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THE EVALUATION OF FORMULA AND DECIMAL C SCRIBNERS; ARE CONVERSION FACTORS NECESSARY TO PROVIDE ACCURATE MILL SCALE VOLUMES FROM FOREST STAND CRUISES?

by
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Many foresters and landowners are uneasy using separate versions of Scribner volume tables for timber cruising and mill log scaling. The Bruce (1925) Scribner Formula Equation is a common basis for many volume tables used in timber cruising. However, the Scribner Log Rule is normally used to determine log volume at the mill. This paper reviews the basis of the Scribner Formula and Log Rules and presents a method of adjusting Scribner Formula timber cruise volumes to more closely reflect the Log Rule mill scale.

EVOLUTION OF SCRIBNER

The Scribner Log Rule was originally constructed using a diagram method (Dilworth, 1974). This method is used to determine the volume of scaling diameter classes by drawing arrangements of one inch boards into graduated circles representing a range of diameter classes. The Scribner Log Rule evolved from its first published form in 1846 to the present Decimal C Log Rule (Husch, et al, 1972). The primary changes in the Scribner Log Rule have been the expansion of the original diameter range of 12- to 48-inches to the current 1- to 120-inch range and the rounding of volume values to the nearest ten board feet. The Northwest Log Rules Advisory Group, an organization of log scaling bureaus and public agencies, published a Revised Scribner Log Rule with some of the irrigularities smoothed out so the rule could be reduced to factors for computer extension of log volumes. This Revised Scribner has been widely accepted by private industry, third party scaling bureaus, and public forestry agencies.

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The Formula Scribner equation, prepared by Bruce in 1925, uses a formula developed through regression techniques to smooth the Scribner Log Rule table values. The Formula is:

$$\text{Volume, board feet} = (.79\ D^2 - 2\ D - 4)(L/16)$$

D = Log scaling diameter, inches

L = Log length, feet

While Formula and Log Rule evolved from a common source, they can result in substantially different board foot values for the same diameter class. For example, the Log Rule value for a 16-foot log with a 6-inch scaling diameter is 20 board feet. The Formula volume for this same log is 12 board feet resulting in a Log Rule value 66.7 percent greater than the Formula volume. The reason for this large difference is the rounding to the nearest ten board feet of the Log Rule method coupled with the calculated Formula value being at the extreme end of the confidence limits of the regression equation. The percentage difference between the values determined by the two methods varies depending on the diameter class as illustrated in Table 1.

Table 1. Formula versus Log Rule board foot volumes for 16-foot logs.

Log Diameter (Inches)	Bruce's Formula (Board Feet)	Revised Scribner Log Rule (Board Feet)	Percentage Difference
6	12	20*	+66.7%**
8	31	30	- 3.2%
10	55	60	+ 9.1%
12	86	80	- 7.0%
14	123	110	-10.6%
16	166	160	- 3.6%
18	216	210	- 2.8%
20	272	280	+ 2.9%
22	334	330	- 1.2%
24	403	400	- 0.7%
26	478	500	+ 4.6%
28	559	580	+ 3.8%
30	647	660	+ 2.0%

* Revised Scribner Log Volume Tables, Columbia River Log Scaling and Grading Bureau, et al, 1972.

** Percentage differences are independent of log length.

METHOD

This study is a part of a larger study that is investigating the suitability of tarif cruising for use in the Redwood Region (Anthony, in progress). Approximately 550 redwood (Sequoia sempervirens [D. Don] Endl.) and Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco) were analyzed in the study. The tree data, contributed by Georgia-Pacific Corporation, Masonite Corporation, Pacific Southwest Forest and Range Experiment Station, and Jackson Demonstration State Forest (JDSF), consist of diameter at breast height (DBH), total tree height, bark thickness ratio (BTR), and upper stem diameter measurements.

The study trees were computer "bucked" into 16- and 20-foot logs using a program developed by the JDSF staff. The scaling diameter of each log was determined by interpolating between upper stem diameters using quadratic functions. This method of determining the diameter inside the bark (dib) was discussed by Wensel (1971). The program assumed that each tree had a one-foot stump, six inches of trim per log segment, and a merchantable top of six inches dib.

The Formula and Log Rule volumes were calculated for each study tree using the log lengths and scaling diameters developed by the computer program. The Formula and Log Rule volumes were summed by DBH class. The Formula to Log Rule conversion factor was calculated using the equation:

$$\text{DBH Conversion Factor} = \left[\frac{\text{Sum Log Rule Volume} - \text{Sum Formula Volume}}{\text{Sum Formula Volume}} \right] + 1$$

The validity of Formula to Log Rule conversion factors was evaluated using the following methods:

1. The sum of the Formula and Log Rule volumes for all study trees were compared by species to determine the total percentage difference between the volume methods.

2. The DBH conversion factors developed by the study were applied to a young growth timber cruise on JDSF to determine the quantitative effects of the use of conversion factors.

RESULTS

The study trees analyzed for the development of DBH conversion factors ranged in DBH from 7 to 56 inches. However, there were only 20 trees exceeding 40 inches in DBH. The mean DBH for redwood was 26.7 inches and 24.0 inches for the Douglas-fir. The Formula and Log Rule volumes for the study trees are shown in Table 2.

Table 2. The comparison of Formula and Log Rule volumes for the study trees.

Species	Log Length Base	Number of Trees	Formula Volume b.f.	Log Rule Volume b.f.	Percentage Difference
Redwood	16	241	242,622	241,940	-0.3%
Douglas-fir	16	279	279,079	278,550	-0.2%
Redwood	20	242	237,060	236,240	-0.3%
Douglas-fir	20	263	269,117	268,920	-0.1%

The difference between Formula and Log Rule volumes for all study trees combined was not more than 0.3 percent. However, the percentage differences vary greatly when the Formula and Log Rule volumes are compared by DBH class. The analyses show the Log Rule overestimates Formula volume for trees with DBH's less than 17 inches (16 inches for 20-foot logs) and greater than 31 inches while underestimating volume for DBH's between 17 and 31 inches. The redwood and Douglas-fir conversion factors were similar enough to allow combining all the study tree data to derive a species independent conversion factor. The Formula conversion factors developed from the combined tree data are shown in Table 3.

Table 3. Formula to Log Rule Scribner volume conversion factors for 16- and 20-foot log lengths of young growth redwood and Douglas-fir.

DBH Class	Conversion factors	
	16-foot log lengths	20-foot log lengths
10	1.31 (16)*	1.21 (14)
11	1.13 (14)	1.20 (11)
12	1.10 (14)	1.19 (12)
13	1.05 (15)	1.09 (13)
14	1.05 (26)	1.02 (25)
15	1.06 (12)	1.05 (14)
16	1.01 (20)	0.97 (19)
17	0.98 (15)	0.96 (17)
18	0.97 (14)	0.96 (14)
19	0.97 (18)	0.95 (21)
20	0.98 (17)	0.96 (16)
21	0.99 (17)	0.97 (15)
22	0.97 (22)	0.97 (22)
23	0.97 (21)	0.98 (32)
24	0.97 (20)	0.98 (19)
25	0.98 (22)	0.98 (22)
26	0.98 (22)	0.99 (22)
27	0.98 (15)	0.99 (16)
28	0.98 (16)	0.99 (16)
29	0.99 (21)	1.00 (19)
30	1.00 (20)	0.99 (19)
31	1.00 (18)	1.00 (18)
32	1.01 (21)	1.01 (22)
33	1.00 (15)	1.01 (15)
34	1.01 (21)	1.01 (12)
35	1.01 (9)	1.01 (10)
36	1.01 (5)	1.01 (6)
37	1.00 (9)	1.02 (8)
38	1.02 (3)	1.02 (2)
39	1.01 (2)	1.02 (3)
40	1.02 (7)	1.01 (7)

( )*Number of sample trees used to determine DBH class conversion factors.

For example, to use Table 3, Bruce Formula volume for the 20-inch DBH class, 16-foot log base, is converted to Scribner Log Rule by multiplying the Formula volume by 0.98.

The DBH distribution of the data trees could vary greatly from the distributions of actual forest stands. While the difference between Formula and Log Rule volume for the data trees is not more than 0.3 percent, it should not be assumed that sample populations from other forest stands would result in similar low percentage differences. However, the Formula Scribner conversion factors developed for each DBH class can be used to adjust timber cruises to Log Rule volumes.

The JDSF Hare Creek 1982 (HC '82) Timber Sale was cruised by the variable plot cruising method, using a basal area factor of 40, on a 4-chain (264 feet) by 4-chain cruise grid over 247 acres. The forest stand is approximately 80 years of age and is comprised of predominantly redwood and Douglas-fir. The silvicultural prescription for the stand is a thinning from below to improve forest stand quality and capture mortality. Approximately 50 percent of the stand basal area was marked for harvest, representing nearly 50 percent of the stand volume. The HC '82 cruise was stratified by species for both the harvest and leave stand. The cruise volumes were adjusted for each DBH class using the Formula conversion factors in Table 3. These adjustments increased the total stand volume by 0.3 percent, (Table 4). The percentage difference between the adjusted and unadjusted Formula Scibner volume is within the level of precision for the HC '82 cruise.

Table 4. Hare Creek 1982 timber cruise volumes adjusted using Formula Scribner conversion factors.

Species	Mean DBH (in.)	Formula Volume, bf/ac Unadjusted	Formula Volume, bf/ac Adjusted	Percentage Difference
		Leave Stand		
Redwood	25.7	24,982	25,016	+0.1%
Douglas-fir	28.6	15,014	15,075	+0.4%
Grand fir	29.3	412	415	+0.7%
		Take Stand		
Redwood	25.0	10,171	10,239	+0.7%
Douglas-fir	27.0	25,791	25,877	+0.3%
Grand fir	25.7	3,595	3,543	-1.4%
Total Stand	26.4	79,965	80,165	+0.3%

DISCUSSION

The Formula to Log Rule conversion factors are dependent on DBH class. The conversion factors are largest for those DBH classes less than 13 inches. This is a result of the relatively large percentage of volume of these trees in logs with a 6-inch scaling diameter. The difference, as shown in Table 1, between Formula and Log Rule volume for 6-inch logs is 66.7 percent. As trees of larger DBH are included in a cruise the effect of the extreme volume differences in small logs is reduced by the higher proportion of larger logs in the trees. The Formula conversion factors for trees with DBH classes over 15 inches never exceeds + or - 3 percent for the 16-foot log length base. The study data trees and HC '82 cruise were comprised of a large quantity of trees over 15 inches in DBH. This allowed the fluctuating differences between Formula and Log Rule volumes to outweigh the effects of the small DBH tree volumes.

In recognition of the differences between Formula and Log Rule volume values, some foresters have attempted to adjust timber cruises by applying a single Formula conversion factor for an entire stand or species of a stand. In these cases the conversion factors are selected based on the mean DBH for the stand or tree species. This practice of applying a conversion factor based on only the mean DBH should be avoided. If the HC '82 cruise was adjusted using the species mean DBH's, the entire cruise volume would decrease by 2 percent. This reduction was calculated by applying a single species conversion factor, from Table 3, to each species volume. However, the adjustments by DBH class result in an increase in volume of 0.3 percent, as shown in Table 4.

Tree volume tables can be constructed using Log Rule Scribner, thus eliminating the need for Formula conversion factors. However the use of Log Rule Scribner tree volume tables has inherent problems. The Log Rule log volumes are based on 1-inch log scaling diameter and do not allow for the use of tenth-inch diameter measurements. The use of Log Rule volume tables for growth and inventory plots measured in tenth-inch DBH classes could indicate disproportional jumps in volume resulting from relatively small increases in diameter.

CONCLUSION

Adjusting forest stand cruise volumes to compensate for the difference between Formula and Decimal C Scribner volumes appears to be of little importance for timber cruises composed of a wide range of DBH classes. The use of Formula conversion factors can be of value for the calculation of delivered mill volume for young growth thinnings when the majority of the trees removed are in DBH classes less than 15 inches or for those stands that have a narrow DBH range. Whenever correction factors are used, they must be applied by diameter class and not the average stand diameter.

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