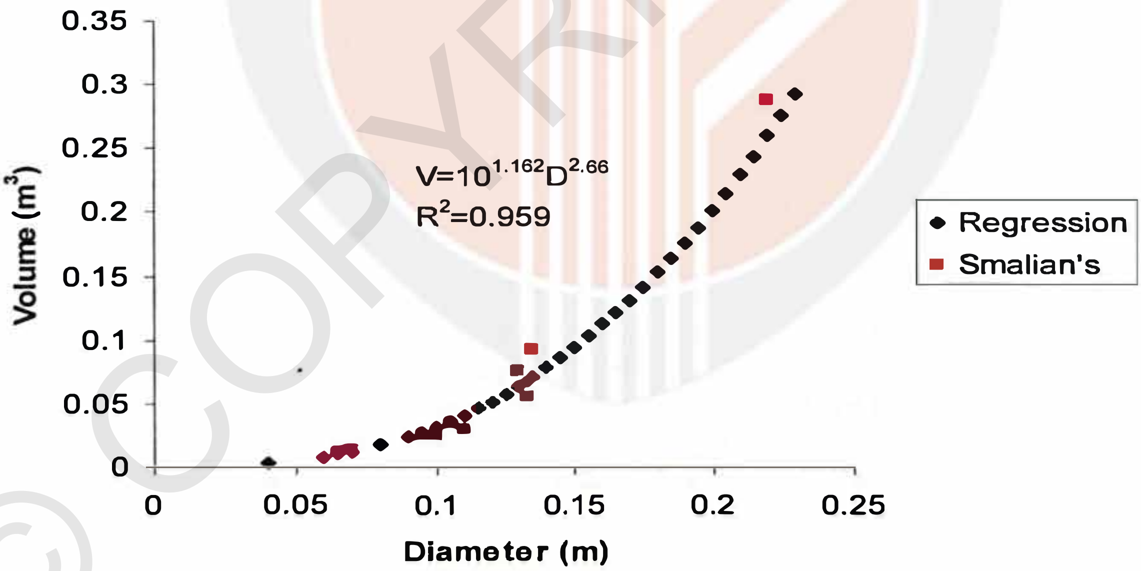

Figure 11: Scatter plot data collected from tree diameter and volume on plot 6 (tree age: 15 year).

4.3 Relationship between volume, diameter and height

According to Table 3, regression analysis shows relationship between volume, diameter and height from each stand (4, 6, 8, 10, 12 and 15 years). All regression has significant value lower than 0.05, which means there are significant linear correlation between log V, log D and log H at the 0.05 significant levels. 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 the linear relationship between log D, log H and log V. While another 35.1% was remaining unexplained which means 35.1% was scatter out from regression line.

The highest coefficient determinant was the regression resulted on plot 5: r^2= 1, which means 100% of the total variation in log V can be explained by the relationship between log D, log H and log V as described by regression equation

Table 3: Regression equation between volume, diameter and height of each plot

Plot	n	Regression equation	R^2	F	Significant
1	10	Log V= -0.852 + 1.407logD + 0.665logH	0.649	6.468	0.026
2	10	Log V= -0.509 + 1.881logD + 0.455logH	0.978	154.932	0.000
3	10	Log V= -0.461 + 1.814logD + 1.062logH	0.978	158.294	0.000
4	10	Log V= 0.485 + 2.346logD + 0.555logH	0.891	28.674	0.000
5	10	Log V= 0.321 + 1.997logD – 0.091logH	1	10817.136	0.000
6	10	Log V= -0.227 + 2.172logD + 0.972logH	0.985	223.714	0.000

4.4 Total volume of standing *Shorea* sp.

Table 4 shows the total volume of *Shorea* sp. using the regression equation. The highest total volume was at plot 6, the oldest tree age with total 1.5792 m^3. The lowest total volume was 0.024607m^3 at plot 1 (tree age: 4 year).

Table 4: Total volume of *Shorea* sp.

Plot	Age	n	Regression equation	Total volume of *Shorea* sp. (m^3)
1	4	30	$V = 10^{-0.552}D^{1.482}$	0.024607
2	6	30	$V = 10^{0.381}D^{2.086}$	0.043996
3	8	30	$V = 10^{0.75}D^{2.342}$	0.143478
4	10	30	$V = 10^{1.138}D^{2.671}$	0.14125
5	12	30	$V = 10^{0.259}D^{1.989}$	0.3713
6	14	30	$V = 10^{1.162}D^{2.66}$	1.5792

4.5 Association between age and volume of standing tree.

4.5.1 Association between age and volume of taper

Table 5 shows total volume taper for each plot using Smalian's formula. The highest volume taper was at plot 6 with the value 0.65165 followed by plot 5, 0.123892, plot 3, 0.058942, plot 4, 0.045833, plot 2, 0.026997 and the lowest was on plot 1. Table 6 shows relationship between age and total volume taper using Smalian's formula. It shows significant value higher than 0.05, which means there, has no significant different between age and total taper volume. Then age and total taper volume has no relationship, which means there was not correlated with each other. Age has no effect on total taper volume.

Table 5: Total volume taper

Plot	Age	Total volume taper
1	4	0.011486
2	6	0.026997
3	8	0.058942
4	10	0.045833
5	12	0.123892
6	15	0.65165

Table 6: Analysis of relationship between age and total taper volume of standing *Shorea* sp.

Mean square	F	Significant
0.196	7.110	0.056
0.028		

4.5.2 Association between age and total volume of standing tree

According to table 7, total volume of standing *Shorea* sp. was calculated using regression equations. The highest volume was on plot 6, with the value 01.5792 and the lowest total volume was on plot 1, with the value 0.024607. Then table 8 shows relationship between age and total volume using regression equation. It shows significant value 0.042, which was less than 0.05. This means that there has been a correlation between age and total volume regression of *Shorea* sp.

Table 7: Total volume regression of *Shorea* sp.

Plot	Age	Total stand volume
1	4	0.024607
2	6	0.043996
3	8	0.143478
4	10	0.14125
5	12	0.3713
6	15	1.5792

Table 8: Analysis of relationship between age, and total volume of *Shorea* sp.

Mean square	F	Significant
1.224	8.653	0.042
0.141		

CHAPTER 5

DISCUSSION

5.1 Measurement of taper volume

Standing *Shorea* sp. at plot 6 shows the bigger volume for each tree. The tree was growing well since 1992 and the diameter and height are growing as the same size. Lowest volume was showed on plot 1, which was the youngest age of stand. Younger tree slightly has the smaller diameter than the older tree.

5.2 Relation between volume and diameter

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, independent variable (diameter) in regression equation has a relationship and correlate with dependent variable (volume).

The youngest plot 2003 shows the regression graph with 40.4% coefficient determinant remain unexplained where they were slightly scatter out from the linear graph. These indicate that the relation between diameter and volume were less correlated compared with the linear graph from other plot. Standing *Shorea* sp. on plot 2003 less unity in diameter growth, where the diameter was varying in size. Some were too small while other was too big.

The highest r^2 belong to figure 10, where the coefficient determinant was 1, which means 100% of total variation in Y can be explained by the linear relationship.

Any variation in diameter measurement can get the exact total volume of standing tree. All the taper volume in figure 10, which was plot 1995, seems to fit the linear graph. This indicates that there has been a great correlation between diameter and volume of the tree. Then just using the regression equation (Log V= 0.259 +1.989D) from this stand age, the volume of other standing tree from the same species can be estimated accurately. Plot 1995 showed the unity in diameter growth of standing *Shorea* sp. which has 100% fit the linear graph.

5.3 Relationship between volume, diameter and height

Significant value of all regression was between 0.000-0.026. This significant value also showed 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 correlate with dependent variable (volume).

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

Plot 2003 again shows the lowest coefficient determinant r^2 where only 64.9 % of total variation in Y can be explained by the linear relationship, while another 35.1 % were remain unexplained and scatters out from the linear graph. This maybe due to the diameter and height of the tree in stand 2003 is varying in size. This was because the 2003 plot was still young and they were competing with other plant species to survive. Some of the *Shorea* sp. was greatly survive and some were very small and unable to survive.

5.4 Association between age and volume of standing tree.

This association was divided by two which was, association between age and taper volume which were calculate 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.

As for the association between age and regression volume shows significant different, which means, using the regression equation, volume will correlate with age of the tree. This was because regression equation gave the standard relation between volume and age.

CHAPTER 6

CONCLUSION

The regression equation generated from taper volume can be use to estimate the other standing tree within the same plot. Volume functions allow estimates to be made for any tree after measurement only of its diameter at breast height and total height. Furthermore, they allow estimation of stem volume between any two points on the stem. Taper functions require rather more care in their development than do volume functions, but the data required doing so is the same in both cases. In future, it is likely that taper functions will replace volume function as they are developed for more and more species. Volume and taper functions have been developed for many of tree species. Measurement taken from 2 parameters, height and diameter shows more accurate volume value than using only diameter but practically taking two measurements need a lot of work. There has been not much different in coefficient determinant reading so estimated using diameter was easier. Relationship between age and volume using Smalian,s formula show's no correlation, so age can't be the indicator for volume estimation.

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APPENDICES

Appendix A-1: Taper volume for plot 1

Number of tree	taper volume
1	0.000732
2	0.001036
3	0.001374
4	0.000915
5	0.001224
6	0.00116
7	0.000753
8	0.001702
9	0.001755
10	0.000835

Appendix A-2: taper volume of plot 2

Number of tree	taper volume
1	0.002784
2	0.005514
3	0.002701
4	0.001615
5	0.001718
6	0.00478
7	0.000652
8	0.002355
9	0.001262
10	0.003616

Appendix A-3: taper volume of plot 3

Number of tree	taper volume
1	0.002677
2	0.003325
3	0.004777
4	0.01385
5	0.004275
6	0.008195
7	0.001595
8	0.002805
9	0.004793
10	0.01265

Appendix A-4: taper volume of plot 4

Number of tree	taper volume
1	0.002057
2	0.001656
3	0.00353
4	0.00247
5	0.004552
6	0.00275
7	0.007275
8	0.01494
9	0.003107
10	0.003496

Appendix A-5: taper volume of plot 5

Number of tree	taper volume
1	0.002879
2	0.004477
3	0.01197
4	0.0321
5	0.008375
6	0.004016
7	0.028
8	0.0163
9	0.007735
10	0.00804

Appendix A-6: Taper volume of plot 6

Number of tree	taper volume
1	0.09181
2	0.012
3	0.075
4	0.01377
5	0.02637
6	0.0305
7	0.03534
8	0.05513
9	0.02543
10	0.2863

PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection to publish the project entitled "Volume Estimation of Standing *Shorea* sp. at UPM-JISE Rehabilitation Project, Bukit Nyabau Bintulu" by the supervisor in a joint authorship. However, it has to be evaluated by the Faculty of Agriculture and Food Sciences, University Putra Malaysia Bintulu Campus and published in the form approved by the Faculty.

IZYAN ALWANI BINTI MOKHSEN ABDULLAH

25 APRIL 2008