A Product Ratio Calculator for Northeastern Tree Species

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Abstract – PRCalc is a stand-alone Windows based program that calculates percent volume of timber products for a given tree list or stand table and product specifications. The program utilizes the merchantable volume ratios approach outlined in Honer et al. (1983). It can be used to assess stand value and to examine effects of varying dimensional species specifications for timber products. PRCalc develops merchantable ratios for both metric and Imperial units.
Key Words: MerchantableVolume, Product Volume, Product Ratios

INTRODUCTION

The abundance of timber products is an important input into stand valuation and forest management planning. Rather than planning based on total merchantable volume, estimates of volume by products such as veneer, sawlog, studwood, pulp, etc. are required. Predicting these volumes is not straightforward, and there are few accessible tools to assist forest managers. Equations or tables to predict these values are not readily available. Foresters might use taper equations to estimate product volumes (Clutter et al. 1983, Husch et al. 2003), but these often require complex integration. Alternatively, taper equations can be used to estimate diameters at various heights along the stem and volumes calculated using Smalian's formula (or some other similar formula for a frustum of a solid). However, taper equations are not widely available for many species in northeastern North America. As a result, important planning functions such as examining effects of different merchantability standards often are not done.

Honer et al. (1983) developed an alternative approach to determining merchantable volume percentages by product. In their approach, quadratic equations are used to estimate Volume Ratio (VR). Volume Ratio is percent volume of a stem attributed to a given merchantable ratio (MR) based on either merchantable height (ht) or top diameter inside bark (dib):

$$\mathbf{VR} = \mathbf{p}_0 + \mathbf{p}_1 \cdot \mathbf{MR} + \mathbf{p}_2 \cdot \mathbf{MR}^2 \tag{1}$$

Here, MR is merchantable height or merchantable top diameter ratio, and the p_i's are regression coefficients. For merchantable height, MR is the merchantable height (ht) to total height (HT) ratio:

$$\mathbf{MR}_{\mathbf{ht}} = \mathbf{ht}/\mathbf{HT} \tag{2}$$

MR for merchantable diameter is the ratio of squared top dib and squared diameter at breast height (DBH), adjusted for the difference between breast height in the metric system (1.3 m) and the Imperial system (1.37 m) (Honer et al. 1983):

$$\mathbf{MR}_{\mathbf{dib}} = \left(\mathbf{dib}^2 / \mathbf{DBH}^2\right)\left(1 - 0.04365 \cdot \mathbf{b}_2\right)^{-2} \tag{3a}$$

where, both dib and DBH are measured in centimeters. The factor b_2 is a species-specific taper adjustment. For Imperial units, the merchantable diameter ratio is:

$$\mathbf{MR}_{\mathbf{dib}} = \left(\mathbf{dib}^2 / \mathbf{DBH}^2\right) \tag{3b}$$

where both dib and DBH are measured in inches. Table 1 shows the height and diameter coefficients and taper adjustment factors presented by Honer et al. (1983).

In this paper we show how Honer et al.'s (1983) volume ratios can be used to develop a fast and efficient tool for estimating volume ratios of timber products in stems.

PRODUCT RATIO CALCULATION

We define a product ratio as the proportion of total tree volume comprised by a given forest product. These products are characterized by minimum top dib and length (Briggs 1994). In our approach, product ratios are developed by using the diameter ratio equation and the height ratio equation iteratively. As an example, consider the case where a sawlog must have a minimum top diameter of 8 inches (20 cm) and length of 12 feet (3.6 m), and the stem has a 50 cm dbh and 22 m total height (even though Canada legally requires the use of metric measurements, most forest products are still specified in Imperial units). Using the average species coefficients (Table 1), the proportion of sawlog volume in the tree is calculated using the following steps.

1) Using equation 3, the MR for minimum top diameter is calculated (Eq. 3a):

$$\begin{aligned}\mathbf{MR_{dib}} &= \frac{20^2}{50^2}(1-0.04365\cdot 0.154)^{-2}\\ &= 0.16(0.9933)^{-2}\\ &= 0.16/0.9866 = 0.1622\end{aligned}$$

2) VR is then calculated using the MR_{dib} and the coefficients for the diameter ratio equation (Eq. 1, Table 1):

$$\mathbf{VR} = 1.0106 - 0.1641\cdot 0.1622 - 0.8266\cdot(0.1622)^2 = 0.9622$$

3) Using VR, the merchantable height ratio (MR_{ht}) to the minimum top diameter is estimated by solving Equation 1 for MR using the coefficients for height ratio:

$$\begin{aligned}&0.9622 = 0.0159 + 2.1331\cdot\mathbf{MR_{ht}} - 1.1631\cdot(\mathbf{MR_{ht}})^2\\ &\text{solve for } \mathbf{MR_{ht}}:\\ &\mathbf{MR_{ht}} = 0.7518\end{aligned}$$

Solutions with roots < 0 and > 1 are discarded.

4) Potential merchantable height is then determined based on the height ratio and total height:

$$\frac{\mathbf{ht}}{\mathbf{HT}} = 0.7518$$
$$\mathbf{ht} = 0.7518 \cdot 22 = 16.5$$

5) Subtracting 1 foot (30 cm) for the stump and allowing 0.3 ft (9 cm) for trim, the number of sawlogs is determined (total sawlog length = 3.6 + .1 = 3.7 m, allowing for trim):

$$\mathbf{L} = \frac{16.5 - .3}{3.7} = 4.4 = 4$$

6) The height at the top of the last log is determined and the final volume estimated from the height ratio equation:

$$\mathbf{ht} = .3 + 4 * (3.7) = 15.1$$
$$\mathbf{MR_{ht}} = 15.1/22 = 0.6864$$
$$\mathbf{VR} = 0.0159 + 2.1331 \cdot 0.6864 - 1.1631 \cdot (0.6864)^2 = 0.9321$$

Thus, the product ratio (percent total volume) for sawlogs in this tree is .93. Volume percentages for smaller products such as pulp or studwood are then determined in a similar manner from the dimensions of the bole remaining after the sawlog portion of the tree is removed.

HOW WELL DOES THE PRODUCT RATIO APPROACH WORK?

Honer’s (1967) standard total volume equations and Honer et al.’s (1983) metric total volume equations were developed from extensive data sources and characterize 21 species (Honer et al. 1983). For this reason, they are widely used throughout eastern Canada and the northeastern United States. To illustrate the efficiency and applicability of the product ratio approach, we use data from an extensive volume study in Quebec, Canada. Approximately 3500 hardwood and almost 10000 softwood trees were included. Stem analysis data were used to estimate total volume for each tree. On hardwood species, we arbitrarily defined "product" dimensions as the portion of the main stem up to the first fork. For softwood species, "product" dimensions were defined as a minimum top diameter of 12 cm. Observed product ratio was calculated using total and "product" volume based on the stem analysis data and compared to predicted ratios based on the method described above.

For both hardwood and softwood species, product ratios based on diameter tended to be underestimated relative to product ratios based on stem analysis data (Figures 1A and 1B). This was particularly evident with smaller observed product ratios. These were primarily smaller trees where upper stem diameters were nearly equal to DBH. For larger trees with larger product ratios, there is less variability and closer agreement between the LOWESS line and the 1:1 line. The height ratios were less variable than the diameter ratios. For the hardwood species, the LOWESS line and the 1:1 line are almost indistinguishable (Figure 1C) and there is much less variability. For the softwoods, the LOWESS line is consistently below the 1:1 line, but there is close agreement and low variability (Figure 1D).

PROGRAM DESCRIPTION

The product ratio calculator is a stand alone program written in Microsoft Visual Basic™. The program utilizes a spreadsheet-like interface. The first screen (Figure 2) collects two inputs. The first is dimensional specifications for each species or species type (Product and Species Specifications Window). Products may be entered in any order; however, the program sorts products by species and from largest top diameter to smallest top diameter since product ratios are calculated from largest to smallest diameter product. There is a radio button to specify Imperial or metric units. If metric units are selected, then dib is assumed to be specified in centimeters and product length in meters. If Imperial units are selected, then dib is assumed to be specified in inches and product length in feet. Tree length products are specified by entering 0 in the product length cell.

The second input is a tree list (DBH and total height) or a diameter class table (DBH class and average height) by species (Tree List Window). Similar to product descriptions, if metric units are selected, the program assumes DBH is measured in centimeters at 1.3 m breast height and total height is measured in meters. Likewise, if Imperial units are specified, the program assumes DBH is measured in inches at 4.5 ft (1.37 m) and total height is measured in feet. Inputs can be cut and pasted from a spreadsheet or similar program. Species may be specified either by their whole name or the species input code (table 1). Unrecognized species names or codes are defaulted to average species.

Once all inputs are entered, the **[Calculate Product Ratios]** button is clicked and an output screen is generated (Figure 3). Product ratios are listed for each tree in the tree list table input window and each corresponding product in the product specification window. The product ratios may be copied from the output screen and pasted into other applications. To change the product dimensions and calculate a new set of product ratios, the output window must be closed. The current version of the program can be found at:

www.ifmlab.for.unb.ca/people/Kershaw/PRCalculator.

The program does not optimize tree utilization and does not allow for variable length products.

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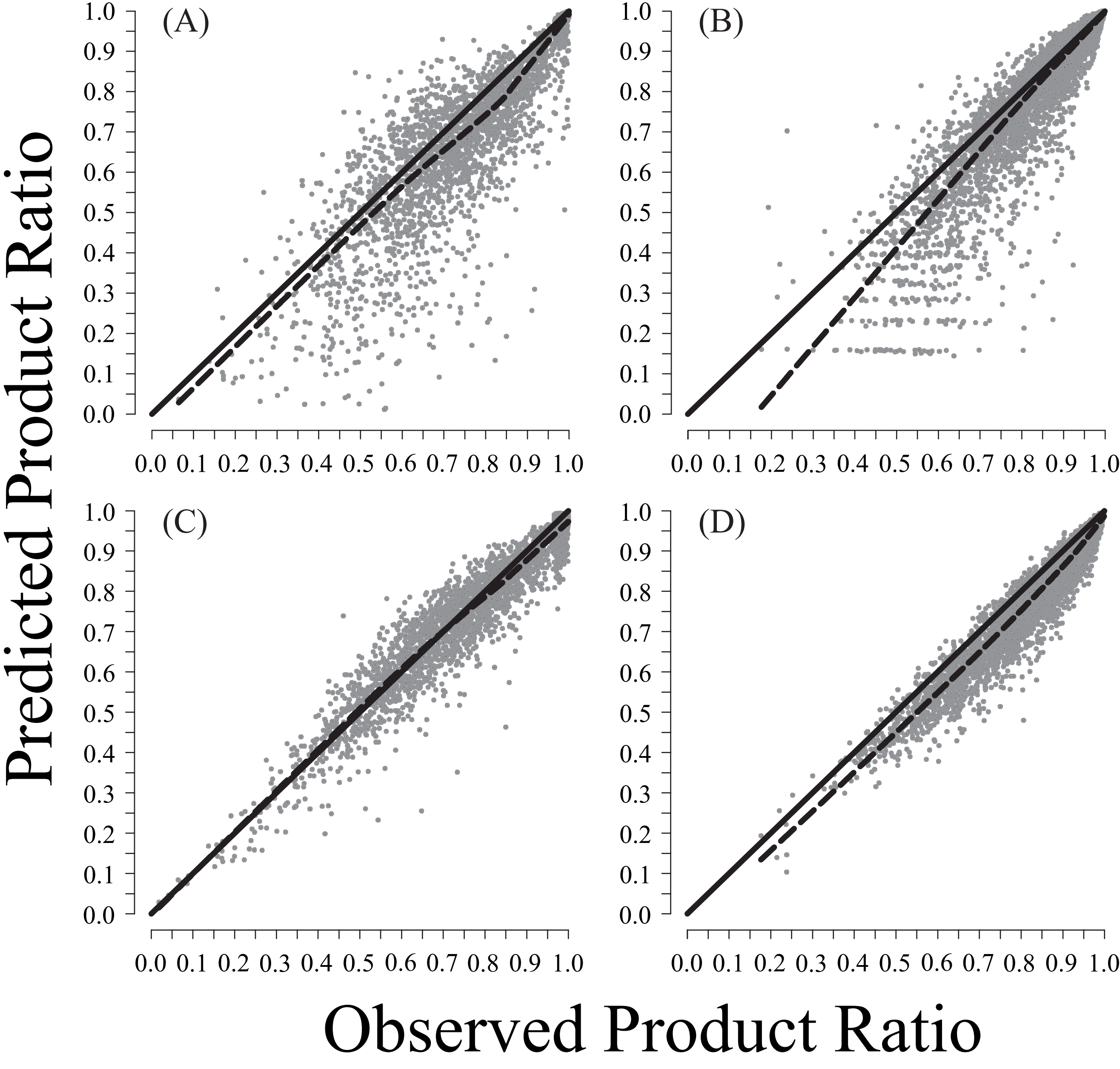
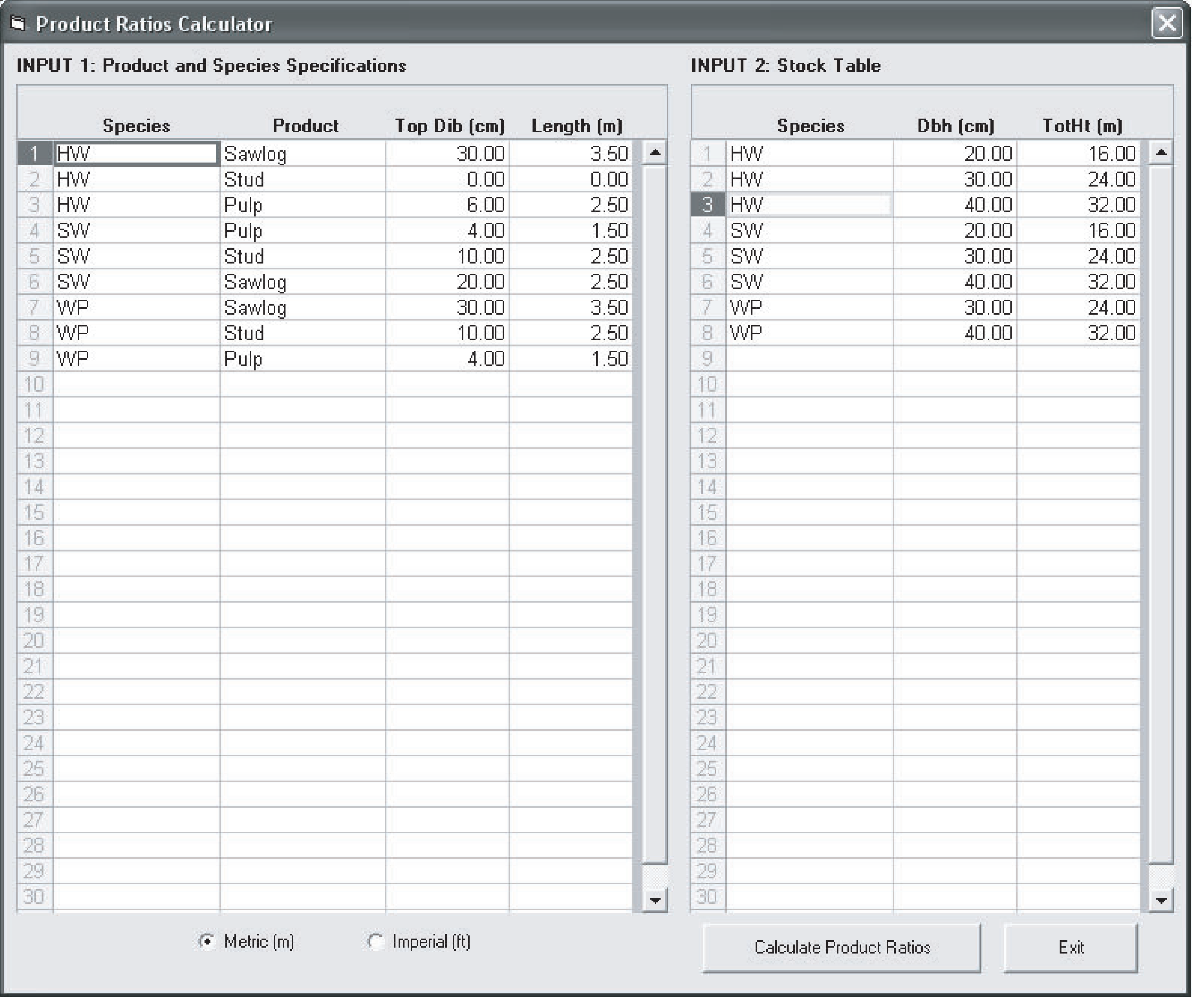
Table 1. Product ratio coefficients by species (species input codes in parentheses) from Honer et al. (1983). Adapted from tables 4 and 5 in Honer et al. (1983).

Species (input code)	Taper Adjustment (b_2)	Height Coefficients p_1	Height Coefficients p_2	Height Coefficients p_3	Diameter Coefficients p_1	Diameter Coefficients p_2	Diameter Coefficients P_3
white pine (WP)	0.184	0.0145	2.1164	-1.1387	1.0180	-0.2323	-0.7736
red pine (RP)	0.151	0.0145	2.0347	-1.0473	1.0073	-0.0461	-1.0794
jack pine (JP)	0.151	0.0760	1.6446	-0.6019	1.0081	-0.1476	-0.8455
lodgepole pine (LP)	0.118	0.0098	2.0442	-1.0562	1.0130	-0.1254	-0.8553
black spruce (BS)	0.164	0.0204	2.1534	-1.1918	1.0038	-0.1022	-0.8572
red spruce (RS)	0.169	0.0202	2.1149	-1.1465	1.0086	-0.1014	-0.7933
white spruce (WS)	0.176	0.0236	2.2191	-1.2705	1.0114	-0.2422	-0.7177
balsam fir (BF)	0.152	0.0117	2.1931	-1.2230	0.9976	-0.0532	-0.8439
other conifer (OC)	0.155	0.0155	2.1158	-1.1419	1.0119	-0.1642	-0.8289
poplar (PO)	0.127	0.0085	2.0945	-1.1055	0.9794	0.0787	-1.1865
white birch (WB)	0.176	0.0232	2.2582	-1.3268	1.0060	-0.2687	-0.6071
yellow birch (YB)	0.181	0.0248	2.4729	-1.6199	0.9921	-0.2492	-0.5793
other hardwood (OH)	0.145	0.0161	2.2378	-1.2990	0.9928	-0.1184	-0.8565
average species (AS)	0.154	0.0159	2.1331	-1.1631	1.0106	-0.1641	-0.8266

LIST OF FIGURES



(A)
(B)
(C)
(D)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Predicted Product Ratio
Observed Product Ratio


Product Ratios Calculator
INPUT 1: Product and Species Specifications
Species Product Top Dib (cm) Length (m)
1 HW Sawlog 30.00 3.50
2 HW Stud 0.00 0.00
3 HW Pulp 6.00 2.50
4 SW Pulp 4.00 1.50
5 SW Stud 10.00 2.50
6 SW Sawlog 20.00 2.50
7 WP Sawlog 30.00 3.50
8 WP Stud 10.00 2.50
9 WP Pulp 4.00 1.50
INPUT 2: Stock Table
Species Dbh (cm) TotHt (m)
1 HW 20.00 16.00
2 HW 30.00 24.00
3 HW 40.00 32.00
4 SW 20.00 16.00
5 SW 30.00 24.00
6 SW 40.00 32.00
7 WP 30.00 24.00
8 WP 40.00 32.00
Metric (m)
Imperial (ft)
Calculate Product Ratios
Exit

Product Ratios Output

	Species	Product	Ratio (%)	Num. Logs
2	HW	Sawlog	0.00	0.00
3	HW	Pulp	0.97	5.00
4	HW	Sawlog	0.00	0.00
5	HW	Pulp	1.00	9.00
6	HW	Sawlog	0.59	3.00
7	HW	Pulp	0.41	8.00
8	SW	Sawlog	0.00	0.00
9	SW	Stud	0.89	4.00
10	SW	Pulp	0.11	4.00
11	SW	Sawlog	0.70	4.00
12	SW	Stud	0.25	3.00
13	SW	Pulp	0.05	4.00
14	SW	Sawlog	0.89	8.00
15	SW	Stud	0.10	4.00
16	SW	Pulp	0.00	1.00
17	WP	Sawlog	0.00	0.00
18	WP	Stud	0.95	7.00
19	WP	Pulp	0.05	4.00
20	WP	Sawlog	0.59	3.00
21	WP	Stud	0.41	8.00
22	WP	Pulp	0.00	1.00

Close