CONVERTING INTERNATIONAL ¼ INCH TREE VOLUME TO DOYLE

Aaron Holley, John R. Brooks, and Stuart A. Moss[1]

Abstract.—An equation for converting Mesavage and Girard's International ¼ inch tree volumes to the Doyle log rule is presented as a function of tree diameter. Volume error for trees having less than four logs exhibited volume prediction errors within a range of ±10 board feet. In addition, volume prediction error as a percent of actual Doyle tree volume was generally less than 10 percent for all trees and less than 5 percent for trees larger than 20-inch diameter at breast height (d.b.h.) This equation was developed for those wanting a more accurate method of converting standard inventory estimates of average volume to an alternative log rule.

INTRODUCTION

Since the advent of log rules in the 1800s, foresters have needed to convert volume calculated using one log rule to a different log rule. In the Appalachian hardwood region, one common conversion is from International ¼ inch (Int ¼) to Doyle or vice versa. A common situation occurs when tree volume in a standard inventory is desired in a different log rule. In the Appalachian region, government entities predominantly report tree volumes in Int ¼ rule while industry more commonly uses Doyle. The best solution is to apply the desired log rule, using either a volume table or an equation, to the original data and avoid the use of any conversions, but this is not always possible. There have been many conversion factors developed over time in search of the best approach, but most of these represent single-value conversion factors which produce solutions based on the assumed average tree size in question (Finley and Rickenbach 1996). When the average inventory tree size is different from that used to develop the conversion factor, large errors can be introduced. This problem also occurs when using published timber market reports. The West Virginia University Appalachian Hardwood Center (2012) utilizes an Int ¼ to Doyle conversion ratio of 1.25 which is based on an average tree size of 21- to 24-inch diameter at breast height (d.b.h.) and merchantable heights between 1 and 5.5 logs. The "Pennsylvania Woodlands Timber Market Report" uses an Int ¼ to Doyle conversion ratio of 1.695 which assumes an average log has a 13-inch diameter at the small end (Pennsylvania State Cooperative Extension 2012). In this case, the conversion would be appropriate for individual logs of this size, but large errors can occur when applying log volume conversion ratios to reports that are based on the average of multiple tree volumes, even if the average tree diameter is 13 inches.

The objective of this study was to provide a means of converting tree volume from Int ¼ to Doyle or from Doyle to Int ¼ as a function of tree size. A conversion equation was developed to permit either individual tree volume conversions or average stand volume conversions based on average stand diameter. The conversion ratio was chosen to be a function of tree diameter since the coefficient of variation within a diameter class was smaller than those within a merchantable log class.

[1] Graduate Student (AH), Professor of Forest Biometrics (JRB), and Assistant Professor of Forest Business (SAM), West Virginia University, Division of Forestry and Natural Resources, P.O. Box 6125, Morgantown, WV 26506. JRB is corresponding author: to contact, call 304-293-5313 or email at John.Brooks@mail.wvu.edu.

DATA AND METHODS

From Maine to Texas, most hardwood volumes are sold based on the Doyle log rule, and the Mesavage and Girard form class volume tables (Mesavage and Girard 1946) are the market standard for estimating tree volume. The Int ¼ and Doyle form class 78 volume tables were used to calculate the conversion factor for each published diameter and merchantable height class listed in the original tables.

Models were fit to volume ratio data to strike a balance between accuracy and simplicity of use. Thirty nonlinear models, including several polynomial and exponential functions, were tested to determine which models would best fit this ratio data. The only criteria used for model selection were minimum standard error of the estimate, high coefficient of determination, and the graphic evaluation of the residuals. A rational function was selected for the proposed model which is of the form:

$$Ratio = \frac{a + bx}{1 + cx + dx^2} \quad (1)$$

Where:

Ratio = ratio of International ¼ tree volume to Doyle tree volume,
x = tree d.b.h. (inches), and
a, b, c, and d = coefficients to be estimated from the data.

The resultant equation was used to predict the Int ¼ to Doyle conversion ratio and then to estimate the Doyle tree volume for every entry in the Mesavage and Girard's (1946) form class 78 volume table. Volume prediction error was plotted as a function of d.b.h. to visually evaluate volume prediction residuals.

RESULTS

Equation 1 was fit to the ratio of Mesavage and Girard's Int ¼ to Doyle tree volumes for diameter classes ranging from 10 to 40 inches and merchantable height from one to five logs, in half log intervals. Parameter estimates for Equation 1 are:

Parameter	Estimate
a	-2.03809450
b	0.32414999
c	0.24692282
d	0.00007506

The equation provided a good distribution of residuals when plotted over d.b.h. and provided the lowest standard error of the estimate (0.0212) and the highest coefficient of determination (0.9919) of all equations tested. Volume prediction error was greatest for larger diameter trees and for those trees having at least four merchantable 16-foot logs. Volume error for trees having less than four logs exhibited volume prediction errors within a range of ±10 board feet (bf) (Fig. 1). Percent volume error, as a percent of actual Doyle volume, is depicted in Figure 2. Volume prediction error as a percent of actual Doyle tree volume was generally less than 10 percent for all trees and less than 5 percent for trees larger than 20 inches d.b.h.

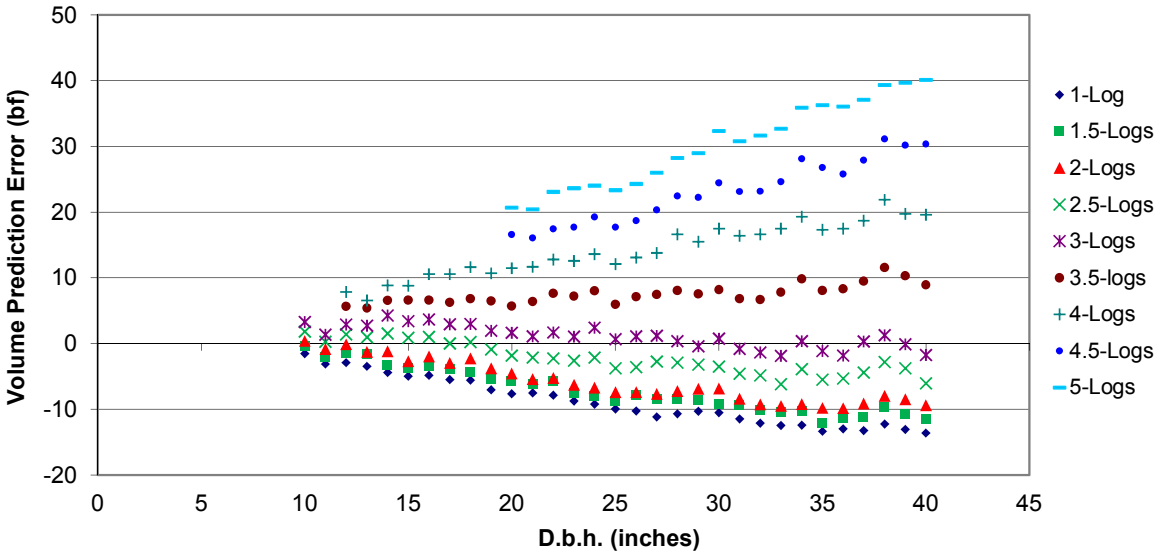

Figure 1.—Doyle board foot prediction error by tree diameter and merchantable log class.

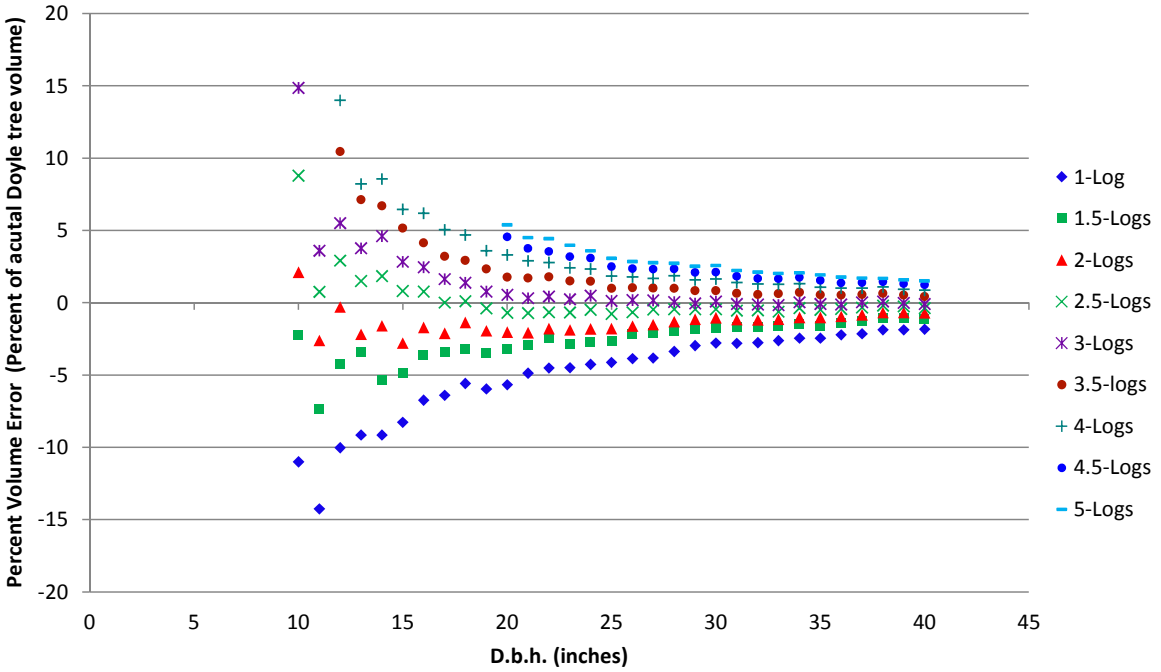

Figure 2.—Percent Doyle board foot prediction error by tree diameter and merchantable log class.

DISCUSSION

An equation was developed to predict the conversion ratio from the Mesavage and Girard form class 78 Int ¼ tree volume to Doyle board feet using a rational function. The purpose was to provide a means for predicting board foot volumes that varies by tree d.b.h. The results indicate that this conversion process is reasonably accurate for trees of all diameter classes having merchantable saw log heights of three and a half logs or less. However, when examined by percent volume error, prediction error decreased with increasing tree diameter throughout the d.b.h. range of the original volume table. The equation form selected was based purely on fit statistics rather than biological significance of the underlying data.

EXAMPLE

Suppose Doyle volume is desired for a 22-inch d.b.h. tree with three merchantable logs whose volume was calculated using the International ¼ rule. Based on Mesavage and Girard's form class 78 volume table, the International ¼ inch volume is 500 bf. Using Equation 1, the conversion ratio for this tree size is 0.78737, resulting in an estimated Doyle volume of 393.68 bf. The volume for this tree calculated directly from the Doyle log rule is 392 bf, an error of less than 2 board feet. The process can also be used to convert Doyle volumes to International ¼ inch by dividing the Doyle volume estimate by the conversion ratio listed in Equation 1. In our example, divide the Doyle volume (392 bf) by the calculated conversion ratio to obtain the predicted International ¼ inch volume of 497.86 bf. This is an error of less than 3 board feet compared to calculating Intl ¼ volume directly. If we assume an inventory results in a per acre volume estimate of 18,000 bf per acre with an average d.b.h. of 22 inches, the conversion ratio from International ¼ inch to Doyle is 0.78737, resulting in an estimate of 14,107 bf per acre, Doyle.

LITERATURE CITED

Findley, J.C.; Rickenbach, M.G. 1996. **Log rule conversions for use in Pennsylvania stumpage price reporting.** Northern Journal of Applied Forestry. 13(3): 110-115.

Mesavage, C.; Girard, J.W. 1946. **Tables for estimating board-foot volume of timber.** Washington, DC: U.S. Department of Agriculture, Forest Service. 94 p.

Pennsylvania State University Cooperative Extension. 2012**. Pennsylvania woodlands: timber market report**. Available at http://extension.psu.edu/timber-market-report. (Accessed July 15, 2012).

West Virginia University Appalachian Hardwood Center. 2012. **West Virginia timber market report**. Available at http://ahc.wvu.edu/ahc-resources-mainmenu-45/timber-market-report-mainmenu-62. (Accessed July 15, 2012).