MODELLING STEM DIAMETER VARIABILITY IN A MULTI-SPECIES STAND: A NEW APPROACH

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Abstract

Little has been done till date, to explore the modelling potentials of standard deviation (SDD) and coefficient of variation (CVD) of stem diameter. This study was aimed at developing and testing models for predicting stem diameter variability in terms of SDD and CVD using data from a tropical rainforest (Ekuri Forest Reserve, Cross River State) of Nigeria. Thirty-two temporary sample plots of size 25m x 25m were sampled. The candidate models for estimating SDD and CVD used commonly available stand variables (e.g. quadratic mean diameter – Dq, number of stems per hectare - N/ha, 24th, 63rd, 76th and 93rd percentiles of diameter distribution) and were compared using corrected Akaike's Information Criterion (AICc) and standard error of estimate (SEE). The most influential variables for predicting CVD and SDD were found to be the 24th and 93rd percentile positions of stem diameter. The smallest relativized SEE, which is a measure of prediction accuracy, was found among the CVD models.

Introduction

Diameter variability is a well-known and widely developed concept useful for effective forest management planning. Several studies (e.g. Bailey and Dell, 1973; Hafley and Schreuder, 1977; Borders *et al.* 1987; Mehtatalo *et al.* 2008; Kayes *et al.* 2012; Poudel and Cao, 2013; and Sipilehto and Mehtatalo, 2013) have put considerable effort to modelling diameter distribution using different theoretical distribution functions. Although, varying degrees of success have been achieved in modeling diameter distribution, there is however, room for improvement. To date, little has been done to explore the modelling potentials of two chief characteristics of stem diameter variability, that is standard deviation of diameter (SDD) and coefficient of variation of diameter (CVD). Zeide and Zhang (2000) proposed a model for estimating SDD using stand attributes such as average diameter, number of stems and age. Their model explained 91% of the variation in SDD. However, standard deviation is often criticized to be unstable in magnitude and tricky to interpret (e.g. McDonald, 2014). A lower standard deviation does not necessarily imply lesser variability. In this study, with particular focus on multi-species stand, the CVD is proposed as a suitable alternative to SDD because its value is stable across different groups of sizes and conditions which is a recurring experience in natural stands. This study therefore investigates whether SDD and CVD are indeed independent from stand attributes.

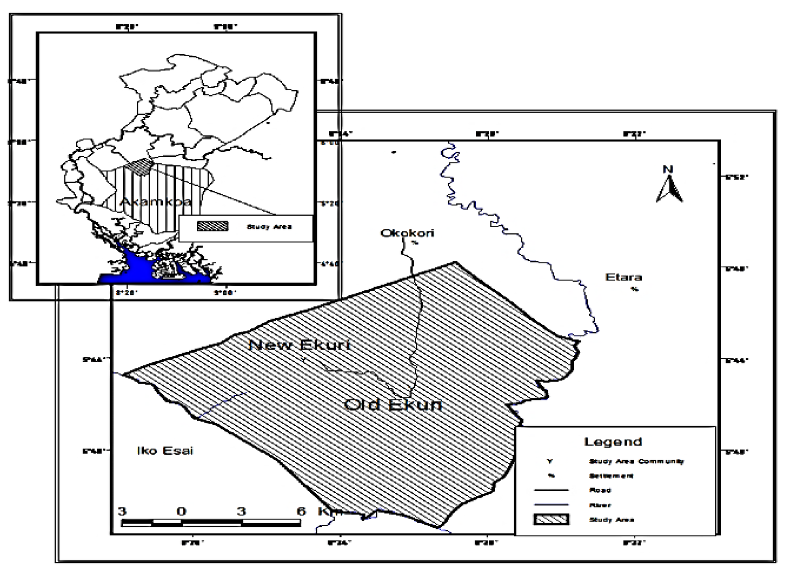

Figure 1. Inset Map of Cross River State Nigeria.

Methods and Materials

The data used for model fitting in this study were collected from Ekuri Community Forest, located in the buffer zone of Cross River National Park of Nigeria (Fig. 1). A total of 32 temporary sample plots of size 25m x 25m were randomly laid. Tree size variables measured within each plot include diameter at breast height(cm), total and merchantable heights(m), number of stems and percentile positions of stem diameter at 24th (P_{24}), 63rd (P_{63}), 76th (P_{76}) and 90th (P_{90}). The merchantable limit was taken as the minimum top diameter of 10cm. Correlation and multiple linear regression analyses were used to analyze the data. The SDD and CVD were used as response variables; while three categories of explanatory variables were investigated (i.e. (i) measures of tree size only – mean diameter, basal area/ha, number of trees/ha, etc.; (ii) measures of distributions – percentile positions P_{24}, P_{63}, P_{76} and P_{90}; and combinations of (i) and (ii)). The set of explanatory variables used were also checked for multicolinearity by observing their variance inflation factor (VIF). Model evaluation and comparison were achieved using standard error of estimate (SEE), relative standard error (RSE), coefficient of determination (R^2), prediction residual sum of squares (PRESS) and corrected Akaike's information criterion (AIC_c).

Results

The rectangular correlation matrix of SDD and CVD against stand variables is presented in Table 1. All the stand variables are correlated with SDD (and positively so) with the exception of number of trees/ha. Highest correlation with SDD was found to be P_{90}. On the other hand, CVD was only correlated with mean dominant height (H_d), basal area per hectare (BA/ha) and P_{90} and positively so. Consistent positive correlation between stand variables and the two measures of variability suggests that diameter variability increases with increase in stand attributes.

Table 1: Rectangular Matrix Correlation Coefficients of SDD and CVD against Stand Attributes

	D_{am}	H_d	N/ha	BA/ha	P_{24}	P_{63}	P_{76}	P_{90}
SDD	0.72*	0.38*	- 0.03	0.85*	0.39*	0.50*	0.38*	0.90*
CVD	0.35	0.47*	0.09	0.59*	0.01	0.08	- 0.01	0.75*

*** = Significant correlation at α level of 0.05**

The selected candidate models, with their corresponding parameter estimates, fit and prediction statistics are presented in Table 2. Among the SDD models, the model with combination of stand size variable and measures of tree size distribution (i.e. Model 3) gave a better fit judging from the fitting and prediction criteria (i.e. higher R^2 of 0.86, lower values of SEE of 2.644, PRESS of 325.91 and RSE of 12.79%). Among the CVD models, the model with mainly, measures of tree size distribution (Model 5) gave a better fit judging from the fitting and prediction criteria (i.e. higher R^2 of 0.78, lower values of SEE of 0.058, PRESS of 0.125 and RSE of 10.91%). Generally, it is not appropriate to compare two models with different response variables using R^2 and SEE. However, such comparison can be made using relativized standard error (defined as the percentage ratio of SEE to average estimate produced by the fitted model). Hence, comparison of the best SDD and CVD models, on the basis of RSE indicates that CVD model (i.e. Model 5) is superior to the SDD model (i.e. Model 3).

Table 2: Candidate Models with Parameter Estimates, Fit and Prediction Statistics

Model No.	Model	R^2	AIC_c	SEE	RSE (%)	PRESS
	SDD Candidate Model					
1	$SDD = -24.9 + 0.743D_{am} + 0.475H_d$	0.61	100.31	4.342	21.01	702.87
2	$SDD = -10.5 + 0.412P_{90}$	0.81	75.33	3.011	14.57	329.19
3	$SDD = -6.62 + 0.102BA + 0.276P_{90}$	0.86	68.55	2.644	12.79	325.91
	CVD Candidate Model					
4	$CVD = 0.348 + 0.003BA$	0.35	-143.14	0.099	18.62	0.41
5	$CVD = 0.428 - 0.024P_{24} + 0.009P_{90}$	0.78	-175.39	0.058	10.91	0.13
6	$CVD = 0.222 - 0.012D_{am} + 0.01P_{90}$	0.70	-165.22	0.069	12.88	0.17

Discussion

In this study, models predicting diameter variability in terms of CVD and SDD were evaluated. Stand variables considered as possible explanatory variables were categorized into (i) tree size, (ii) stem size distribution and (iii) combination of (i) and (ii). Quite many studies have provided information on the capacity of stand variables to predict percentile based diameter distribution (e.g. Borders *et al.* 1987;and Poudel and Cao, 2013). However, few studies, to date, have pointed out the relationship between measures of variability (i.e. SDD and CVD) and stand growth variables (e.g. Zeide and Zhang, 2000).

The SDD was correlated with most of the stand variables, while CVD was not. This, probably could be because CVD is a ratio. Cohen *et al.* (2003) pointed out that the Pearson product-moment correlation may be spurious and misleading when used to measure association between a ratio and another ratio or variable. Among the six candidate models tested, CVD model having P_{24} and P_{90} as predictors was found to be the best in terms of prediction accuracy and goodness of fit. This was consistent with the findings of McDonald (2014).

Conclusions

The modeling potentials of two chief characteristics of stem diameter variability, standard deviation of diameter (SDD) and coefficient of variation of diameter (CVD) were investigated in a multi-species stand. The study shows that models with measures of stem diameter distribution (i.e. percentile positions) as explanatory variables ranked overall best. The stability of CVD in measuring variability across different groups of stand sizes also support preference for CVD over SDD. The CVD increases with P_{90} and it decreases with increase in P_{24}. This trend raise a question: why does CVD decrease with increase in P_{24}, but increases with increase in P_{90}? It is expected that stand level growth models based on stem diameter variability can be improved by using the CVD model 5.

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