FOREST RESEARCH REPORT

Honer's Standard Volume Table Estimates Compared to Nova Scotia Stem Analyses

Introduction

One commonly used method of estimating tree volume in Nova Scotia, is with Honer's standard volume tables. These tables list total and merchantable volume by diameter and height for several tree species found in Eastern Canada. They were originally developed in imperial units (Honer, 1967) and later converted for use when measuring in metric units (Honer *et al*, 1983). How accurate are these tables for trees grown in Nova Scotia? Which estimates are best for species found in Nova Scotia but not included in Honer's tables? To help answer these questions, Honer's estimates for total and merchantable volumes were compared with actual volumes determined by stem analyses for trees in Nova Scotia.

Methods

The stem analyses data used for comparison were taken from various trials carried out by the Research Section of the Nova Scotia Department of Natural Resources. The locations of these trials are shown in Figure 1.

Two hundred and two softwood trees were measured at 9 of these locations (Appendix Ia). They consisted of mature co-dominant and dominant balsam fir (*Abies balsamea* (L.) Mill.), red spruce (*Picea rubens* Sarg.), black spruce (*Picea mariana* (Mill. B.S.P.), red pine (*Pinus resinosa* Ait.), white pine (*Pinus strobus* L.), jack pine (*Pinus banksiana* Lamb.) and larch (*Larix laricina* (Du Roi) K. Koch). They ranged in age from 38 to 92
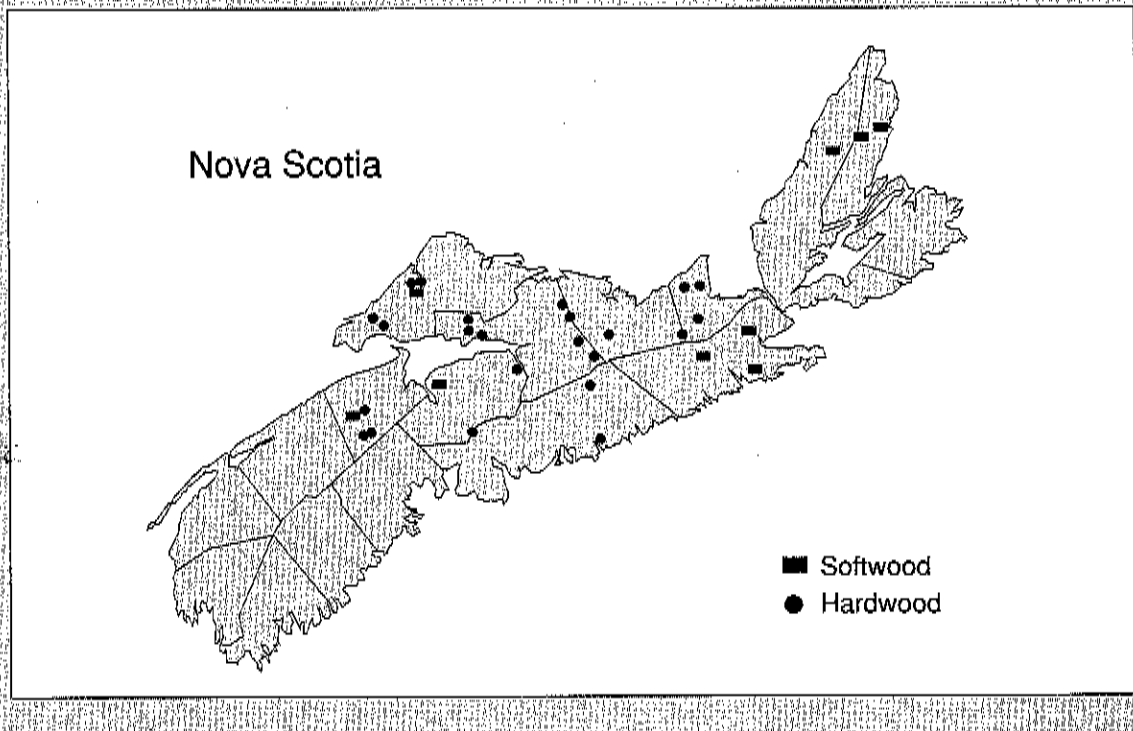
Canadä

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Figure 1. Location of softwood (-) and hardwood (•) stands where trees were measured for stem analyses.

years, spanned 10 to 33 cm in Diameter at Breast Height (DBH), and 9.2 to 19.4 metres in height (Table 1). Four hundred and seventy-nine hardwood trees were measured at 23 locations (Appendix Ib). They were dominant, mature red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), trembling aspen (*Populus tremuloides* Michx.), white ash (*Fraxinus americana* L.), white birch (*Betula papyrifera* Marsh.) and yellow birch (*Betula alleghaniensis* Britton). They ranged in age from 40 to 96 years, 13 to 34 cm in DBH, and 11.4 to 24.0 metres in height (Table 1).

Stem analyses consisted of cutting each tree into 1 m or 4 ft sections and measuring inside bark diameter and bark thickness at stump height (15 cm or 6 inch[1]), breast height (1.3 m or 4.5 ft[1]) and the top end of each section. Individual tree total volume was determined by calculating the volume of the stump as a

cylinder, each section as a paraboloid frustum (Smalians formula) and the top as a paraboloid (Appendix II), (Husch *et al*, 1982). Tree volumes calculated from stem analyses will be referred to as "Actual" volumes.

"Estimated" total and merchantable volumes were calculated for each stem analysis tree using Honer's equations (Appendix II). These were compared with the corresponding actual volumes obtained by stem analysis, and averaged by species over all sites. Percent differences for individual trees were examined in relation to diameter with scatter graphs (Appendices III - VI).

In the case of larch and white ash, Honer does not provide volume estimates. In these cases, the actual volumes were compared to estimates for other native species. For larch, actuals were compared to other softwood species, and white ash were compared to other hardwoods.

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[1] These measurements spanned a 22 year period. Therefore, some data were collected in imperial units and some were collected in metric.

Table 1. Sample size, diameter, height and age of trees used in study.

Species	Sample Size	Description	Stump Diameter (cm)	DBH[1] (cm)	Top Merch[2] Diameter (cm)	Height (m)	Age (yrs)
Balsam Fir	80	Mean	23	18	7	13.3	57
		Min	11	10	6	9.2	38
		Max	34	27	9	17.4	92
Red Spruce	22	Mean	29	23	8	15.4	56
		Min	21	16	6	12.5	48
		Max	38	28	9	18.1	65
Black Spruce	10	Mean	25	20	8	15.0	51
		Min	21	18	7	13.5	49
		Max	26	21	9	16.8	53
Red Pine	50	Mean	31	25	8	15.6	59
		Min	22	18	6	12.7	39
		Max	46	33	10	19.4	76
White Pine	20	Mean	34	27	7	16.0	53
		Min	25	20	6	13.2	46
		Max	46	33	9	18.6	59
Jack Pine	10	Mean	20	17	8	13.4	45
		Min	15	13	7	11.7	43
		Max	25	21	9	15.0	47
Larch	10	Mean	22	17	8	16.7	51
		Min	17	14	7	15.9	47
		Max	25	19	9	17.7	54
Softwood	**202**	**Mean**	**26**	**21**	**8**	**14.6**	**56**
		Min	11	10	6	9.2	38
		Max	46	33	10	19.4	92
Sugar Maple	175	Mean	24	20	7	15.7	54
		Min	15	13	4	11.9	40
		Max	41	34	10	20.5	96
Red Maple	20	Mean	24	21	8	17.5	59
		Min	16	13	7	14.5	53
		Max	33	28	10	20.0	69
Yellow Birch	124	Mean	26	21	7	15.8	61
		Min	17	15	4	11.4	42
		Max	39	31	9	19.2	92
White Birch	20	Mean	22	17	8	14.7	54
		Min	18	15	6	12.9	49
		Max	26	19	9	16.4	59
White Ash	130	Mean	27	23	7	19.0	62
		Min	18	16	5	14.6	45
		Max	43	34	9	24.0	94
Trembling Aspen	10	Mean	24	22	8	16.3	48
		Min	19	19	7	14.4	44
		Max	27	24	9	18.3	51
Hardwood	**479**	**Mean**	**25**	**21**	**7**	**16.6**	**58**
		Min	15	13	4	11.4	40
		Max	43	34	10	24.0	96
All	**681**	**Mean**	**25**	**21**	**7**	**16.0**	**57**
		Min	11	10	4	9.2	38
		Max	46	34	10	24.0	96

[1] Diameter Breast Height outside bark.
[2] Diameter inside bark of top closest to 7 cm (metric measurements) or 3 in (imperial measurements).

Results

Total Volume

Honer's estimates of total volume for soft-woods average 3% lower than stem analysis volumes. Table 2 shows the average volumes and differences between estimated and actual by species along with their ranges. These average differences are relatively small ranging from 0 to 10%. The largest variation (-10% or 0.02 m²) is for a sample of 10 black spruce, however, the estimated volume of all 10 trees (Appendix III) fell within the range of accuracy determined by Honer (1967) when deriving his volume equations (± 17% at the 95% confidence level).

Since Honer did not provide equations to predict larch volumes, actuals were compared with estimates of other softwood species. The comparison indicates that the jack pine equation best predicts the actual total volume of larch (Figure 2, Appendix III) and is only 0.3% low on average for the 10-tree sample.

Like softwoods, the estimated total volumes of hardwoods are on average lower (Appendix IV) than the actuals. In the case of hardwoods, the volume is only 1% lower than the actuals (Appendix IV, Table 2, Figure 2). Trembling aspen shows the largest average deviation (8%), but again, all 10 trees are within the ± 17.9% accuracy for this species. White ash (not estimated by Honer) is best predicted by maple, providing estimates averaging 2% higher than actual total volume.

Only 3 of the 681 trees in this study had total volume estimates that were outside of Honer's stated accuracy levels (Table 2).

Merchantable Volume

Merchantable volume is calculated in Honer's by multiplying the total volume estimate, as previously described, with an estimate of the ratio of merchantable to total volume.

As is the case for total volume, Honer's merchantable volume estimates are on average lower than actuals (Appendix V). The merchantable volume differences though, are greater than the total volume differences. Estimates for both the merchantable to total volume ratio and total volume are generally lower than actuals (Table 2 and Table 3), thereby compounding the differences between actual and estimated merchantable volume. The merchantable volume differences for softwoods average -5% (0.01m³) (Table 2) and range from -13% for the 10 black spruce to +2% for the 50 red pine (Figure 2). The merchantable volume estimate for larch is 2% low using jack pine.

The same patterns are evident when comparing hardwood merchantable volume. Overall, Honer's equations underestimate the merchantable volume of hardwoods by 8%. Differences range from +6% for trembling aspen (n=10) to -15% for both yellow birch (n = 124) and white birch (n = 17) (Table 2, Appendix VI). Honer's estimate of merchantable volume of white ash, averages 5% low using "Maple" coefficients.

Only 3 of the 681 trees in this study had merchantable volume estimates that were outside of Honer's stated accuracy levels (Table 2).

Table 2.   Comparison of actual and estimated volumes.

Species	Honer Species Coefficients[1]		Description	Total Volume			Honer Equation Accuracy[3]% (Trees[4] %)	Merchantable Volume			Honer Equation Accuracy% (Trees[4] %)
	Total Volume	Merchantable Ratio		Stem Analyses (m³)	Honer (m³)	Difference[2] (%)		Stem Analyses (m³)	Honer (m³)	Difference[2] (%)	
Balsam Fir	Balsam Fir	Balsam Fir	Mean	0.185	0.180	-2.0	±17.8 (98)	0.173	0.164	-5.0	±20.9 (98)
			Min	0.037	0.034			0.025	0.023		
			Max	0.388	0.368			0.374	0.342		
Red Spruce	Red Spruce	Red Spruce	Mean	0.310	0.309	0.6	±13.6 (100)	0.294	0.292	-0.4	Not tested
			Min	0.131	0.127			0.121	0.116		
			Max	0.524	0.479			0.501	0.459		
Black Spruce	Black Spruce	Black Spruce	Mean	0.225	0.203	-9.8	±17.0 (100)	0.213	0.186	-12.9	±20.7 (100)
			Min	0.181	0.167			0.173	0.153		
			Max	0.261	0.241			0.249	0.225		
Red Pine	Red Pine	Red Pine	Mean	0.354	0.364	2.3	±17.3 (100)	0.339	0.346	1.6	±22.5 (100)
			Min	0.187	0.180			0.176	0.169		
			Max	0.581	0.614			0.555	0.588		
White Pine	White Pine	White Pine	Mean	0.441	0.422	-3.8	±16.5 (95)	0.422	0.402	-4.7	±24.6 (100)
			Min	0.201	0.209			0.193	0.197		
			Max	0.770	0.730			0.750	0.703		
Jack Pine	Jack Pine	Jack Pine	Mean	0.165	0.156	-5.4	±15.5 (100)	0.152	0.139	-9.4	±24.4 (90)
			Min	0.085	0.075			0.077	0.055		
			Max	0.275	0.244			0.258	0.225		
Larch	Jack Pine	Jack Pine	Mean	0.174	0.174	-0.3	±15.5 (100)	0.160	0.156	-2.6	±24.4 (100)
			Min	0.119	0.110			0.105	0.095		
			Max	0.204	0.219			0.193	0.200		
Softwood			**Average**	**0.266**		**-2.6**		**0.252**		**-4.8**	
Sugar Maple	Maple	Hardwood[5]	Mean	0.222	0.209	-5.8	±30.3 (100)	0.211	0.185	-12.2	±37.6 (100)
			Min	0.093	0.071			0.085	0.058		
			Max	0.778	0.701			0.756	0.632		
Red Maple	Maple	Hardwood[5]	Mean	0.260	0.258	-1.2	±30.3 (100)	0.243	0.227	-6.5	±37.6 (100)
			Min	0.091	0.088			0.074	0.070		
			Max	0.535	0.496			0.518	0.446		
Yellow Birch	Yellow Birch	Yellow Birch	Mean	0.244	0.233	-4.4	±34.3 (100)	0.231	0.196	-14.9	±39.2 (100)
			Min	0.103	0.100			0.093	0.082		
			Max	0.537	0.524			0.519	0.451		
White Birch	White Birch	White Birch	Mean	0.162	0.154	-4.9	±22.5 (100)	0.148	0.125	-15.1	±35.7 (100)
			Min	0.125	0.114			0.113	0.093		
			Max	0.215	0.197			0.204	0.160		
White Ash	Maple	Hardwood[5]	Mean	0.316	0.323	2.4	± 30.3 (100)	0.303	0.288	-4.7	±37.6 (100)
			Min	0.114	0.118			0.105	0.101		
			Max	0.796	0.832			0.770	0.750		
Trembling Aspen	Trembling Aspen	Poplar[5]	Mean	0.244	0.264	8.2	±17.9 (100)	0.230	0.244	5.8	±22.6 (100)
			Min	0.173	0.184			0.161	0.170		
			Max	0.334	0.352			0.317	0.327		
Hardwood			**Average**	**0.253**		**-1.0**		**0.240**		**-7.9**	
All			**Average**	**0.260**		**-1.8**		**0.246**		**-6.4**	

1. The species coefficients used to predict total volume and the merchantable to total volume ratio (from Honer's (1983) equations).
2. Difference is the average of individual-tree differences measured in percent.
3. Accuracy levels stated by Honer (1967) for his equations, based on the data used to derive them. For example, the balsam fir total volume estimates are accurate to ± 17.8%, 95 times out of 100.
4. The percent of trees from this study that were estimated by Honer's equations within his stated accuracy [see footnote (3)]. For example, the estimated total volume for 98% of the 80 balsam fir measured in this study were within Honer's stated accuracy of ± 17.8%.
5. Honer used the coefficients for "Hardwood" species to determine the merchantable ratio for maple and "Poplar" coefficients for trembling aspen merchantable ratios.
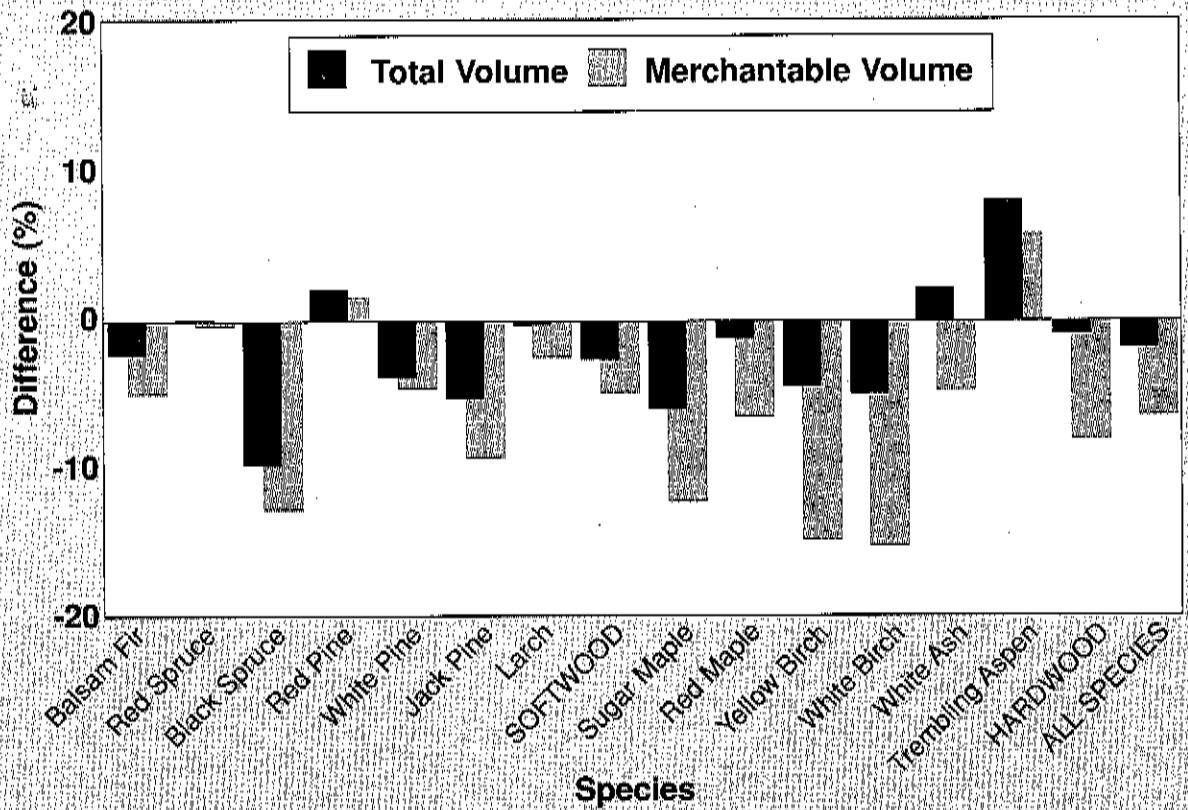
Figure 2. The average difference between actual and predicted volumes by species. Positive differences result when the estimates (predicted) are higher than actuals. Negative values result when estimates are lower than actuals.

Table 3. Average Merchantable to Total Volume Ratios[1] for actual and estimated volumes by species.

Species	Ratio[1] of MV/TV		
	Actual	Estimate	Difference[2] (%)
Balsam Fir	0.910	0.881	-2.9
Red Spruce	0.944	0.940	-0.5
Black Spruce	0.949	0.916	-3.3
Jack Pine	0.919	0.879	-4.0
Red Pine	0.956	0.949	-0.7
White Pine	0.956	0.947	-0.9
Eastern Larch	0.916	0.895	-2.1
Softwood	**0.932**		**-2.1**
Red Maple	0.919	0.869	-5.0
Sugar Maple	0.945	0.880	-6.5
Trembling Aspen	0.945	0.925	-2.1
White Ash	0.953	0.887	-6.6
White Birch	0.914	0.816	-9.8
Yellow Birch	0.941	0.837	-10.4
Hardwood	**0.944**		**-6.7**
Average	**0.938**		**-4.4**

[1] Ratio of merchantable volume over total volume; essentially gives percent of total volume which is merchantable wood; for example, .912 means 91.2% of balsam fir total volume is merchantable.
[2] Difference is the average of individual tree differences.

Conclusions/Recommendations

Honer's volume estimates were compared to stem analyses data from 202 softwood and 479 hardwood trees. This comparison shows that:

1. Averaging all species, Honer's tables (1967, 1983) underestimate total and merchantable volumes by 2% and 6% respectively.

2. For softwood species, total and merchantable volume estimates average 3% and 5% less than actuals respectively.

3. For hardwood species, total and merchantable volume estimates average 1% and 8% less than actuals.

4. Less than 1% of the estimates of total and merchantable volume were outside of the range of accuracy stated by Honer.

5. Continued use of Honer's Standard Volume tables, without adjustment is recommended.

6. For species that Honer (1967) does not provide equations; jack pine estimates should be used for larch and maple estimates for white ash.

It is cautioned that Honer's volume estimates should not be adjusted based on this sample. Numerical differences are presented to give an indication of the applicability of Honer's to Nova Scotia, but not to develop adjustments for these tables. Further sampling would be required to develop new tables or adjust the present ones.

Literature Cited

Honer, T.G. 1967. *Standard volume tables and merchantable conversion factors for the commercial tree species of central and eastern Canada.* For. Mgt. Res. Inst., Info. Rept. FMR-X-5, 78 pp.

Honer, T.G., M.F. Ker, and I.S. Alemdag. 1983. *Metric timber tables for the commercial tree species of central and eastern Canada.* Info. Rept. M-X-140, 139 pp.

Husch, B., C.I. Miller and T.W. Beers. 1982. *Forest mensuration* 3rd edition, Toronto, John Wiley & Sons, 410 pp.

Appendix Ia. Location and sample size of softwood trees by species.

Location, County	Balsam Fir	Red Spruce	Black Spruce	Red Pine	White Pine	Jack Pine	Larch	Softwood
Chignecto, Cumberland	10	10	10	10	10	10	10	70
Three Corner Lake, Guysborough	15							15
Aspen, Guysborough	12	3						15
Moshers Lake, Guysborough	31							31
Stanley, Hants					30			30
Fielding Road, Inverness	5							5
Lake George, Kings		9		10	10			29
Mariana Road, Victoria	5							5
Wreck Cove, Victoria	2							2
Total	80	22	10	50	20	10	10	202

Appendix Ib. Location and sample size of hardwood trees by species.

Location, County	Red Maple	Sugar Maple	White Birch	Yellow Birch	White Ash	Trembling Aspen	Hardwood
Browns Mountain, Antigonish		19		9			28
Mayfield, Antigonish		19		10			29
Sylvan Mountain, Antigonish		9					9
Bass River, Colchester		10		9	10		29
Dickey Lake Road, Colchester				7			7
Earltown, Colchester		10					10
Economy Lake, Colchester		10					10
Gully Lake Road, Colchester		10					10
Riversdale, Colchester				10			10
Simpson Lake, Colchester		8					8
Chignecto, Cumberland	10	10	10		10		40
Maybe Road, Cumberland		10			20		30
Twelve Mile Road, Cumberland					10		10
Welton Lake, Cumberland		20		10			30
Lake Charlotte, Halifax				10			10
Lewis Lake, Halifax				40			40
Sherlock Lake, Halifax		10		9			19
Georgefield, Hants				10			10
Lake George, Kings	10		10		10	10	40
Chain Lake, Kings					60		60
Mistake Lake, Kings					10		10
Greens Brook, Pictou		20					20
Lorne, Pictou		10					10
Total	20	175	20	124	130	10	479

Appendix II

Formulas

Actuals (Stem Analyses)

Cylinder:
$$V \quad = \quad A_t * h$$
where,

A_t = Area of the top of the stump, and

h = height of the stump.

Paraboloid frustrum (Smalian's Formula):
$$V \quad = \quad ((A_b + A_t)/2) * h$$
where,

A_b = area of the bottom of the section,

A_t = area of the top of the section, and

h = section length.

Paraboloid:
$$V \quad = \quad \tfrac{1}{2} * A_b * h$$
where,

A_b = area of the bottom of the top section, and

h = length of the top section.

Estimates (Honer)

When stem analysis measurements were taken in imperial units, Honer (1967) was utilized to make volume estimates. When these measurements were taken in metric units, Honer *et al* (1983) was used to estimate volume.

Imperial Estimates (Honer, 1967)

Total volume:

$$VTCF \quad = \quad (DBH_{4.5ob}{}^2/(a + (b/TH)))$$
where,

$VTCF$ = total volume in cubic feet,

$DBH_{4.5ob}$ = diameter outside bark at 4.5 feet from mean ground level measured in inches,

$a\ \&\ b$ = species specific coefficients, and

TH = total height of tree measured in feet.

Merchantable volume:

$$VMCF = VTCF(a+bX+cX_2)$$

where,

VMCF	=	merchantable volume in cubic feet,
VTCF	=	total volume in cubic feet,
a ,b & c	=	species specific coefficients, and

$$X = (TOPD_{ib}/DBH_{4.5ob})^2 * (1.0+(StumpH/TH))$$

where,

$TOPD_{ib}$	=	top section diameter inside bark which was closest to 3 inches measured in inches,
$DBH_{4.5ob}$	=	diameter outside bark at 4.5 feet from mean ground level, measured in inches,
StumpH	=	stump height, measured in inches, and
TH	=	total height, measured in feet.

Metric Estimates (Honer *et al*, 1983):

If diameter and heights were measured in metric units, (diameter in centimetres at 1.3 m) the metric version of Honers (*et al*, 1983) standard volume tables were used. These tables make allowance for taper between the metric and imperial breast heights (1.3 m vs 4.5 ft), convert inputs from metric to imperial, calculate volume in imperial units according to the previous Honer's (1967) equations, and convert the result to cubic metres.

Appendix III. The difference between Actual and predicted **total softwood volumes** versus diameter. Points above the line have **estimated** volume greater than **actual**, while trees represented by points below the line have **estimated** volume less than the **actual.**
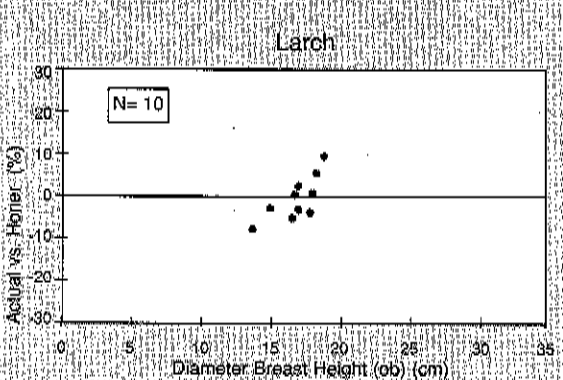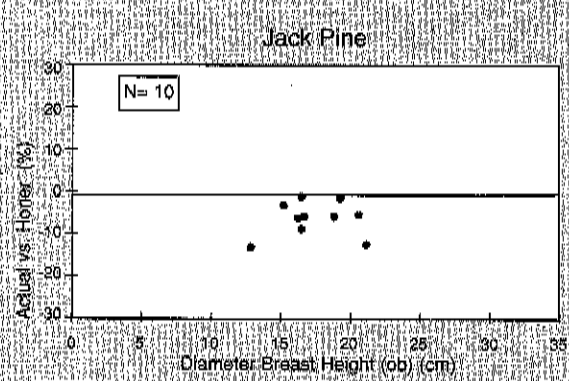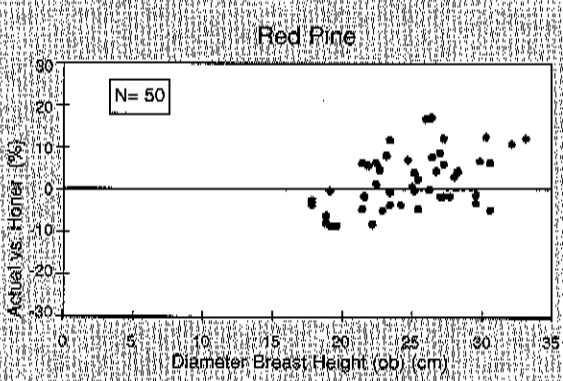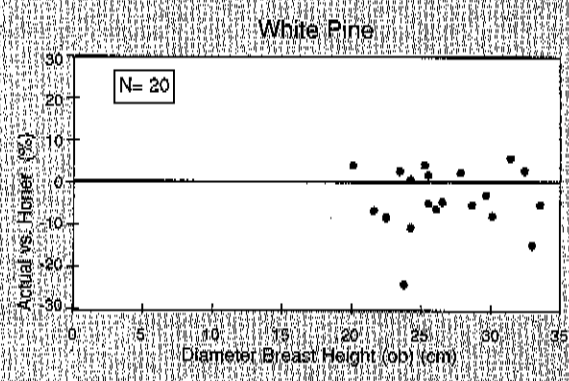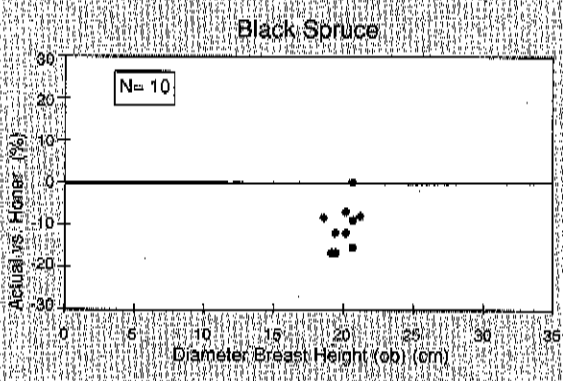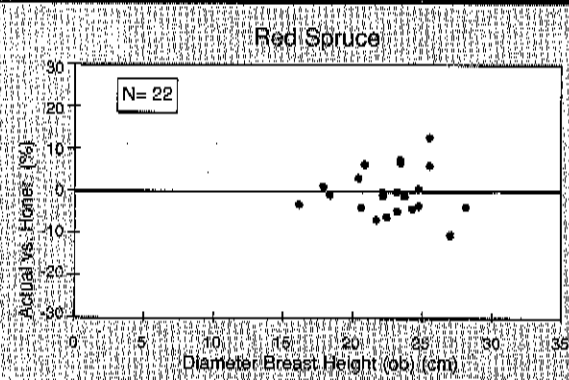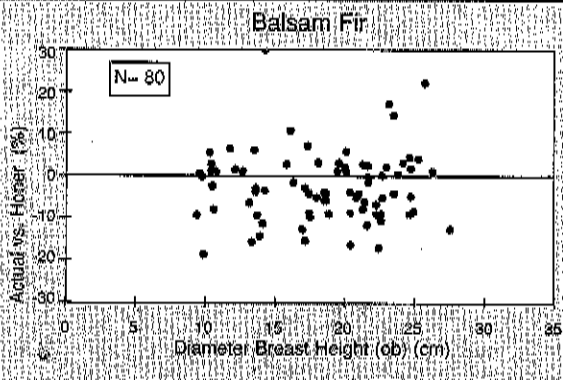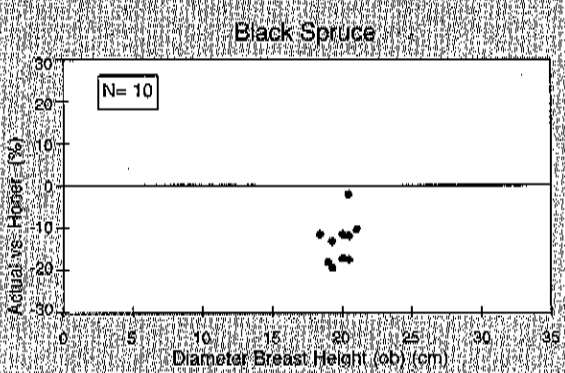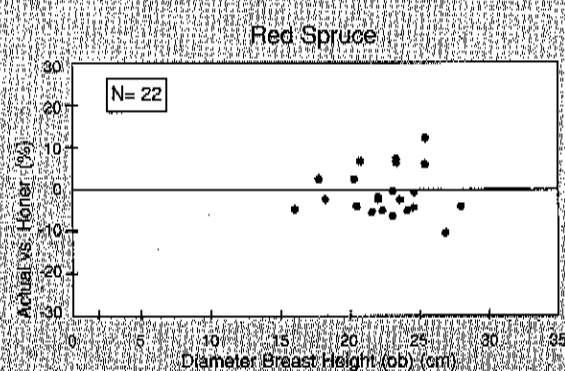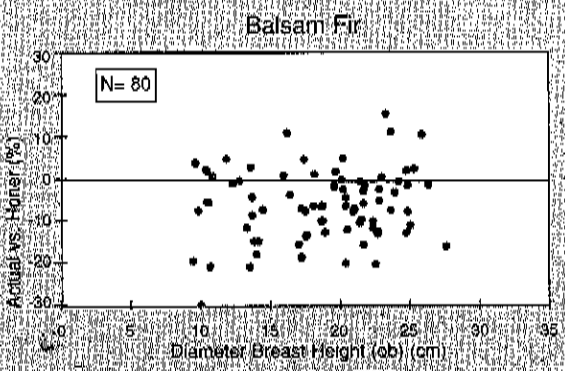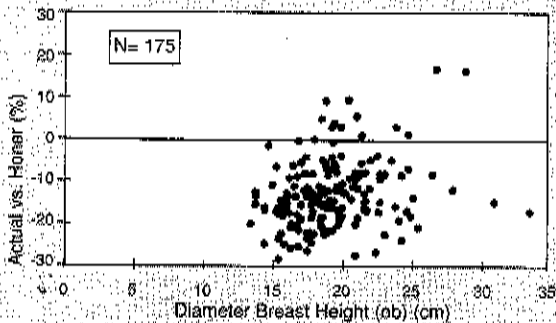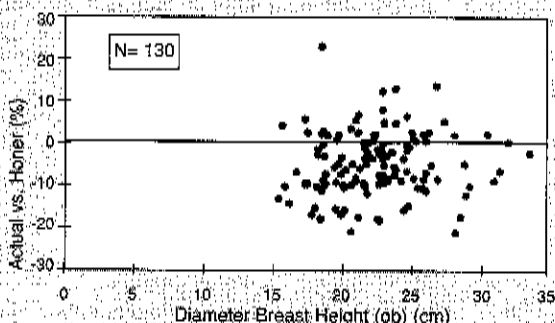
The difference between Actual and predicted **merchantable hardwood volumes** versus diameter. Points above the line have **estimated** volume greater than **actual**, while trees represented by points below the line have **estimated** volume less than the **actual**.
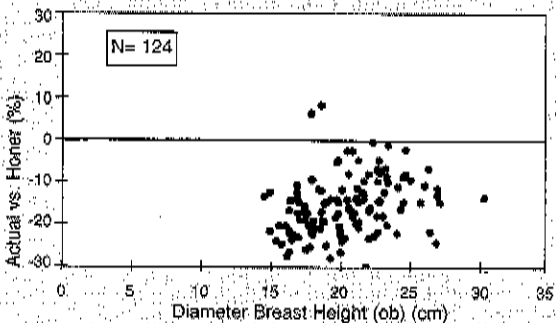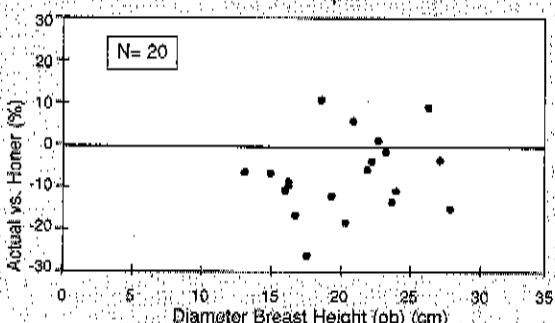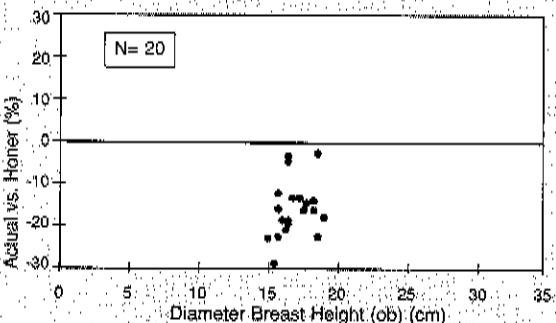
Balsam Fir — N= 80 (Actual vs. Honer (%) vs. Diameter Breast Height (ob) (cm))

Red Spruce — N= 22 (Actual vs. Honer (%) vs. Diameter Breast Height (ob) (cm))

Black Spruce — N= 10 (Actual vs. Honer (%) vs. Diameter Breast Height (ob) (cm))

White Pine — N= 20 (Actual vs. Honer (%) vs. Diameter Breast Height (ob) (cm))

Red Pine — N= 50 (Actual vs. Honer (%) vs. Diameter Breast Height (ob) (cm))

Jack Pine — N= 10 (Actual vs. Honer (%) vs. Diameter Breast Height (ob) (cm))

Larch — N= 10 (Actual vs. Honer (%) vs. Diameter Breast Height (ob) (cm))

Sugar Maple — N= 175

White Ash — N= 130

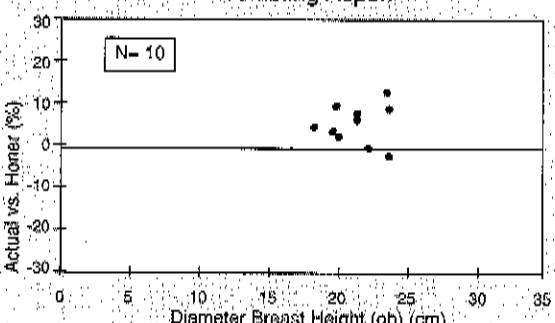Yellow Birch — N= 124

Red Maple — N= 20

White Birch — N= 20

Trembling Aspen — N= 10

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