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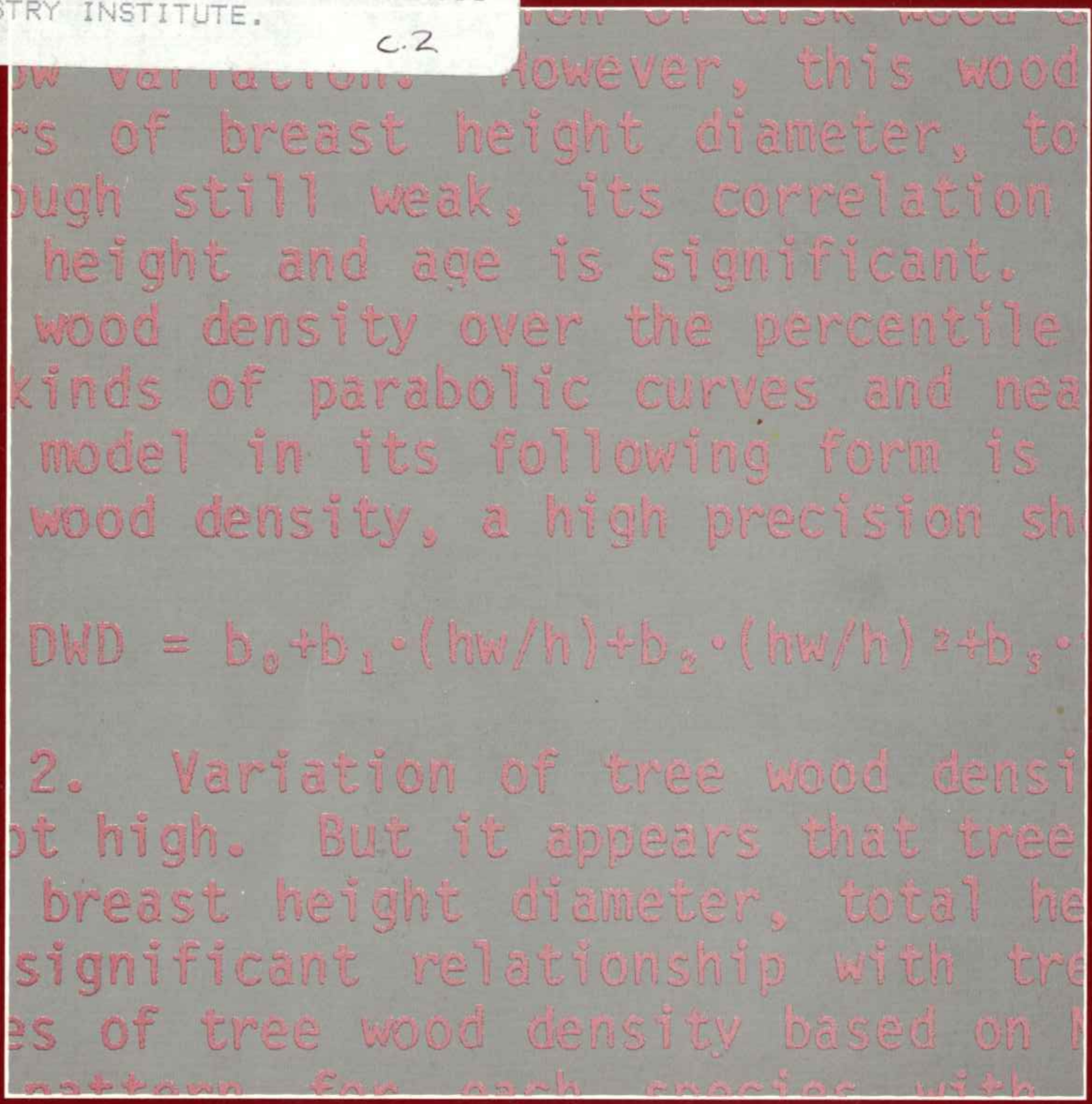
Wood density variation of 28 tree species from Ontario

I.S. Alemdag

Information Report PI-X-45
Petawawa National Forestry Institute



PETAWAWA NATIONAL FORESTRY INSTITUTE

The Petawawa National Forestry Institute (PNFI) was formed on April 1, 1979, as the result of an amalgamation of the Petawawa Forest Experiment Station with the Ottawa-based Forest Management and Forest Fire Research Institutes. The Forestry Statistics and Systems Branch was established at PNFI in 1980.

In common with the rest of the Canadian Forestry Service, the Petawawa National Forestry Institute has as its objective the promotion of better management and wiser use of Canada's forest resource to the economic and social benefit of all Canadians. Because it is a national institute, particular emphasis is placed on problems that transcend regional boundaries or that require special expertise and expensive equipment that cannot be duplicated in CFS regional establishments. Such research is often performed in close cooperation with staff of the regional centres or provincial forest services.

Research at the Institute is in two main areas:

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Through the FORSTATS program, which involves all regional establishments of the Canadian Forestry Service, the FSSB coordinates the acquisition and publication within the CFS of national statistics on the forest of Canada.

Every five years, the FSSB publishes Canada's Forest Inventory; the official report on the location, extent, species, and condition of the forest resource. In addition, the FSSB is working closely with the provinces to expand the information available on changes to the forest from fire, harvesting, insects and disease, and from forest management activities. This information is essential to the development of sound policies for the improved management of this important and renewable natural resource.

WOOD DENSITY VARIATION OF 28 TREE SPECIES FROM ONTARIO

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Contents

Abstract

The basic wood density at different heights along the stem and average basic wood density of stems were studied based on 1652 sample trees of 10 softwood and 18 hardwood species in Ontario. Some equation models were tested relating these variables to various tree characteristics. It was found that the relationships of disk and tree wood densities with measurable tree variables are very weak and developing reliable estimation equations are not easy. However, since variation on tree wood density was found to be small, average wood densities of each species can be used with confidence.

Résumé

Ont été étudiées la masse volumique basale du bois à différentes hauteurs ainsi que sa valeur moyenne pour la tige chez 1 652 arbres échantillons appartenant à 10 espèces résineuses et 18 espèces feuillues en Ontario. Quelques modèles d'équation exprimant ces variables en fonction de diverses caractéristiques des arbres ont été éprouvés. Les rapports entre la masse volumique à différentes hauteurs ou la masse volumique moyenne de la tige et des variables mesurables des arbres sont très faibles, et il n'est pas facile d'établir des équations d'estimation fiables. Toutefois, comme la variation de la masse volumique du bois des arbres est faible et fluctue dans un intervalle étroit, les masses volumiques moyennes pour chaque espèces peuvent être employées avec confiance.

WOOD DENSITY VARIATION OF 28 TREE SPECIES FROM ONTARIO

INTRODUCTION

The most comprehensive definition of wood density is by Elliott (1970) who observed that this physical wood property "...is not a simple characteristic, but is a complex of the effect of several growth and physiological variables compounded into one fairly easily measured wood characteristic. In its most straightforward interpretation, wood density is an excellent index of the amount of wood substance contained in a dry piece of wood, and, as such, (1) it is a good indicator of strength properties of wood, (2) it has often been strongly related to the general quality of wood, and (3) it is frequently correlated with pulp yield. To the wood technologist, wood density is important since an increase in its value can result in higher timber strength and a greater yield of pulp. To the forester, wood density is of interest since it is known to be strongly influenced by the growing conditions of the tree, thus providing a potential means of controlling the nature of raw material."

Wood density is the simplest and most useful index to the suitability of wood for many important uses (Wahlgren et al. 1966) and it is directly related to the caloric content of wood (Harrington and DeBell 1980). When the ovendry mass of wood is to be calculated from the volume of wood, variations in wood density in different species become important, and when variations with height in the bole are also considered, additional information becomes available for further evaluation in planning multiple product utilization (See et al. 1974). In the absence of biomass estimation equations, wood density is the only means for calculating the ovendry mass of the tree stems by their volumes.

Wood density has been widely studied over the years. Its rather complex relationships with age, diameter, height, radial growth, geographical locations, site and other growing conditions, silvicultural treatments and source of seed were investigated for several tree species growing in plantations or in natural stands. However, in only a few of the studies were the relationships of wood density to these various factors mathematically formulated. Spurr and Hsiung (1954) and Elliott (1970) present comprehensive summaries regarding such relationships.

The species of eastern Canada were investigated by Kennedy et al. (1968), of western Canada by Smith (1970), and of the Prairie provinces by Singh (1984) in order to obtain reliable information on their average tree wood densities. Jessome (1977) in his study of the wood properties of Canadian species included average wood densities of several Ontario species.

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Hale and Prince (1940) investigated density in relation to rate of growth in the spruces and balsam fir of eastern Canada. Heger (1974 a,b) presented the variation of wood density with height for black spruce and balsam fir growing in Quebec and for open- and forest-grown balsam fir in Ontario. Scott et al. (1982) examined the influence of fertilization and thinning on plantation jack pine wood density in Ontario. Because several other softwood and hardwood species are yet to be investigated in Ontario, the aim of the present study was to examine and, if possible, mathematically express (1) longitudinal variation of wood density within the stem of the same species, (2) variation of tree wood density between the stems of the same species, and (3) variation of average tree wood density among the species.

The present report deals with basic wood density. By definition it is the ratio of ovendry mass of wood to its green volume, expressed in terms of mass per unit volume; in the present study, kg/m^3.

The 28 tree species (10 softwoods and 18 hardwoods) studied in this report are listed at the end of the report.

DATA

Wood density data were collected from a full range of sites in Ontario. After each tree was felled, four disks 3 cm-4 cm in thickness were cut from the stem (Figure 1): at breast height and at 1/3, 2/3, and top of the merchantable height (where diameter outside bark is 9.1 cm). These disks were processed at the laboratory where average diameter of each disk (inside- and outside-bark) was measured, and a wedge of the most uniform wood cut from each disk. The density of the wedge was determined by the water immersion method as described in the Technical Association of the Pulp and Paper Industry (TAPPI) paper (1953)[1]. The wedge was ovendried at 105°C and measurements taken of the mass of the wood to 0.1 g and the volume of the wedge to 0.1 cm^3.

The wood density at different heights up the stem (hereafter called disk wood density, DWD) was calculated by dividing wedge ovendry mass in grams by the wedge volume in cubic centimetres and then multiplying by 1000. After this was done, the average wood density of the stem wood (hereafter called tree wood density, TWD) was calculated as a weighted average of the four disk densities, the weighting factor being the square of the inside-bark diameter of the disks.

The summary of data regarding sample tree sizes and ages is provided in Table 1, and disk and tree wood densities in Table 2.

METHODS OF ANALYSIS

When dealing with a large number of species it is impractical to study each species in depth for the preliminary tests. It is preferable to examine a few species first and then to run further tests in order to understand the behaviour of a particular relationship, and to relate it to studies made earlier on

[1]A more recent version of this paper was published in 1976, bearing the number T258 os-76.

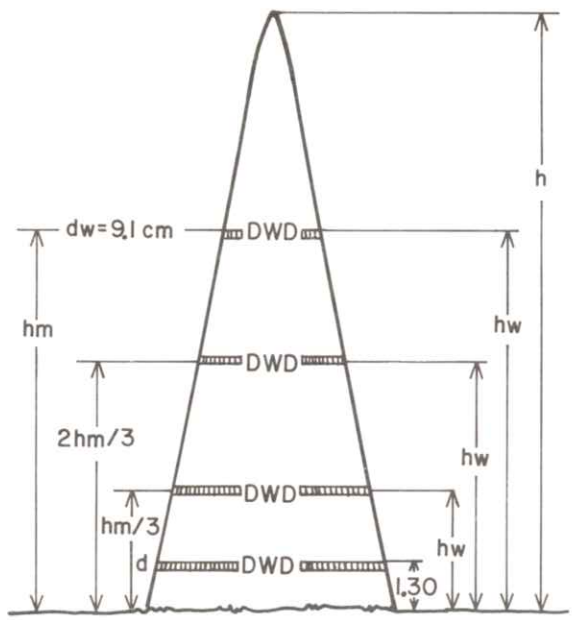

Figure 1. Schematic description of the data collected.

the same subject. For these initial investigations two softwoods, eastern white pine and white spruce, and two hardwoods, trembling aspen and sugar maple, were chosen as test species.

First, wood density at different heights on the stem and average wood density of the stem were computer plotted over the following variables: diameter at breast height (outside bark, d), total height (h), total age (t), tree size ($d^2 \cdot h$), disk height (hw), relative disk height or disk height per unit of tree height (hw/h), disk diameter (outside bark, dw), and relative disk diameter or disk diameter per unit of breast height diameter (dw/d).

Examination of the distributions of points in these diagrams suggested some regression models of which the most logical are in Table 3. The relationships for disk wood density and tree wood density were then tested, and the models which performed best were applied to all of the species covered in this report. The criteria for determining the best models were the coefficient of multiple determination (R^2) and the standard error of estimate as a percent of the mean (SEE%) produced by each model.

RESULTS AND DISCUSSIONS

Within-tree variation

Several researchers have attempted to explain the magnitude of the longitudinal distribution of wood density within the stem for various species growing under different conditions in different regions. Their explanations have been quite diverse. It is perhaps true from a mensurational point of view that there is no constant pattern regarding axial variation, as there is, for instance, in the height/diameter or diameter/age relationships. Relation of disk wood density to tree size or to tree size combined with other variables

Table 1. Summary of sample tree data

Species	Number of trees	d(cm) Mean	d(cm) Range	h(m) Mean	h(m) Range	t(years) Mean	t(years) Range
			Softwoods				
Cedar, eastern red	16	18.6	10.8 - 38.2	9.19	6.30 - 12.80	54	35 - 64
Cedar, eastern white	66	22.7	10.2 - 38.8	13.02	8.30 - 19.00	97	41 - 197
Fir, balsam	17	15.5	11.5 - 21.5	15.22	9.00 - 18.10	59	33 - 92
Hemlock, eastern	122	29.6	10.2 - 51.4	16.72	5.17 - 26.50	130	60 - 308
Pine, eastern white	128	34.5	9.9 - 68.7	21.13	5.40 - 35.90	90	19 - 255
Pine, jack	69	16.6	10.2 - 26.8	17.78	11.90 - 23.50	-	-
Pine, red	94	29.0	10.3 - 55.1	18.44	7.10 - 34.35	74	18 - 253
Spruce, black	39	13.4	9.4 - 22.2	13.35	8.20 - 18.90	-	-
Spruce, white	56	16.7	9.9 - 35.8	13.89	6.20 - 23.20	-	-
Tamarack	60	20.8	10.3 - 33.8	19.93	11.05 - 26.70	78	28 - 124
			Hardwoods				
Ash, black	18	18.31	10.1 - 33.1	15.12	9.15 - 20.30	74	40 - 120
Ash, red	24	23.3	12.0 - 40.2	19.66	13.50 - 26.70	61	35 - 89
Ash, white	64	26.3	10.7 - 53.7	18.83	11.75 - 26.93	70	37 - 145
Aspen, largetooth	11	25.4	15.3 - 39.2	18.78	14.10 - 23.00	59	55 - 81
Aspen, trembling	28	21.8	10.3 - 41.8	20.07	14.30 - 26.80	50	20 - 90
Basswood	62	30.8	12.3 - 54.8	19.56	10.01 - 26.10	70	23 - 112
Beech, American	63	27.8	10.5 - 44.1	19.85	9.72 - 26.50	97	40 - 148
Birch, white	44	21.3	13.3 - 32.7	19.60	14.90 - 22.25	72	46 - 90
Birch, yellow	83	37.2	10.4 - 70.3	20.45	10.00 - 25.60	107	37 - 210
Cherry, black	64	26.1	9.5 - 49.6	18.55	8.35 - 25.92	55	26 - 91
Elm, white	68	23.0	11.3 - 55.2	14.64	7.96 - 23.24	63	26 - 129
Hickory	67	23.5	10.0 - 46.6	21.25	11.60 - 29.40	63	24 - 110
Maple, red	36	28.1	13.5 - 45.2	20.04	10.76 - 25.35	71	32 - 122
Maple, silver	31	27.4	13.3 - 45.3	21.99	14.15 - 26.38	41	28 - 58
Maple, sugar	86	31.4	10.0 - 57.8	19.71	9.86 - 26.41	80	34 - 139
Oak, red	100	25.6	10.1 - 53.3	16.64	9.92 - 23.00	70	35 - 101
Oak, white	49	28.5	9.9 - 74.3	13.02	5.00 - 21.50	81	17 - 127
Poplar, balsam	87	25.5	10.0 - 53.2	18.81	8.70 - 27.00	42	24 - 90

is reported as strong, weak, or nonexistent. The literature on this matter includes Spurr and Hsiung (1954), Zobel and McElwee (1958), Elliott (1970), Johnstone (1970), Okkonen et al. (1972), Cody (1972), Farr (1973), Maeglin (1973), Lenhart et al. (1977), and Taylor and Burton (1982).

A commonly accepted idea is that disk wood density varies on the stem with height, and more strongly with the relative disk height. It decreases upwards in the stem in pines (Jayne 1958, Conway and Minor 1961, Tackle 1962, Johnstone 1970, Markstrom and Yerkes 1972, Lenhart et al. 1977, and Scott et al. 1982). However, in spruces, this change is either inconsistent or nonexistent (Elliott 1970), or exhibits an increasing trend (Farr 1973). In

Table 2. Summary of disk and tree wood densities of sample trees

	Disk wood density (kg/m³)					Tree wood density (kg/m³)			
Species	Number of trees	Number of disks	Mean	Range+	CV* (%)	Number of trees	Mean	Range+	CV* (%)
				Softwoods					
Cedar, eastern red	16	64	438	367 - 542	7.3	16	437	391 - 472	5.3
Cedar, eastern white	66	264	319	247 - 420	10.3	66	311	257 - 371	7.4
Fir, balsam	17	68	340	273 - 398	7.9	17	341	299 - 370	6.7
Hemlock, eastern	122	488	404	211 - 790	14.9	122	406	336 - 677	11.3
Pine, eastern white	128	512	340	214 - 523	14.7	128	342	237 - 447	11.1
Pine, jack	69	276	411	308 - 531	9.2	69	418	371 - 483	6.2
Pine, red	94	376	359	213 - 543	14.8	94	372	270 - 477	12.1
Spruce, black	39	156	436	320 - 546	9.2	39	437	367 - 520	8.5
Spruce, white	56	224	382	293 - 524	9.9	56	383	314 - 476	9.1
Tamarack	60	240	487	382 - 612	9.2	60	494	436 - 565	6.3
				Hardwoods					
Ash, black	18	72	543	451 - 652	6.8	18	545	509 - 571	2.9
Ash, red	24	96	551	461 - 681	8.3	24	555	500 - 608	5.2
Ash, white	64	256	594	348 - 707	8.6	64	594	483 - 664	6.6
Aspen, largetooth	11	44	388	324 - 480	7.2	11	388	376 - 404	2.3
Aspen, trembling	28	112	387	295 - 507	12.4	28	387	313 - 469	11.6
Basswood	62	248	425	248 - 682	16.0	62	428	354 - 597	11.0
Beech, American	63	252	605	498 - 733	7.6	63	607	540 - 692	5.1
Birch, white	44	176	539	467 - 600	4.8	44	539	490 - 583	3.7
Birch, yellow	83	332	595	474 - 705	7.6	83	596	512 - 686	6.2
Cherry, black	64	256	568	238 - 721	8.8	64	569	494 - 647	5.1
Elm, white	68	272	579	491 - 708	7.9	68	580	512 - 676	7.2
Hickory	67	268	615	509 - 764	6.8	67	616	550- 673	3.9
Maple, red	36	144	581	479 - 702	7.7	36	588	521 - 655	5.1
Maple, silver	31	124	476	403 - 565	6.7	31	480	421 - 528	5.0
Maple, sugar	86	344	612	495 - 716	7.0	86	616	518 - 673	5.2
Oak, red	100	400	593	413 - 908	7.8	100	590	468 - 690	6.1
Oak, white	49	196	644	548 - 726	5.6	49	646	600 - 708	3.7
Poplar, balsam	87	348	357	286 - 462	7.3	87	354	304 - 412	5.4

*Coefficient of variation = standard deviation/arithmetic mean.
+In some species, the presence of a few very high or very low values resulted in the range being larger than expected.

Table 3. Regression models tested

Model No.	Model form
	For disk wood density
1	$DWD = b_0 + b_1 \cdot hw + b_2 \cdot dw + b_3 \cdot d + b_4 \cdot h$
2	$DWD = b_0 + b_1 \cdot hw + b_2 \cdot dw + b_3 \cdot (hw \cdot dw)$
3	$DWD = b_0 + b_1 \cdot (hw/h) + b_2 \cdot (hw/h)^2 + b_3 \cdot d + b_4 \cdot h$
4	$DWD = b_0 + b_1 \cdot (hw/h) + b_2 \cdot (dw/d) + b_3 \cdot d + b_4 \cdot h$
5	$DWD = b_0 + b_1 \cdot (hw/h) + b_2 \cdot (hw/h)^2 + b_3 \cdot t + b_4 \cdot t^2$
	For tree wood density
6	$TWD = b_0 + b_1 \cdot d + b_2 \cdot h + b_3 \cdot t$
7	$TWD = b_0 + b_1 \cdot d^2 + b_2 \cdot h + b_3 \cdot (d^2 \cdot h)$
8	$TWD = b_0 + b_1 \cdot (d^2 \cdot h) + b_2 \cdot (d^2 \cdot h)^2 + b_3 \cdot t + b_4 \cdot t^2$
9	$TWD = b_0 + b_1 \cdot (d^2 \cdot h) + b_2 \cdot t$
10	$TWD = b_0 + b_1 \cdot (\text{stem volume outside bark})$

some cases, such as demonstrated by Wahlgren et al. (1966) and Heger (1974 a,b), disk wood density forms a concave curve when plotted over the relative disk height.

In the present study, analysis of the test species, and later of the other species, indicated that the variation in disk wood density itself is not high (Table 2). For softwoods, the coefficient of variation varied from 7.3% to 14.9%; for hardwoods it was from 4.8% to 16.0%. However, distribution of disk wood density with regard to d, h, t, dw or hw was very scattered and difficult to put into a reliable mathematical formula. On the other hand, scatter diagrams of the disk wood densities over relative disk height for the four test species suggested some models, but these were not strongly marked and there was no consistent pattern for all the test species. The regression analyses of Models 1-5 indicated that the best combined predictors are relative disk height and age, although their correlations with disk wood density are still low.

Among the five models tested, Model 5 was found to be statistically the most satisfactory. A similar model has been used by Lenhart et al. (1977). This model, when used with each of the species in order to develop prediction equations for the wood density at various levels in the stem, produced relatively weak (e.g. white ash, American beech, hickory) or relatively strong (e.g. largetooth aspen, trembling aspen, red pine) relationships where R^2 ranged from only 0.005 to 0.555, and SEE% from 16.0 to 4.9. At the same time, for some species, t^2 produced unacceptable results. For a given age this model formed curves of concave type (e.g. eastern white pine), convex type (e.g. black cherry), decreasing convex type (e.g. silver maple), or increasing concave type (e.g. eastern white cedar).

Between-tree variation

Studies reported in the literature which provide a means of predicting average wood density of the stem based on tree dimensions and age as well as various other factors lead to diverse conclusions. However, there seems to be a consensus that tree wood density is highly variable and impossible to estimate with any degree of reliability. Although a few studies have demonstrated fairly strong relationship of tree wood density with various factors for some species - e.g. with growth rate (Hale and Prince 1940); with age and geographical location (Wheeler and Mitchell 1962)-its relationship is reported to be minimal and rather unpredictable with tree size and age by Farr (1973), See et al. (1974), Gilmore and Jokela (1978), and Harrington and DeBell (1980); with growth rate by Cockrell (1943), Harrington and DeBell (1980), and Taylor and Burton (1982); with site by Farr (1973), See et al. (1974), and Harrington and DeBell (1980); and with region and geographical location by Gilmore and Jokela (1978).

In the present study, examination of tree wood density showed a small variation between individual stems. As can be seen in Table 2, the coefficient of variation ranged from 5.3% to 12.1% in softwoods, and from 2.3% to 11.6% in hardwoods. But, when wood density was plotted against d, h, $d^2 \cdot h$, and t for the four test species, it was found that its variation over all of these independent variables was large. It was difficult to discover a mathematical model to fit this distribution. However, some models were tested for the estimation of tree wood density, and the most suitable are listed in Table 3.

Regression tests using these models indicated that the relationship between tree wood density and any of the above single variables is weak. The strongest variable-combinations were found to be d, h, and t (Model 6) for most of the species with an R^2 value from only 0.011 to 0.339 and a SEE% from 11.1 to 2.8; and $d^2 \cdot h$ and t (Model 9) for the rest of the species with an R^2 value from 0.044 to 0.575 and a SEE% from 8.0 to 2.2.

Inter-species variation

The average tree wood density varies with species because of the different anatomical characteristics of each species. Such variations are noted in the literature; for eastern Canada see, for example, Kennedy et al. (1968), and Jessome (1977). In addition to other wood properties, they list average wood densities of many eastern Canadian species.

In the present study, these wood densities were calculated for each species as being the arithmetic average of the tree wood densities (Table 2). They range from 311 kg/m^3 in eastern white cedar to 646 kg/m^3 in white oak. Some of them compare with the findings of Jessome (1977) and Kennedy et al. (1968) quite well (e.g. jack pine, eastern hemlock, largetooth aspen), whereas others do not (e.g. black ash, red ash, basswood) (Table 4). These disagreements may be due to different processing and calculation methods or to regional variation. Singh's (1984) ovendry wood densities (ovendry mass/ovendry volume) for Prairie species cannot be compared to the basic wood densities presented in this report.

The average tree wood density values presented here supersede all figures previously published by the present author (Alemdag 1981, 1982, 1983).

SUMMARY AND CONCLUSIONS

Based on 11 to 128 sample trees from each of 10 softwood and 18 hardwood species in Ontario, the results of this study can be summarized as follows:

1. The examination of disk wood density along the stem indicates a rather narrow variation. However, this wood density is not dependent on tree parameters of breast height diameter, total height, tree age, and disk height. Although still weak, its correlation with the combined variable of relative disk height and age is significant. Based on Model 5, the curve pattern of disk wood density over the percentile height for a given age is inconsistent: all kinds of parabolic curves and near-straight lines are present. Although this model in its following form is found to be best for the estimation of disk wood density, a high precision should not be expected:

$$DWD = b_0+b_1 \cdot (hw/h)+b_2 \cdot (hw/h)^2+b_3 \cdot t+b_4 \cdot t^2 \qquad \text{(Model 5)}$$

2. Variation of tree wood density among tree stems of the same species is not high. But it appears that tree wood density is not strongly correlated with breast height diameter, total height, and age. However, it has a poor yet significant relationship with tree size expressed as $d^2 \cdot h$. Prediction curves of tree wood density based on Models 6 and 9 illustrate a characteristic pattern for each species with regard to diameter, height, and age: decreasing, increasing, or remaining relatively horizontal. If developed,

Table 4. Comparison of basic wood densities of the present study with those reported by Jessome (1977), and Kennedy et al. (1968)

Species	Present study kg/m³	n*	Jessome kg/m³	n*	Kennedy et al. kg/m³	N+
			Softwoods			
Cedar, eastern red	437	16	-	-	-	-
Cedar, eastern white	311	66	299	19	306	44
Fir, balsam	341	17	335	26	329	571
Hemlock, eastern	406	122	404	31	356	166
Pine, eastern white	342	128	364	25	323	253
Pine, jack	418	69	421	25	397	95
Pine, red	372	94	392	25	357	67
Spruce, black	437	39	406	32	402	318
Spruce, white	383	56	354	43	353	204
Tamarack	494	60	485	11	447	47
			Hardwoods			
Ash, black	545	18	468	5	-	-
Ash, red	555	24	373	6	-	-
Ash, white	594	64	570	13	-	-
Aspen, largetooth	388	11	390	10	-	-
Aspen, trembling	387	28	374	20	-	-
Basswood	428	62	360	4	-	-
Beech, American	607	63	590	17	-	-
Birch, white	539	44	506	16	-	-
Birch, yellow	596	83	559	25	-	-
Cherry, black	569	64	510	5	-	-
Elm, white	580	68	524	23	-	-
Hickory	616	67	628	5	-	-
Maple, red	588	36	516	6	-	-
Maple, silver	480	31	461	5	-	-
Maple, sugar	616	86	597	19	-	-
Oak, red	590	100	-	-	-	-
Oak, white	646	49	654	5	-	-
Poplar, balsam	354	87	372	10	-	-

*Number of trees.
+Number of specimens.

these equations should be used with caution. The forms of these two models are as follows:

$$TWD = b_0+b_1 \cdot d+b_2 \cdot h+b_3 \cdot t \quad \text{(Model 6)}$$

$$TWD = b_0+b_1 \cdot (d^2 \cdot h)+b_2 \cdot t \quad \text{(Model 9)}$$

3. The average wood densities calculated for all species regardless of tree dimensions or tree age vary between 311 kg/m³ and 494 kg/m³ in softwoods, and between 354 kg/m³ and 646 kg/m³in hardwoods. Because tree wood density did not show a consistent pattern of change with d, h, and t, it suggested that the average wood densities can be used quite reliably for every size and age of a tree for any species. Their main application will be in the the estimation of ovendry mass of stem wood by the stem's inside-bark volume in the availability of tree dimensions but the absence of biomass prediction equations based on tree dimensions, or vice versa.

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LIST OF THE SPECIES STUDIED

Softwoods

Cedar, eastern red	*Juniperus virginiana* L.
Cedar, eastern white	*Thuja occidentalis* L.
Fir, balsam	*Abies balsamea* (L.) Mill.
Hemlock, eastern	*Tsuga canadensis* (L.) Carr.
Pine, eastern white	*Pinus strobus* L.
Pine, jack	*Pinus banksiana* Lamb.
Pine, red	*Pinus resinosa* Ait.
Spruce, black	*Picea mariana* (Mill.) B.S.P.
Spruce, white	*Picea glauca* (Moench) Voss
Tamarack	*Larix laricina* (Du Roi) K. Koch

Hardwoods

Ash, black	*Fraxinus nigra* Marsh.
Ash, red	*Fraxinus pennsylvanica* Marsh.
Ash, white	*Fraxinus americana* L.
Aspen, largetooth	*Populus grandidentata* Michx.
Aspen, trembling	*Populus tremuloides* Michx.
Basswood	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Birch, white	*Betula papyrifera* Marsh.
Birch, yellow	*Betula alleghaniensis* Britton
Cherry, black	*Prunus serotina* Ehrh.
Elm, white	*Ulmus americana* L.
Hickory	*Carya* Nutt. spp.
Maple, red	*Acer rubrum* L.
Maple, silver	*Acer saccharinum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, red	*Quercus rubra* L.
Oak, white	*Quercus alba* L.
Poplar, balsam	*Populus balsamifera* L.