Quest Journals
Journal of Research in Agriculture and Animal Science
Volume 2 ~ Issue 3 (2014) pp: 01-08
ISSN(Online) : 2321-9459
www.questjournals.org

Research Paper

Modeling Individual Tree Diameter Increment for Dipterocarpaceae and Non-Dipterocarpaceae In Tropical Rainforest

Nurashikin Saaludin[1], Yasmin Yahya[2], Suriyati Harun[3], Wan Suriyani Che Wan Ahmad[4]

[1]*Universiti Kuala Lumpur 1016 Jalan Sultan Ismail 50250 Kuala Lumpur, Malaysia +603-21754229*
[2]*Universiti Kuala Lumpur 1016 Jalan Sultan Ismail 50250 Kuala Lumpur, Malaysia +603-21754225*
[3]*Universiti Kuala Lumpur 1016 Jalan Sultan Ismail 50250 Kuala Lumpur, Malaysia +603-21754230*
[4]*Universiti Kuala Lumpur 1016 Jalan Sultan Ismail 50250 Kuala Lumpur, Malaysia +603-21754228*

Received 19March, 2014; **A**ccepted 07April, 2014

ABSTRACT: *Growth model provides an efficient way in preparing resource forecasts especially on decision making options and silvicultural alternatives. Diameter increment is one of the common and important tree characteristics used in forest management decision making. In this paper, diameter increment models were developed for individual tree of dipterocarpaceae and non-dipterocarpaceae tree species in semi-evergreen forest in Seam Reap, Cambodia. Regression analysis is the preferred technique used in growth and yield modeling in forestry. The stepwise ordinary least square (OLS) regression technique has been used to fit model parameters. The predictor variables in both models represent tree size attribute, which are diameter at breast height (DBH) and basal area (BA) and also the tree position attribute, which is sum of basal area (m^2) in trees with DBHs are larger than subject tree's DBH (BAL). Each model was then validated and found to be good predictor by the small values of the four lacks of fit statistics. As a result, both of the models give better fit especially with regards to bias and relative bias.*

Keywords:*Diameter increment, dipterocarpaceae, predictors, multiple linear regression, model validation.*

I. INTRODUCTION

Diameter increment models are a fundamental component of forest growth and yield frameworks [11]. Tree diameter is the easiest and commonly measured tree attribute and become the most important variable for growth and yield equations; a very useful tool for forest management planning. Individual-tree diameter growth models enable a more detailed description of a stand structure and its dynamics than stand-level models [21]. According to [13] diameter at breast height (DBH) increment was the most important variables to fit hypothesized production models for Peninsular Malaysia mixed forest. DBH is also a very common and important tree characteristics used in forest management decision making [3].

Ordinary Least Square regression analysis (OLS) is the classical statistical method used in forest modeling [7]. Past researches have found that individual tree diameter growth can be expressed as a function of tree size, competitive effect, stand structure and site quality [8], [11], [18], [4] and [24].

Tropical rainforests with a wide diversity of tree species are an important ecological resource providing many functions and values such as wildlife habitat, natural medicines and timber production. [6] mentioned that tropical forests occupy approximately 42% of the global forest area (1,755 million ha). Most people in developing countries depend on forests for food, water, fuel, timber, and other resources. In the last few decades, the rate of deforestation has increased considerably owing to population explosion. [15] pointed out a

*Corresponding Author: Nurashikin Saaludin
[1]*Universiti Kuala Lumpur 1016 Jalan Sultan Ismail 50250 Kuala Lumpur, Malaysia +603-21754229*

slight decrease in the rate of deforestation; however, deforestation will continue to be a matter of concern over the next several decades.

Several researchers for instance [19],[20] and [16] discussed the development of diameter increment of species groups in tropical rainforest. However, very few studies have been done regarding diameter increment models specifically for tropical rainforest in Seam Reap, Cambodia. The objective of this study is to develop individual tree diameter increment model for dipterocarpaceae and non-dipterocarpaceae in semi-evergreen forest in Seam Reap, Cambodia and to validate the models using statistical methods.

II. DATA AND METHOD

2.1 The data base

Tropical rainforests are known of comprising of a huge number of species; however, most of them are represented by only a few trees. It is very unlikely to develop one growth model for all species as their growth rate significantly differ. On the other hand, it is almost impossible to develop one model for each species. Thus, species need to be grouped using criteria which appropriately reflect the intended use of the model being built. In this study, data were divided into two groups for analysis according to tree families. There were 35 families exist in this forest with dipterocarpaceae as the major family. Dipterocarpaceae is well-known trees of the Asian rain forest which consist over 500 species [5]. In this study, the dipterocarpaceae family consists of only three species which are *Dipterocarpusalatus*Roxb, *Dipterocarpuscostatus*Gaertn.and*Dipterocarpusintricatus*Dyer while other families were grouped in non-dipterocarpaceae. The non-dipterocarpaceae consists of 32 different species (Table 1).

Data used in this study were obtained from permanent sample plots established and maintained by the Department of Forestry and Community Forestry, Phnom Penh, Cambodia. The study site was located in the Seam Reap province, northern Cambodia where eight semi-evergreen forest plots were located at UTM (Universal Transverse Mercator) of 0377407-1485292 and 0377811-1486311 in lowland dipterocarpaceae. They provide valuable woods, aromatic wood oils, balsam and resins.

The area has terrain conditions with a gentle slope of an elevation range of 20 m above sea level. It is also located in monsoon Asia and tropical climatic zones, with two pronounced seasons: dry from November to April and wet from May to October. The heaviest precipitation was recorded in Seam Reap Province (2002-2009), where it averages 1,943.78 mm/ year. The maximum precipitation was 2,747. 30 mm/year while minimum 1,368.60 mm/year. February was marked the driest month during that year and October as the wettest month [17].

The plots design were 50 by 50 meters (quarter hectare) in which all trees with diameter at breast height (DBH) 30 cm and greater were numbered and measured for diameter in this area. While all trees with DBH 7.5 cm to less than 30 cm were measured in the sub plots of 20 by 20 meters. The counting of saplings and seedlings were done in the sub plots of 5 by 5 meters and 2 by 2 meters respectively.

Data were collected over 13 years from 1998 to 2011 with the interval of two to five years. There are four measurements taken place which was in year 1998, 2000, 2005 and 2011. For every re-measurement, diameter at breast height (DBH) was re-measured; mortality trees and recruitment trees were also recorded. From the entire data set, only live trees with four measurements of DBH were selected and used in this analysis. We used individual-tree model approach that predicts annual diameter increment growth as a function of tree size and competitive position. The stand structure such as crown competitive factor was not used in this study as it is not available in the data. The independent variables evaluated in this analysis were tree diameter (DBH), tree diameter squared (DBH^2), diameter increment (DI), basal area (BA) and total basal area of trees larger than subject tree (BAL). The DI was calculated repeatedly on the same tree as the difference of two consecutive observations of diameter over the interval of two to five years measurement.

Table 1. The tree species in Dipterocarpaceae and Non- Dipterocarpaceae family

Dipterocarpaceae	Non-Dipterocarpaceae		
***Dipterocarpusalatus*Roxb.**	*Adina cordifolia*, Hook. f.	*DiospyroscrumenataThwaies*	*CombretumquadangulareKurz*
***Dipterocarpuscostatus*Gaertn .**	*Aglaiacambodiana Pierre*	*DiospyrosdecandraLour.*	*Cryptocaryaoblongifolia Bl.*
***Dipterocarpusintricatus*Dyer.**	*Alangiumridleyi King*	*DiospyrossylvaticaRoxb.*	*DalbergianigrescensKurz*
	Alstoniascholaris (L.) R. Br.	*Ficuscallophylla Bl.*	*Dehaasiacuneata, Bl.*
	Anthocephaluschinensis (Lam.) A.Rich. exWalp.	*Garciniadelpyana Pierre*	*Polyalthiathorelii (Pierre) Fin. &Gagnep.*

	AntidesmacambodianaGagnep.	*Hydnocarpusanthelmintica Pierre*	*Schleicher oleosa (Lour.) Oken*
	AporosatetrapleuraHance	*Hymenodictyonorixense(Roxb.) Mabb.*	*StreblusasperLour.*
	ArtocarpusasperulaGragn.	*KnemacorticosaLour .*	*Strychnosnux-vomica L.*
	Atalantiacitroides Pierre ex Guill.	*Lagerstroemia sp.*	*BaccaurearamifloraLour.*
	Averrhoacarambola L.	*MarkhamiapierreiDop*	*Bombax insigne Wall.*
	ParinariumannamensisHance	*Microcostomentosa Sm.*	

2.2 Data analysis

2.2.1 Normality test

In order to develop linear model, the distribution of the dependent variables should be normal. In this study, two ways of testing normality were used; graphical and numerical methods.

Graphical methods such as Q-Q plot, histogram and box plot can be used to visualize the distributions of random variables or differences between an empirical distribution and a theoretical distribution (e.g., the standard normal distribution). In this study Q-Q plot has been selected to re-examine the normality. Numerical methods present summary statistics such as skewness and kurtosis, or conduct statistical tests of normality. For numerical method the p-value of Kolmogorov-Smirnov or Shapiro-Wilk greater than 0.05 or 0.01(95% and 90% confidence level) indicates that the data are approximately normal.

Data which are not normal can cause bias estimation; as such, they need to be transformed so that the distribution approaches approximately normal. Data transformation is used to make the data conform to the assumptions of the statistical methods. The transformation type that is commonly used in forestry research is log transformation. A problem may arise with the logarithmic transformation of increment data because of the presence of zero periodic annual diameter increment. The data contained significant observations of zero increments and it was considered necessary to include these in the regression. An offset value was added to the dependent variables[13], [19]and [1].

2.2.2 Regression analysis

In building the regression linear model, the dependent variable is something that we want to estimate. The predictor variables will be regressed in step wise multiple linear regression model with the significant level of 5%. Non-significant variables will be removed in the modeling process, leaving only the significant variables.The linear model may be expressed as;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \varepsilon \qquad (1)$$

where Y is a diameter growth increment; X_i is the predictor variables; β_i is the coefficients to be estimated and ε is a random error.

Serial correlation and spatial correlation might be expected for re-measured permanent plot data. These correlations violate the assumption of independent error terms in most statistical methods, thus the t-test, the F-test, ANOVA and the confidence intervals may bias[9].

Several growth and yield researchers preferred Ordinary Least Squares (OLS) technique to mixed method to fit a regression model because OLS is unbiased [18]. Hence, incorporating a more reasonable variance structure may not be necessary since users are often only interested in prediction [14]. According to [3], OLS provided a better fit for predicting future tree DBH and predicting periodic annual diameter increment compared to mixed linear models. [1] suggested that the OLS assumes equal variance and unbiased estimates of the model parameters if the observations are independent and have equal variances.

2.2.3 Model validation

Model validation is important in any empirical analysis. It is an integral part of model building as well as quality assurance and quality control [22]. Model validation is not used to prove that a model is correct, but rather to show that model predictions are close enough to independent data and that decisions made based on the model are defensible [22]. For selecting the most suitable regression model, it is generally advisable to use some measure**s** of lack of fit in combining with one or more test statistics [10].

Two procedures commonly used in model validation are the use of new data (independent data set) and the use of data splitting. Data splitting is regarded as an acceptable alternative by most researchers provided that the data set is large enough [22]. In this study, independent data set was used to validate the prediction models as done by [23]. In this study, data were taken from permanent sample plots that were not used for constructing the models. The models were validated using four lacks of fit statistics, where *n* is the number of observations; Y_i is an actual observation of a given dependent variable, and $\widehat{Y}_i$ is the actual predicted value of a given observation of the dependent variable.

$$\text{Mean Square Error (MSE)} = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2$$

$$\text{Mean Bias (MB)} = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)$$

$$\text{Absolute Mean Bias (AMB)} = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i - \hat{Y}_i\right|$$

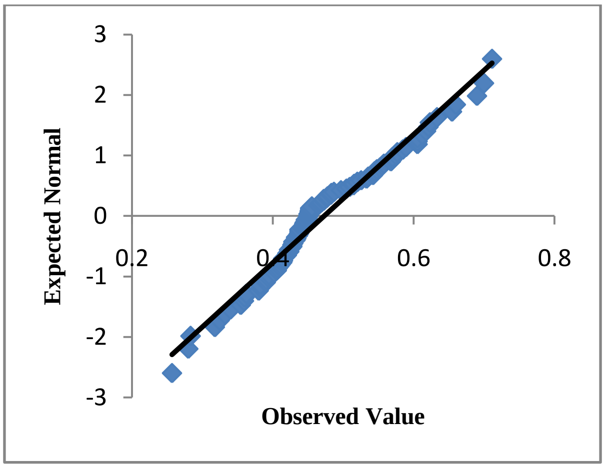
$$\text{Mean Percent Error (MPE)} = \frac{1}{n}\sum_{i=1}^{n}\frac{Y_i - \hat{Y}_i}{Y_i}$$

III. RESULT AND DISCUSSION

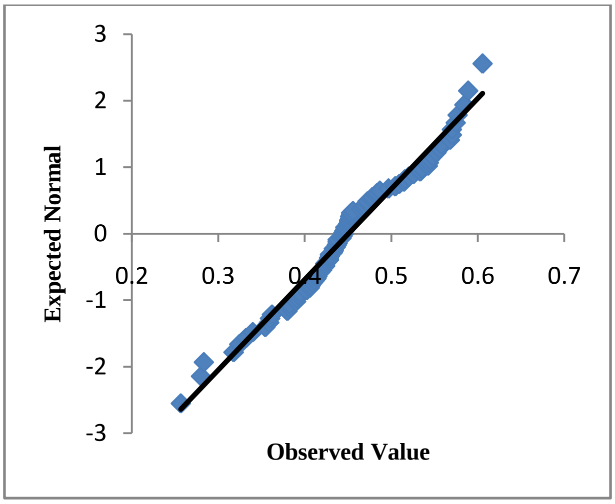
3.1 Normality test and logarithmic transformation

In this study, diameter increment (DI) is used as a dependent variable for both dipterocarpaceae and non-dipterocarpaceae models. Shapiro-Wilk test was preferred to measure the normality of the DI. According to [12], Shapiro-Wilk is the most powerful normality test as compared to Anderson Darling test, Lilliefors test and Kalmogorov-Smirnov test. Shapiro-Wilk test is also often used in estimating small samples but can handle up to the size of 2000 [25].

The p-value for non-dipterocarparceae dependent variable is 0.161. This value indicates that the data were approximately normal. However logarithmic transformation need to be performed to dipterocarpaceae since the p-value of the dependent variable was significant; which is less than 0.05. The transformation in the form of $\ln(DI+1)$ increased the p-value to 0.058. Thus, the models for both groups can be developed. The p-values were also supported by the Q-Q plot. The graphs show that all the values of data are not varies from a straight line and the result implies the same conclusion of numerical method that the dependent variable data approaches normality.



Dipterocarpacea



Non-Dipterocarpaceae

Figure 1: Normal Q-Q plots for dipterocarparceae and non-dipterocarparceae

3.2 Model development

The dependent variable, annual diameter increment, DI (cm) was regressed to predictor variables which were tree DBH (cm), sum of basal area (m^2) in trees with DBHs larger than subject tree's DBH (BAL), BA (m^2) and DBH^2 (cm^2). In this study, data analysis was performed by using SPSS software. Table 2 shows the descriptive statistics for all variables used to develop the diameter increment models.

Table 2. Descriptive statistics for data used to develop annual diameter increment models

	Dipterocarpaceae (*n* =106)				Non-Dipterocarpaceae (*n* = 94)			
Variable	**Mean**	**Std. dev**	**Min**	**Max**	**Mean**	**Std. dev**	**Min**	**Max**
DBH (cm)	69.09	23.93	12.70	124.50	34.98	21.29	10.80	104.90
DBH^2 (cm^2)	5340.10	3308.42	161.29	15500.25	1671.80	2019.46	116.64	11004.01
BA (m^2)	0.42	0.26	0.01	1.22	0.13	0.15	0.01	0.86
BAL (m^2h^{-1})	29.67	13.07	0.00	44.44	9.60	3.14	0.00	12.37
DI (cm)	0.47	0.09	0.26	0.71	0.38	0.10	0.15	0.65

After performing stepwise multiple linear regressions and dropping all non-significant predictor variables, the model to estimate annual diameter increment for dipterocarpaceae and non-dipterocarpaceae keep BA, DBH and BAL as significant predictor variables. These models were supported by [3]. They used these three main predictors to predict diameter increment for modeling stem increment for Pinusoccidentalis Sw. trees in Dominican Republic. Both of them opined that BAL is useful in predicting diameter increment and should be considered as a complementary variable to stand basal area. In general, the predictors variables in both models represent tree size attribute (DBH and BA) and tree position attribute (BAL). The parameter estimates, standard error of estimates and the goodness of fit statistics are displayed in Table 3.

Table 3.Parameter estimates and goodness of fit statistics

Model	**Parameter**				**Model performance**	
	Const.	**BA**	**DBH**	**BAL**	**R^2**	**RMSE**
Dip	**0.236 (0.031)**	**55.898 (2.147)**	**0.003 (0.000)**	**-0.002 (0.000)**	**0.898**	**0.02022**
Non-Dip	**0.095 (0.132)**	**161.537 (11.919)**	**0.007 (0.001)**	**-0.020 (0.009)**	**0.703**	**0.05701**

$p < 0.05$; Dependent Variable: Dipterocarpacea(Dip)_ln (DI + 1) ; Non-Dipterocarpacea(Non-Dip)_DI

The coefficients of determination (R^2) for both dipterocarpaceae and non-dipterocarpaceae models are more than 0.70, which means that more than 70% of the total variation in the models can be explained by independent variables. The values of root mean square error (RMSE) for both types of models are very small, approaching zero which assert that the two models can be said accurate.

The tree diameter increments for both groups are dependent on their tree size attribute which are BA and DBH. However, the coefficients of BAL for both models are negative; indicating competitive factor of tree position would reduce the annual diameter growth rates. Therefore, the largest diameter tree would have a BAL value of zero, while the smallest diameter tree would have a BAL value near to the total basal area. The result is consistent with [18].

The logarithmic bias correction to the intercept term was estimated by adding half of the mean squared error to the intercept term [2]. It is suggested that for degrees of freedom, *df*> 30 and s^2< 0.5, the multiplicative correction of $e^{s^2/2}$ is usually adequate. All standard errors estimates presented in the Table 3 and figures are based on the transformed logarithmic values and the correction term is added into the intercept.

3.3 Model Validation

For the purpose of validating the models, 41 dipterocarpaceae trees and 38 non-diptercarpaceae trees were taken from permanent sample plots which are not been used in constructing the models. The summary statistics for validation datasets are displayed in Table 4. There were no big differences in mean values of all variables for both groups.

Table 4. Summary statistics for validation datasets to develop annual diameter increment

	Dipterocarpaceae (n = 41)				**Non-Dipterocarpaceae (n = 38)**			
Variable	**Mean**	**Std. dev**	**Min**	**Max**	**Mean**	**Std. dev**	**Min**	**Max**
DBH (cm)	**35.70**	**9.52**	**11.50**	**66.00**	**30.85**	**15.28**	**11.50**	**66.70**
DBH^2 (cm^2)	**1363.40**	**729.59**	**132.25**	**4356.00**	**1179.00**	**1176.85**	**132.25**	**4448.89**
BA (m^2)	**0.11**	**0.06**	**0.01**	**0.34**	**.09**	**0.08**	**0.01**	**0.35**
BAL (m^2h^{-1})	**2.69**	**1.25**	**0.00**	**4.38**	**2.89**	**1.02**	**0.00**	**3.85**
DI (cm)	**0.31**	**0.08**	**0.16**	**0.49**	**0.30**	**0.09**	**0.14**	**0.63**

The MSE, MB, AMB and MPE values used to measure the accuracy of the examined model of dipterocarpaceae and non-dipterocarpaceae are presented in Table 5.

Table 5.Lack of fit statistics for Dipterocarpaceae and Non-Dipterocarpaceae models

Model	***N***	**MSE**	**MB**	**AMB**	**MPE**
Dipterocarpaceae	**38**	**0.0034**	**0.0434**	**0.0482**	**0.1356**
Non- Dipterocarpaceae	**41**	**0.0231**	**0.1465**	**0.1465**	**0.4995**

The observed diameter increment was compared to the predicted corresponding diameter increment. The four lacks of fit statistics for these two models show small values with the dipterocarpaceae model are found to be smaller than that of the non-dipterocarpaceae model. Consequently, both models can be categorized as significantly better fit especially with regards to bias and relative bias. This proved that both models developed predict well.

Fig.2 illustrates the scatter plot of diameter increment and DBH for dipterocarpaceae model, showed small differences between the distributions of observed and predicted value of diameter growth.In Fig.3, the scatter plot of diameter increment and DBH for non-dipterocarpaceae model below shows that most of the predicted values are bit lower than the observed values. The pattern reflects the lack of statistics result above (Table 5).

As displayed in Table 1, only three species were grouped in dipterocarpaceae family while 32 species were grouped in non-dipterocarpaceae family. Such a big difference in the number of different species grouped together could be the reason why all the values of lacks of fit statistics for non-dipterocarpaceae model are greater than dipterocarpaceae model in predicting the annual diameter increment.

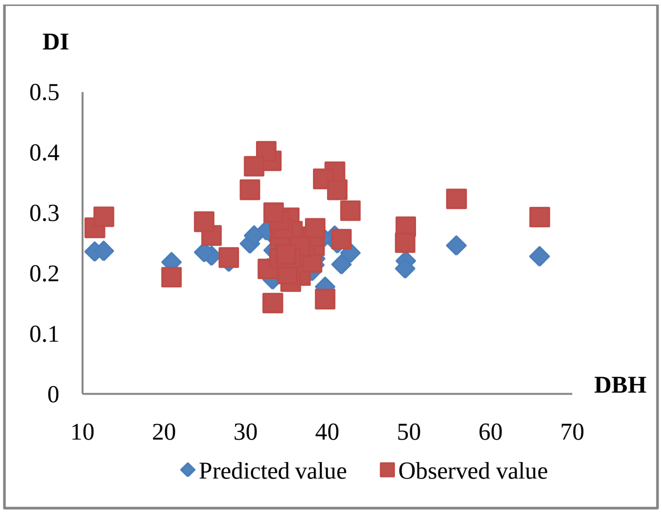


Figure 2. Distribution of observed and predicted values for Dipterocarpaceae

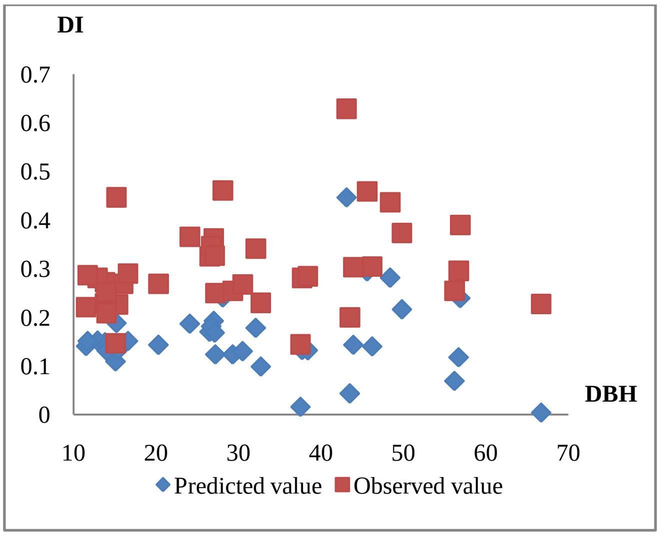


Figure 3. Distribution of observed and predicted values for Non-Dipterocarpaceae

The drawbacks encountered in this study are limited number of sample size and lack of some important variables such as tree crown competition factor, site index and slope of the plots were not included in model development as they are not available in the data.

IV. CONCLUSION

Individual tree diameter increment models were developed for dipterocarpaceae and non-dipterocarpaceae in Siem Reap of northern Cambodia. Tree growth data were collected from permanent sample plots of semi-evergreen forest for all tree species. The Stepwise Ordinary Least Squares (OLS) technique was applied in which all non-significant predictor variables were dropped leaving only BA, DBH and BAL for both models result the final models.

Model for dipterocarpaceae:

$$Ln(DI+1) = 0.236 + 55.898\,BA + 0.003\,DBH - 0.002\,BAL \qquad (2)$$

Model for non-dipterocarpaceae:

$$DI = 0.095 + 161.537\,BA + 0.007\,DBH - 0.02\,BAL \qquad (3)$$

Comparison between observed and predicted diameter increment was done on the validation data. The model validation indicated that both models produced very small prediction errors and biases. However, model

(3) produced larger errors and biases as compared to model (2). Tree diameter growth is an important component in predicting growth and yield of individual tree and having a good model is crucial in planning for future forest management; hence, deforestation can be controlled and nature can be preserved. Besides tree diameter growth model, other models which are equally important in yield prediction system such as height growth, mortality and regeneration. For future plan, we will develop these models as well as to optimize the parameters.

ACKNOWLEDGMENTS

We are grateful to Mr. SamrethVanna and Mr. KhornSaret, Deputy Director of the Department of Forestry and Community Forestry for providing the data used in this study. Special thanks to Prof. Dr. Roslan Ismail for his assistance and comments in this manuscript.

REFERENCES

[1] Ahmad Zuhaidi Y. 2006. Modelling Tree Diameter Growth Of Plantation Grown DryobalanopsSumatrensis. J. Tropical Forest Sc. 18 (4), 203 – 211
[2] Baskerville, G. L. 1972. Use of Logarithmic regression in the estimation of plant Biomass. Can. J. Forest Res. 2, 49-53
[3] Bueno S, Bevilacqua E. 2010. Modeling stem increment in individual Pinusoccodentalis Sw. tree in La Sierra, Dominican Republic. Forest Systems 19(2), 170-183
[4] Calama R, Montero G. 2005. Multilevel linear mixed model for tree diameter increment in Stone pine (Pinuspinea): a calibrabing approach. Silva Fenn 39:37-54
[5] Dayanandan S,Peter S. Ashton,Scott M. Williams,and Richard B. Primack. 1999. Phylogeny Of The Tropical Tree Fami, lyDipterocarpaceae Based On Nucleotide Sequences Of The Chloroplast RbclGenE. American Journal of Botany 86(8): 1182–1190. 1999.
[6] Dixon R.K, Solomon A.M, Brown S, Houghton A, Trexler M.C, Wisniewski J. 1994. Carbon pools and flux of global forest ecosystems. Science 263:185–190.
[7] Fox, J.C., Bi, H. &Ades, P.K. 2008. Modelling spatial dependence in an irregular natural forest. Silva Fennica 42(1): 35–48.
[8] Hokka H., Alenius V., Penttila T.1997. Individual-tree basal area growth models for Scots pine, pubescent birch and Norway spruce on drained peatlands in Finland. Silva Fennica 31(2): 161-178.
[9] Kozak A. 1997. Effects of multicolliniearity and autocorrelation on the variable-exponent taper functions. Can. J. For. Res. 27 (25), 619-629
[10] Kozak A, Kozak R. 2003. Does cross validation provide additional information in the evaluation of regression models? Can. J. For. Res. 33, 976-987
[11] Lhotka J.M, Loewenstein E.F. 2011. An individual-tree diameter growth model for managed uneven-aged oak-shortleaf pine stands in the Ozark Highlands of Missouri, USA. Forest Ecology and Management 261, 770 – 778
[12] Mohd Razali N., Yap B.W. 2011. Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling test. Journal of Statistics Modeling and Analytics 2(1), 21-23.
[13] Mohd W.R. 1988. Modelling the tree growth in mixed tropical forest I. Use of diameter and basal area increments. J. Tropical Forest Sc.1(2), 114-121
[14] Monleon, V.J. 2004. A hierarchical model for tree height prediction. In: Proceedings of the 2003 Meeting of the American Statistical Association, Section on Statistics & the Environment, Alexandria, VA, pp 2865 – 2869
[15] Pahari K, Murai S 1999. Modelling for prediction of global deforestation based on the growth of human population. ISPRS J Photogrammetry & Remote Sensing 54:317–324.
[16] Phillips P.D, Brash T.E, IrsyalYasman, PraptoSubagyo, P.R. van Gardingen. 2003. An individual-based spatially explicit tree growth model for forests in East Kalimantan (Indonesian Borneo). Ecological Modelling 159, 1- 26
[17] Seam Reap Metrological Station, 2010. Data of rainfall and temperature in Seam Reap province.
[18] Uzoh F.C.C. and Oliver W.W. 2008. Individual tree diameter increment model for managed even-aged stands of ponderosa pine throughout the western United State using multilevel linear mixed effect models. Forest Ecology and Management 256, 438-445.
[19] Vanclay JK. 1989. A growth model for North Queensland Rainforests. Forest Ecology and Management 27, 245-271
[20] Vanclay, JK. 1991. Aggregating tree species to develop diameter increment equations for tropical rainforests. F. Eco. Man, vol. 42, no. 3-4,143-168.
[21] Vanclay J. K. 1994. Modelling forest growth and yield: application to Mixed Tropical Forest. CAB International, Wallingford. 312 pp.
[22] Yang Y, Monserud R.A, Huang S. 2004. An evaluation of diagnostic tests and their roles in validating forest biometric models. Can. J. For. Res. 34, 619-629
[23] Yaussy D., Iverson L. and Prasad A. 1997. Diameter – growth model across shortleaf pine range using regression tree analysis. Empirical and process-based models for forest tree and stand growth simulation, 21-27
[24] Zhao D, Borders B, Wilson M. 2004. Individual-tree diameter growth and mortality models for bottomland mixed species hardwood stands in the lower Mississippi alluvial valley. Forest Ecology Management 199:307-322
[25] Retrieved https://statistics.laerd.com/spss-tutorials/testing-for-normality-using-spss-statistics.php. 12 July 2011