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Multivariate Regression Model for Partitioning Tree Volume of White Oak into Round-Product Classes

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Abstract

Describes the development of multivariate equations that predict the expected cubic volume of four round-product classes from independent variables composed of individual tree-quality characteristics. Although the model has limited application at this time, it does demonstrate the feasibility of partitioning total tree cubic volume into round-product classes based on tree-quality characteristics.

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Introduction

Information is lacking on techniques for predicting the future multiproduct potential of young hardwood trees and stands. Future product prediction and quality estimation are necessary before economic analyses can be used to accurately determine potential tree and stand values that result from various cultural treatments. There are two steps in the development of the relationship between the quality-related tree characteristics and future end products. First, prediction equations must be developed that relate the yield of multiproducts to individual tree characteristics in mature trees. Second, a technique for predicting the final values of tree characteristics at the time of harvest based on initial values, time, and cultural treatments must be developed. This study was concerned only with the first step—relating individual tree characteristics to the expected cubic-foot volumes of four broad-product groups (veneer logs, high-grade factory lumber logs, low-grade factory lumber logs and construction lumber logs, and fiber).

The product prediction equations are not intended to replace the hardwood tree grades for predicting factory-lumber yields (Hanks 1976). Rather, they will be used for predicting the future product potential of young trees and stands. The hardwood tree grades are used primarily for predicting expected volumes and values of lumber by lumber grade for mature timber.

Data

The data used in this study came from two areas. The first source (site index 70) was part of a white oak lumber-grade yield study near Moorehead, Kentucky. The second source was from a smaller group of trees (site index 75) cut specifically for this study near Dundas, Ohio.

The data set from Kentucky consisted of 80 trees that were bucked into sawlogs and sawed into factory lumber. No veneer bolts were produced. The surface characteristics of all logs were diagrammed so that the entire length of the sawlog portion of the tree stem could be reconstructed to include veneer volume if present.

The reconstructed tree stems were separated into four broad product classes in the following priority:

1. Veneer bolts[1]
2. Grade 1 and grade 2 sawlogs (Rast et al. 1973)
3. Grade 3 and construction grade logs (Rast et al. 1973)
4. Fuel and fiber

The dbh of all trees in this study was large enough for the butt log to be included in any of the product classes.

[1]Rast, E. D. "Preliminary grades and volume relationships for sliced northern red oak and black cherry veneer logs." Unpublished paper presented at the Society of American Foresters Meeting, White Sulphur Springs, W. Va., 1978.

Diameters of each product section that were different from the original measurement were calculated using Ormerod's taper equation and coefficients proposed by Oderwald and Yaussy (1980).

The cubic-foot volumes of all bolts and logs were determined using Smalian's formula. The fuel and fiber component was found by subtracting the volumes of the sawlog and veneer portions of the tree from the total tree volume calculated by using a combined variable equation developed by Yaussy (1978).

Gross cubic-foot volumes were used because scalable defect deductions were very small for the sample trees.

The independent variables examined in this study were the surface quality characteristics as described by Sonderman (1979) and tree size (dbh and total height). Because total tree heights were not measured in the Kentucky study, they were estimated using an equation developed by Hilt and Dale (1981).

All data for the 35 trees in the Ohio sample were collected by actual measurement before and after felling.

Model Development

Because volumes by product class were the dependent variables of a regression model, multivariate linear regression was an appropriate form of analysis. Although Sonderman's quality classification system measures 20 tree characteristics, only these four proved statistically significant in predicting the volumes by product classes:

1. Dbh (D)
2. Total height (H)
3. Number of epicormics (E), transformed into a code
4. Number of limb-related defects (L)

In the quality classification system, the number of epicormic branches or bundles in the lowest two 8-foot sections of the tree need not be counted. Instead, a code is used to indicate the relative numbers (that is, 0—no branches or bundles, 1—1 to 6 branches or bundles, 2—7 or more branches or bundles). For this study, the coding was modified to consider the number of epicormics in the entire 16-foot butt section. The code was modified by adding the codes from each of the two 8-foot sections. This means that E could range from 0 to 4. The number of limb-related defects was determined by summing the number of live limbs, dead limbs, and overgrowths in the 16-foot butt section of the tree. Averages and ranges for the independent variables are presented in Table 1.

Table 1.—Averages and ranges of the tree measurements for 115 trees

Variable	Average	Minimum	Maximum	Standard deviation
Dbh (inches)	18.2	12.6	31.4	3.7
Total height (feet)	95.8	78.0	119.0	8.0
Epicormic code	1.6	0.0	4.0	1.3
Number of limb-related defects	5.6	0.0	21.0	4.6

The model has the form:

$$Y_i = b_{i0} + b_{i1} \cdot D^2 + b_{i2} \cdot D^2H + b_{i3} \cdot E + b_{i4} \cdot L$$

where

Y_i = inside bark cubic foot volume of the ith product class

$i = 1, \ldots, 4; Y_i$ = veneer, . . . , fuel and fiber

b_{ij} = coefficients determined by regression for the ith product class and the jth independent variable.

Coefficients for this model are presented in Table 2.

Results and Discussion

An overall Wilks-Lambda statistic of 3×10^{-6} indicates a very good fit of the model to the data. In the univariate case, the Wilks-Lambda statistic is equivalent to $1\text{-}r^2$. The actual and predicted average yields for the pooled data set are presented in Table 3. Even though the model fits the data very well, the veneer volume prediction for 12-inch dbh trees with large numbers of limbs is negative.

Because the data used in this study is limited in scope, we recommend that the model be used cautiously. Tests should be made to verify its reliability. This study should be considered a demonstration of model development rather than an operational tool at this time. However, the results of this study provide a framework for partitioning total tree cubic-foot volume into round-product classes that are based on tree quality characteristics. These results will be combined with additional data and models that predict change in individual tree characteristics over time by cultural treatment.

Table 2.—Matrix of coefficients (b_{ij}) for the model

Product classes		Independent variables (j)				
	(i)	Intercept 0	D^2 1	D^2H 2	E 3	L 4
Veneer	1	8.6180	0.0970	−0.0007	−1.5027	−1.1561
Ones and twos	2	−2.5759	0.0291	0.0006	−2.4606	0.1881
Threes and construction	3	12.4497	−0.1246	0.0015	0.9195	0.7944
Fuel and fiber	4	−20.9934	0.0062	0.0026	3.1827	0.1618

Table 3.—Averages and ranges of actual and predicted cubic-foot values by product class

Product class	Average	Minimum	Maximum	Standard deviation
Veneer	10.1 (10.1)[a]	0.0 (−12.2)	80.3 (30.6)	14.1 (7.5)
Ones and twos	25.1 (25.1)	0.0 (2.6)	134.0 (95.4)	22.7 (14.7)
Threes and construction	26.2 (26.2)	0.0 (13.9)	88.8 (68.6)	17.1 (7.8)
Fuel and fiber	74.6 (74.6)	23.4 (17.1)	307.1 (295.2)	45.1 (43.1)

[a]Numbers in parentheses are predicted; others are actual.

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