Quest Journals
Journal of Research in Agriculture and Animal Science
Volume1 ~ Issue 1 (2013) pp: 01-07
ISSN(Online) :2321-9459
www.questjournals.org

Research Paper

Modeling Individual-Tree Height Prediction for Semi-Evergreen Forest: MultilevelLinear Mixed Effect Model Approach

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Received 21 October, 2013; **A**ccepted 02 November, 2013

ABSTRACT: *Individual-tree height models were developed for dipterocarpaceae and nondiptoracarpaceaetree family for semi-evergreen forest in Seam Reap, Cambodia. Tree variables data were collected from long term permanent sample plots for all species. The models were first fitted using multiple linear regressions since it is the most commonly used statistical method in forest modeling. The models then were fitted using multilevel linear mixed-effects model due to correlated measurements of tree height over time. Both models were compared using validation data with two statistics calculations; prediction error and prediction bias. The results indicated that the mixed-effects model performed better than the regression model.*
Keywords: *Height model, regression, mixed-effects model, dipterocarpaceae*

I. INTRODUCTION

Forest growth modeling techniques have been receiving increased attention as they provide detailed information on future stand. Tree height and diameter relationship is one of most important elements of forest growth and yield modeling. Diameter at breast height (DBH) and total tree height are two essential forest inventory measures. These variables can be used to estimate timber volume as well as other important variables in forest growth and yield [1].Tree diameters are usually easy to measure compared to tree heights as tree heights are more costly and time-consuming to obtain. For these reasons, tree diameter is measured for all trees in the sample plots, but only a sub-sample of trees is measured for total height and diameter. The data from the sub-sample trees is use for the development of a statistical model that predicts total height. Then, this model is used to predict total height for the other trees that were not measured for height. Foresters are usually welcome an opportunity to estimate this variable with an acceptable accuracy. Missing heights may be estimated using suitable height-diameter function [2].

Different statistical techniques have been applied to estimate the coefficients of linear or nonlinear forest growth and yield models, including diameter increment and total height equations. Many studies had been done on the relationship between tree height and tree diameter using various equations and techniques. In forestry applications, tree height is predicted from either published regression equations or model development. The examples of most frequently used models are Chapman-Richards and Exponential models.

A lot of studies had been done on height-diameter prediction models for some specific tree species using linear or nonlinear regression; however, these equations have included only diameter as independent variable [2, 3, 4, 5, 6, 7, 8]. These equations had been improved by including other independent variables such as stand basal area, total basal area larger than the subject tree, slope, site index, crown competition factor and precipitation and soil factors [9, 10].Recently there were a lot of researchers proved the strong relationship existed between tree diameter and height. Buba [11] carried out simple linear regression to develop prediction equation of height-diameter of *Parkiabiglobasa* in the Nigerian guinea savanna. Dauda et al. [12] proved the strong relationship existed between tree diameter and height of the three selected species in a tropical forest; they applied both linear and nonlinear regression analysis.

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Benedicto et al. [15] applied mixed model technique to estimate fixed- and random-effects parameter for the height-diameter function where an unstructured stochastic component was added to the mixed-effects model developed. Besides regression and mix-effects model methods, other methods such as generalized least square and geographically weighted regression methods were also implemented by some researchers in the parameter estimation of the random parameter model. Zhang et al. [14] model the spatial variations in the tree diameter–height relationship using geographically weighted regression (GWR).GWR attempts to capture spatial variations by calibrating a multiple regression model fitted at each tree, weighting all neighboring trees by a function of distance from the subject tree.Researcher [13]used generalized least square method in his model applications where the development of the height–diameter pattern was predicted with the parameters of the fixed model part. Very little study had been done to develop tree height models for semi-evergreen forest in Cambodia; therefore, the objectives of this study were to(1) develop models for predicting tree height for dipterocarpaceace and nondipterocarpaceace family for semi-evergreen forest inSeam Reap, Cambodia using multilevel linear mixed-effect model and (2) validate the models using statistical methods.

II. DATA AND METHODS

2.1 The Data Base

Data used in this study were obtained from permanent sample plots established and maintain 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 dipterocarp. 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 [28].

The mean annual temperature of the area ranged from 25.5°C to 27.5°C. The coldest month was January with an average monthly T° of 19.05°C. On the other hand, the warmest month was April and May with average 38.35 °C during day time [28].

The plots design were 50 by 50 meters (quarter hectare) in which all trees with 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 meter. 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 was re-measured; mortality trees and recruitment trees were also recorded and tree height were measured for sub-sample only. Tree height were measured using clinometers where the peak of the tree was pointed at certain distance from the tree and then the reading of the angle on the clinometersand the distance of the tree base to the operator (measured with the measurement tape) were recorded. Tree height was calculated by multiplying distance of the tree by tangent of the angle. From the entire data set, only live trees with measured height values were selected and used in this analysis.

The data were divided into two groups for analysis according to tree families. There were 17 families exist in this forest withdipterocarpaceae as the major family. Dipterocarpaceae is well-known trees of the Asian rain forest which consistover 500 species [16]. In this study, the dipterocarpaceae family consists of only two species which are *DipterocarpusalatusRoxb*and *Dipterocarpusintricatus Dyer* while other families were grouped innondipterocarpaceae.The nondipterocarpaceaeconsists of 18 different species (Table 1).

Table 1: The existence of tree species in each family

Dipterocarpaceae	Non Dipterocarpaceae
DipterocarpusalatusRoxb.	***Adina cordifolia, Hook. f.***
Dipterocarpusintricatus Dyer.	***Aglaiacambodiana Pierre***
	Alstoniascholaris (L.) R. Br.
	Averrhoacarambola L.
	BaccaurearamifloraLour.
	Cryptocaryaoblongifolia Bl.
	DalbergianigrescensKurz
	Dehaasiacuneata, Bl.
	DiospyroscrumenataThwaies

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	DiospyrossylvaticaRoxb.
	Hydnocarpusanthelmintica Pierre
	KnemacorticosaLour .
	Lagerstroemia sp.
	ParinariumannamensisHance
	Polyalthiathorelii (Pierre) Fin. &Gagnep.
	Schleicher oleosa (Lour.) Oken
	StreblusasperLour.
	Strychnosnux-vomica L.

The available data were split into two sets: the majority (60%) was used to estimate model parameters, and the remaining data (40%) were reserved to validate the models.There were 47 trees used for model development which 26 of them were dipterocarpaceaeand 21 of them were nondipterocarparceae. Overall, the mean tree diameter, basal area, tree height, and diameter increment were larger for dipterocarpaceae family compared to the non-dipterocarpaceae family. As can be seen from Table 2, the mean tree height for dipterocarpaceae family was almost double than that of the nondipterocarpaceae family. The mean tree diameter was also about 33% more than the mean tree diameter for the nondipterocarpaceae family. In contrast, BAL (total basal area larger than the subject tree) was larger for nondipterocarparceae family which is about 25% more than BAL for dipterocarpaceae family. The validation data comprised of 32 trees in which 18 were dipterocarpaceae and 14 were non-dipterocarpaceae. Table 3 demonstrated the summary statistics of stand variables for model validation data set. It was almost the same pattern with the distribution of the variables in the model development in which all variables except for BAL were larger for dipterocarpaceae than that of the non-dipterocarpaceae family.

Table 2: Summary statistics of stand variables for model development

Dip	Mean	Std. Deviation	Minimum	Maximum
Tree diameter (cm)	54.53	21.98	9.40	99.80
Basal area (m2)	0.27	0.20	0.01	0.78
Tree height (m)	34.23	6.91	18.10	58.00
BAL*	12.59	5.81	0.00	20.24
Diameter increment (cm/yr)	0.46	0.11	0.25	0.77
Non-Dip				
Tree diameter (cm)	36.52	19.77	7.10	99.80
Basal area (m2)	0.13	0.15	0.00	0.78
Tree height (m)	19.00	7.49	6.00	38.00
BAL*	16.78	4.24	0.93	20.25
Diameter increment (cm/yr)	0.41	0.16	0.20	1.05

Table 3: Summary statistics of stand variables for model validation

Dip	Mean	Std. Deviation	Minimum	Maximum
Tree diameter (cm)	57.85	25.74	9.4	99.1
Basal area (m2)	0.37	0.26	0.01	0.86
Tree height (m)	33.49	6.07	18.8	41.6
BAL*	11.55	5.94	1.8	20.24
Diameter increment (cm/yr)	0.44	0.13	0.25	0.77
Non-Dip				
Tree diameter (cm)	35.74	15.42	7,50	56.40
Basal area (m2)	0.15	0.10	0.01	0.31
Tree height (m)	20.08	6.22	8.40	32.60
BAL*	17.21	2.88	12.31	20.25
Diameter increment (cm/yr)	0.39	0.13	0.23	0.77

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a. Normality Test

In order to develop linear model, the distribution of the dependent variable should be normal. In this study, two ways of testing normality was used; graphical and numerical methods. Graphical methods visualize the distributions of random variables or differences between an empirical distribution and a theoretical distribution (e.g., the standard normal distribution). Numerical methods present summary statistics such as skewness and kurtosis, or conduct statistical tests of normality. For graphical method, the bell-shaped of histogram and linear line of normal Q-Q plot indicate that the data approaches 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.

2.3 Linear Regression Model and Linear Mixed Effect Model

The dependent variable, total height (m) was regress to predictor variables which were tree DBH (cm), the sum of basal area (m^2/h) in trees with DBHs larger than subject tree's DBH (BAL), basal area (m^2) (BA), DBH square (cm^2) (D^2) and species group (SG) as dummy variables.The predictor variables were regress in step wise multiple linear regression model with the significant level of 5%. Non-significant variables were removed in the modeling process, leaving only three significant variables in the following model:

$$TH = \beta_0 + \beta_1(DBH) + \beta_2(BAL) + \beta_3(SG) + \varepsilon \quad (1)$$

Where $\beta_0 \sim \beta_3$ are regression coefficients to be estimated, and ε is the model error term. Equation (1) was fitted for dipterocarpaceae and non-dipterocarpaceace trees separately. The dummy variables for species group will provide two different models of tree height prediction for dipterocarpaceae and non-dipterocarpaceae family. The dummy variable approach had been done in the study of height-diameter relationship among different ecoregions by Peng et al. [8].

Linear mixed-effect model method was used to estimate the regression coefficients $\beta_0 \sim \beta_3$ in equation (1) because the tree growth was repeated measurement; as pointed by Uzoh and Oliver [17] two measurements taken at adjacent units of time and/or space are more highly correlated than two measurements taken several time points or space apart. Different error covariance structure were evaluated to find the desirable fit based on Akaike Information Criterion (AIC), Schwarz's Bayasian Criterion (BIC), and -2 Restricted Log Likelihood [18]. A heavier penalty in the calculation of BIC than AIC was imposed when the number of parameters in the model increased [19]. The error covariance structure with the smallest values of AIC and BIC is considered most desirable.

The models were validated using two statistical methods, the mean of prediction error (E) and prediction bias express as percentage (% Bias). The two statistics were computed as follows:

$$E = \frac{\sum_{i=1}^{n}\left(TH_i - \hat{TH}_i\right)}{n}$$

$$\%Bias = \frac{E}{\bar{TH}} \times 100$$

Where TH_i is the observed tree total height, $\hat{TH}_i$ is the predicted tree total height calculated from equation (1), $\bar{TH}_i$ is the mean of observed tree total height, $i = 1, 2, 3, \ldots n$ and n is the number of observations in the model validation data. The mean prediction error and bias percentage were calculated and compared for both multiple regression model and linear mixed-effect model.

III. RESULTS AND DISCUSSION

Information on the relationship of height-diameter of trees in forest stand is greatly needed as height is often predicted from diameter measurements rather than being measured.The height equations developed in this study was very significant since these equations will be used to predict tree height for other trees that had not been measured. Furthermore, they can be used to group the trees based on the tree's height such as crown classes. In this research, the first step ofdata analysis was to test the normality of the variables. Normality test was done to tree height and tree diameter to examine whether their distribution were normal. As can be seen from Table 4, the p-value of greater than 0.05 or 0.01for both Klomogorov-Smirnov and Shapiro-Wilk suggested that the null hypothesis could not be rejected at significant level of 5% and 10% respectively. Thus, the distribution of tree height and diameter were approximately normal for both groups. By visualizing the

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histogram and normal Q-Q plot, the bell-shaped of histograms and linear line of the normal Q-Q plots proposed that those variables were approached normality.
Hypothesis for normality test:
H_0 : Distribution of tree height and tree diameter are normal

Table 4: Normality test for variables tree height and tree diameter

Variable	Klomogorov-Smirnov		Shapiro-Wilk	
	Statistic	p-value	Statistic	p-value
Tree height (Dip)	**0.136**	**0.129****	**0.907**	**0.008**
Tree height (NonDip)	**0.154**	**0.188****	**0.963**	**0.550****
DBH (Dip)	**0.193**	**0.003**	**0.920**	**0.020***
DBH (NonDip)	**0.121**	**0.200****	**0.921**	**0.080****

**Significant at 5%
*Significant at 1%

The relationship between tree height and diameter within-stand is obviously different from that of between stand as the ecological processes that control those relationships are different. Mix-effect models allow for the explicit separation of between and within-stand relationships, and consequently for a correct specification of the model.

Selecting an appropriate covariance model is important in repeated measures analyses. If an important correlation is ignored by using a model that is too simple, the risk of Type I error rates is increased for fixed effects tests. If the model is too complex, power and efficiency is sacrificed. This decision process can be assisted by using the goodness of model fit criteria (AIC) [20].

There were four common covariance structures used in this study to find the desirable specification; scale identity, diagonal, autoregressive (AR(1)) and unstructured. There were compared by three of the model-fitting criteria; Akaike Information Criterion (AIC), Schwarz's Bayesian Criterion (BIC) and -2Restricted Log Likelihood. Table 5 showed the values of the four covariance structures analysis and the goodness of fit of the height model. All the covariance structures were highly significant with the unstructured covariance structure reported the best model fit overall as it produced the smallest AIC, BIC and -2RLL. Hence, the unstructured error covariance structure was used to fit equation (1). Tree diameter (Dbh) and basal area larger than the subject tree (BAL) were the most influenced predictor variables in this model. Table 6 displayed parameter estimates of the final model using unstructured covariance structure. As can be seen the predictor variables of tree diameter (Dbh) and intercept had positive values but BAL and species group (dummy variable) had negative values. It is certainly true that the tree height will increase as the diameter increased. This is obviously presented by the positive sign of Dbh of the model. The negative sign for species group indicated that dipterocarpaceae family had less tree height as compared to non-dipterocarpaceae family; while the negative sign for BAL indicated that the suppressed tree (larger BAL) would have less height than that of a dominant tree (smaller BAL). In addition, BAL is considered as tree competitive position as the height of the tree is dependent on its competitive status relative to neighboring trees. Thus, the largest diameter tree would have a BAL value of zero, while the smallest diameter tree would have a BAL value of nearly the total basal areas. The following equations provided the best fit for dipterocarpaceae and nondipterocarpaceae family.

Dipterocarpaceae

$$TH = 26.629 + 0.178(DBH) - 0.0149(BAL) - 11.79 \quad (2)$$

Non-Dipterocarpaceae

$$TH = 26.629 + 0.178(DBH) - 0.0149(BAL) \quad (3)$$

Table 5: Model fitting statistics of the different error covariance structures

Criterion	Scale Identity	Diagonal	AR(1)	Unstructured
AIC[a]	1197	1203	540	439.5
BIC[b]	1203	1219	553	481.2
-2RLL[c]	1193	1193	532	413.5
p-value	<0.000	<0.000	<0.000	<0.000

[a]AIC is Akaike Information Criterion
[b]BIC is Schwarz's Bayesian Criterion
[c]-2RLL is -2 Restricted Log Likelihood

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Table 6: Coefficient estimates of the final model (unstructured covariance structure)

Coefficient	Estimate	Std Error	p-value
Intercept	26.629	3.114	0.000
Diameter (Dbh)	0.178	0.0189	0.000
BAL*	-0.0149	0.0071	0.044
Species Group	-11.79	1.721	0.000

*BAL is Basal area larger than subject tree

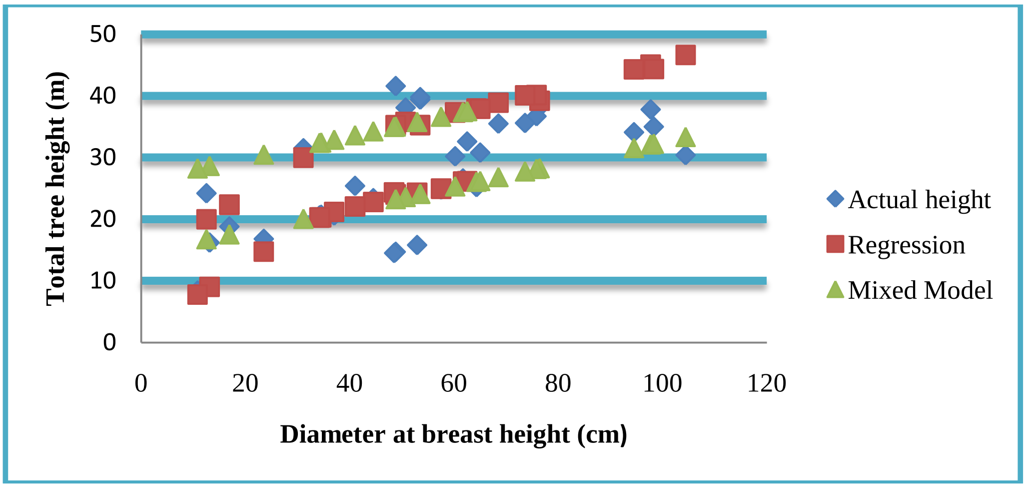

Fig.1. Prediction of tree height by regression and mixed model compared to actual tree height

Model validation is an essential part of the model development process if models to be accepted and used to support decision making. Validation ensures that the model meets its intended requirements in terms of the methods employed and the results obtained. The ultimate goal of model validationis to make the model useful in the sense that the model addresses the right problem, provides accurate information about the system being modeled, and to makes the model actually used [22]. There are many types of validation methods available; some are qualitative and others are quantitative [21]. Equations (2) and (3) were fitted into validation data set to predict the tree height; then the prediction error and prediction bias was calculated.

Table 7: Prediction error and prediction bias (%) by linear mixed model and regression model using validation data set

Model	*n*	Prediction error	Prediction bias (%)
Linear mixed	32	1.690	6.116
Multiple linear regression	32	2.186	7.912

The results showed that the mixed model predictions were closer to the validation data set than is the regression model prediction. In addition, the mixed-effects model provided better model fitting and more precise estimations. The prediction error and prediction bias (Table 7) of linear mixed effect model was lower than that of multiple linear regression. Our finding confirms the previous findings (Hall and Bailey, 2001; Kowalchuk and Keselman, 2001;Sharma M. and Parton J., 2007; Budhathoki et al., 2007; Lee Y.J. et al., 2009; Jiang L. and Li Y., 2010). Figure 1 demonstrated the scatter plot of tree diameter versus tree height of the linear mixed-effects model and linear regression model as compared to the actual tree height. The scatter plot of linear mixed-effects model is noticeablyclosed to the actual tree height.

IV. CONCLUSION

The equations for the tree total height had been developed for trees in semi-evergreen forest in Seam Reap, Cambodia. The trees were grouped into two major families namely dipterocarpaceae and nondiptoracarpaceae family. Tree variables data were collected from long term permanent sample plots of semi-evergreen forest in the range of thirteen years. The significant explanatory variables used to predict the total height were tree diameter (dbh), sum of basal area larger than the subject tree(BAL) and species group as dummy variable. The mixed-effects model was compared to regression model using validation data to show how well mixed-effects model predicts the tree total height; consequently, the mixed model performed better

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than the regression model. It is proved that the mixed-effects model best predicts total height for both species groups. The ability of mixed models to include both fixed and random effects makes the model unique (Hall and Bailey, 2001). Though additional computation is needed, we strongly recommend that the equations can be used to predict the total height for dipterocarpaceae and nondiptoracarpaceae species specifically in semi-evergreen forest; hence, the timber volume can be calculated for future forest management planning.

REFERENCES

[1]. Vanclay J. K. 1994. Modelling forest growth and yield: application to Mixed Tropical Forest. CAB International, Wallingford. 312 pp.

[2]. H. Temesgen and K. v. Gadow. 2004. Generelized height-diameter models – an application for major tree species in complex stands of interior British Columbia. European Journal Forest Research (2004) 123:45-51

[3]. El Mamoun H. Osman, El Zein A. Idris and El Mugira M. Ibrahim. 2013. Height-Diameter Prediction Models for Some Utilitarian Natural Tree Species. Journal of Forest Products & Industries, 2013, 2(2), 31-39

[4]. Mahmud D. Avsar. 2004. The Relationship between Diameter at Breat Height, Tree Height and Crown Diameter in Calabrian Pines (Pinusbrutia Ten.) of Baskonus Mountain, Kahramanmaras, Turkey. Journal of Biological Sciences 4 (4): 437-440, 2004

[5]. Oyebade B.A. and EbitimiOnyambo. 2011. Height-Diameter Predictive Equations for Rubber (*HeveaBrasilliensis-A*. Juss-Muell) Plantation, Choba, Port Harcourt, Nigeria. Journal of Agriculture and Social Research (JASR) Vol. 11, No. 1, 2011

[6]. Mahadev Sharma*&Shu Yin Zhang. 2004. Height–Diameter Models Using Stand Characteristics for *Pinusbanksiana* and *Piceamariana.* Scandinavian Journal of Forest Research, Volume 19, Issue 5, 2004

[7]. UlisesDiéguez-Aranda, Harold E. Burkhart, Roque Rodríguez-Soalleiro. 2005. Modeling dominant height growth of radiata pine (Pinusradiata D. Don) plantations in north-western Spain. Forest Ecology and Management, Volume 215, Issues 1–3, 25 August 2005, Pages 271–284

[8]. ChanghuiPeng, Lianjun Zhang, Xiaolu Zhou, Qinglai Dang and Shongming Huang. 2004. Developing and Evaluating Tree Height-Diameter Models at Three Geographic Scales for Black Spruce in Ontario. Northern Journal of Applied Forestry, Volume 21, No. 2, June 2004.

[9]. Uzoh Fabian C.C., 2001. A height increment equation for young ponderosa pine plantations using precipitation and soil factors.Forest Ecology and Management. 142, 193-203

[10]. Wang Chao-Huan and Hann David W., 1988.Height-diameter Equations for Sixteen Tree Species in the Central Western Willamette Valley of Oregon.Forest Research Laboratory, Oregon State University, Corvallis, USA.Research Paper 51.

[11]. TomaBuba. 2012. Prediction equations for estimating tree height, crown diameter, crown height and crown ratio of *Parkiabiglobosa* in the Nigerian guinea savanna. African Journal of Agricultural Research Vol. 7(49), pp. 6541-6543

[12]. T.O. Dauda, L.O. Ojo and S.K.Nokoe (2004), Unexplained Relationships of Height-Diameter of Three Tree Species in a Tropical Forest. Global Nest: the Int. J. Vol 6, No 3, pp 196-204, 2004

[13]. KalleEerikäinen. 2003. Predicting the height–diameter pattern of planted Pinuskesiya stands in Zambia and Zimbabwe. Forest Ecology and Management, volume 175, Issues 1–3, 3 March 2003, Pages 355–366

[14]. LianjunZhang,Huiquan Bi, Pengfei Cheng, Craig J Davis. 2004. Modeling spatial variation in tree diameter–height relationships. Forest Ecology and Management, volume 189, Issues 1–3, 23 February 2004, Pages 317–329

[15]. Benedicto Vargas-Larreta, Fernando Castedo- Dorado, Juan Gabriel Álvarez-González, Marcos Barrio-Antaand Francisco Cruz-Cobos (2009).A generalized height–diameter model with random coefficients for uneven-aged stands in El Salto, Durango (Mexico).Forestry, Vol. 82, No. 4, 2009. May 2009

[16]. S. Dayanandan,Peter S. Ashton,Scott M. Williams,and Richard B. Primack. 1999. Phylogeny Of The Tropical Tree Family Dipterocarpaceae Based On Nucleotide Sequences Of The Chloroplast *Rbcl*GenE. American Journal of Botany 86(8): 1182–1190. 1999.

[17]. Uzoh F.C.C. 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.

[18]. Littell R.C., Milliken G.A., Stroup W.W., Wolfinger R.D., Schabenberger O. 2006. SAS for Mixed Model, Second Edition. SAS Institute Inc Cary, NC, USA. 731 pp.

[19]. MehrdadVossoughi, SMT Ayatollahi, Mina Towhidiand FarzanehKetabchi. 2012.On summary measure analysis of linear trendrepeated measures data: performancecomparison with two competing methods. Vossoughi et al. BMC Medical Research Methodology 2012, 12:33 http://www.biomedcentral.com/1471-2288/12/33

[20]. Fabian C.C. Uzoh and William W. Oliver (2006), Individual tree height increment model for managed even-aged stands of ponderosa pine throughout the western United States using linear mixed effects models. Forest Ecology and Management 221, 147 – 154

[21]. Sargent Robert G. 1999. Validation And Verification of Simulation Models. P. A. Farrington, H. B. Nembhard, D. T. Sturrock, and G. W. Evans, eds., Proceedings of the 1999 Winter Simulation Conference, 5-8 December 1999, Phoenix, Ariz, Institute of Electrical and Electronics Engineers, New York, pp. 39-48

[22]. Macal Charles M. 2005. Model Verification and Validation. Workshop on "Threat Anticipation: Social Science Methods and Models" The University of Chicago and Argonne National Laboratory, April 7-9, 2005 Chicago, IL

[23]. Hall, Daniel B., Bailey Robert L., 2001. Modeling and Prediction of Forest Growth Variables Based on Multilevel Nonlinear Mixed Models. Forest Science 47(3) 2001

[24]. Kowalchuk RK, Keselman HJ., 2001. Mixed-model pairwise multiple comparisons of repeated measures means. Psychol. Methods 6(3):282-296.

[25]. Sharma Mahadev and Parton John, 2007. Height-diameter equations for boreal tree species in Ontario using a mixed-effects modeling approach. Forest Ecology and Management 249 (2007) 187 – 198

[26]. Budhathoki Chakra B., Lynch Thomas B., and Guldin James M. 2008. A Mixed-Effects Model for dbh-Height Relationship of Shortleaf Pine (*Pinusechinata* Mill.). South. J. Appl. For. 32(1) 2008

[27]. Lee Y.J., Coble Dean W., Pyo J.K., Kim S.H., Lee W.L., and Choi J.K., 2009. A mixed-effect Height-Diameter Model for *Pinusdensiflora* Trees in Gangwon Province, Korea. Jour. Korean For. Soc. Vol. 98. No. 2, pp. 178-182

[28]. Jiang L. and Li Y., 2010. Application of Nonlinear Mixed-Effects Modelling Approach in Tree Height Prediction. Journal of Computers, Vol. 5, No. 10, October 2010.Seam Reap Metrological Station, (2010) Data of rainfall and temperature in Seam Reap province.

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