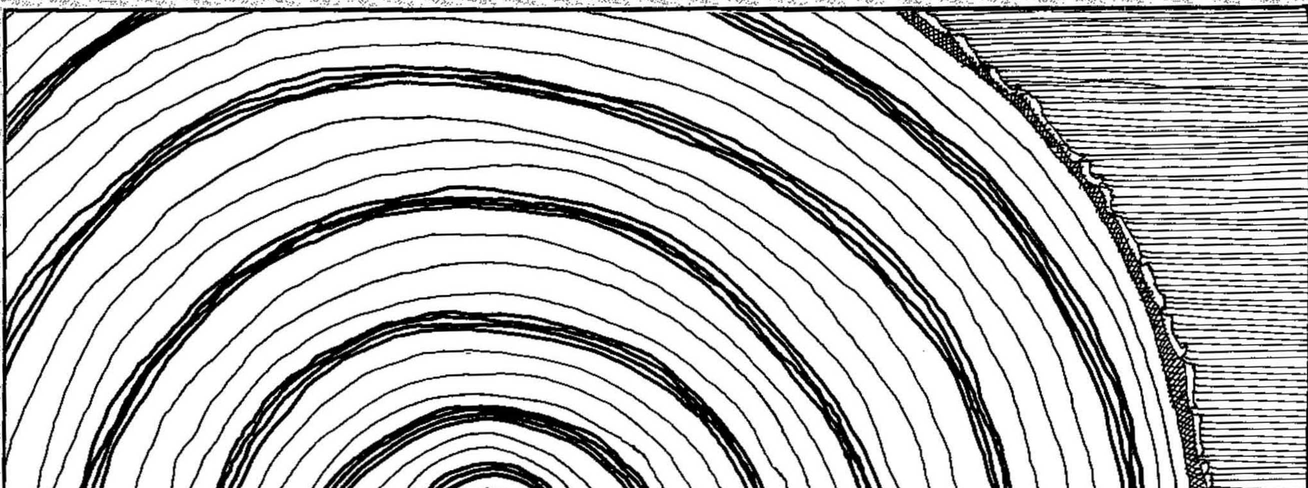
Wood density of Canadian tree species

J.S. Gonzalez

Northwest Region • Information Report NOR-X-315



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Regional activities are directed from the Northern Forestry Centre in Edmonton, Alberta, and there are district offices in Prince Albert, Saskatchewan, and Winnipeg, Manitoba. The Northwest Region is one of six regions and two national forestry institutes of Forestry Canada, which has its headquarters in Ottawa, Ontario.

Forêts Canada, région du Nord-Ouest, représents le gouvernement fédéral en Alberta, en Saskatchewan, au Manitoba et dans les Territoires du Nord-Ouest en ce qui a trait aux recherches forestières, à l'aménagement du territoire et au transfert de technologie. Cet organisme s'intéresse surtout à la recherche et à l'aménagement du territoire en vue d'améliorer l'aménagement forestier afin que tous les Canadiens puissent en profiter aux points de vue économique, social et environnemental. Le bureau de la région du Nord-Ouest est également responsable de la mise en oeuvre des ententes forestières fédérales-provinciales au sein de ces trois provinces et du territoire concerné.

Les activités régionales sont gérées à partir du Centre de foresterie du Nord dont le bureau est à Edmonton (Alberta); on trouve également des bureaux de district à Prince Albert (Saskatchewan) et à Winnipeg (Manitoba). La région du Nord-Ouest correspond à l'une des six régions de Forêts Canada, dont le bureau principal est à Ottawa (Ontario). Elle représente également deux des instituts nationaux de foresterie de ce Ministère.

WOOD DENSITY OF CANADIAN TREE SPECIES

J.S. Gonzalez[1]

INFORMATION REPORT NOR-X-315

FORESTRY CANADA
NORTHWEST REGION
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ABSTRACT

Total-stem and breast-height wood density data from published and unpublished sources are presented for Canadian tree species grown in and outside of Canada. Calculations for mean density and coefficient of variation were made when necessary. Variations, geographic sources, and characteristics of sample trees are included to assist the reader in making comparisons with the density values presented. Sampling locations, methods of sampling, and density calculations are described. To assist the reader in converting wood density values from green-volume to ovendry-volume basis, the conversion formula and a table of percent volumetric shrinkage are also presented.

RESUME

Les résultats d'une compilation des données disponibles, publiées ou inédites, sur la densité du bois, pour l'ensemble de la tige et à hauteur de poitrine, d'arbres canadiens poussant au Canada ou ailleurs sont présentés. Les moyennes et les coefficients de variation ont été calculés au besoin. Pour rendre les comparaisons plus faciles, les variations, les sources géographiques et les caractéristiques des arbres-échantillons sont indiqueés. Des détails sur les lieux et les méthodes d'échantillonnage ainsi que sur le calcul de la densité sont aussi inclus. Enfin, une formule de conversion et une table des pourcentages de retrait volumétrique sont fournies pour aider le lecteur à convertir les valeurs de la densité à l'état vert aux valeurs correspondants à l'état anhydre.

FOREWORD

ENFOR (ENergy from the FORest) is a contract research and development (R&D) program managed by Forestry Canada. It is aimed at generating sufficient knowledge and technology to realize a marked increase in the contribution of forest biomass to Canada's energy supply. The program was initiated in 1978 as part of a federal interdepartmental initiative to develop renewable energy sources.

The ENFOR program deals with biomass supply matters such as inventory, growth, harvesting, processing, transportation, environmental impacts, and socio-economic impacts and constraints. A technical committee oversees the program, developing priorities, assessing proposals, and making recommendations. Approved projects are generally carried out under contract.

General information on the operation of the ENFOR program, including the preparation and submission of R&D proposals, is available upon request from:

The ENFOR Secretariat
Forestry Canada
Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec
K1A 1G5

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NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by Forestry Canada.

INTRODUCTION

Density is one of the most important indicators of wood quality because of its relationship to other properties that make wood suitable for a variety of uses. The influence of density on the properties and uses of wood is well documented (Armstrong et al. 1984; Brazier 1972; De Montmorency 1965; Doucet et al. 1983; Einspahr et al. 1969).

Information on wood density is of value to both growers and users of wood. Wood density of trees along with estimates of wood volume allow users to predict the dry-weight productivity of a unit area of land or the productivity potential of a stand of trees. A good data base for wood density is essential in tree improvement programs because wood density, although a heritable trait, can be influenced by environmental factors or silvicultural treatments (Briggs and Smith 1986; Harris 1978; Paul 1963; Zobel and Rhodes 1955). For the pulp industry, where products are sold on a weight basis and yield is a major consideration, wood density is probably the most important characteristic of the raw material. In building designs, wood density is an important factor in the choices of structural material.

Many mechanical properties of wood are a function of wood density (Armstrong et al. 1984). The American Society for Testing and Materials therefore allows for establishment of clear wood strength values from density through previously established relationships between strength properties and relative density (American Society for Testing and Materials 1986).

Data on wood density are numerous. A wood density survey in the United States, initiated in 1960 in an effort to develop a tree quality rating system, has resulted in several publications (Maeglin 1973; Maeglin and Wahlgren 1972; Saucier and Taras 1969; U.S. Forest Service 1965; Wahgren et al. 1968). These and the earlier publication of Markwardt and Wilson (1935) comprise a rich source of density information on North American species.

In Canada, the most comprehensive sources of density data for native species are the bulletin by Jessome (1977), which was an update of earlier publications (Kennedy 1965; Kennedy et al. 1968), and the wood density survey of Canadian western species (Smith 1970). More recently, biomass evaluations of Canadian forests have resulted in several publications providing valuable wood density information (Alemdag 1984; Johnstone 1970; Singh 1984, 1986, 1987; Standish 1983).

The earliest studies on wood density of North American species evaluated the strength properties of clear wood samples and their related physical properties (Markwardt and Wilson 1935; Rochester 1933). Studies on individual species continued to add to the list (Gerhards 1965; Kennedy 1965; Littleford 1961; McGowan 1963; Snodgrass and Noskowiak 1968).

The objective of this report is to compile all wood density information available on Canadian species grown in Canada, the United States, and outside of North America, including relevant information on geographic origin and methods of sampling and analysis where available.

METHODS AND RESULTS

A literature search was done mainly through computer access to forestry data bases and through *Forestry Abstracts*. As well, letters requesting unpublished density data and inaccessible published literature were sent to researchers in countries known to grow Canadian species. The information received was not always complete and is presented here to the extent that it was provided.

The main sources of information from the United States are density survey reports. Thesis work and other university-supervised studies were excluded unless they had been published as journal articles. Data from European countries were fewer and less accessible; therefore, unpublished studies of even limited nature have been included. Because the focus of this publication is wood density of Canadian species, values obtained on similar species grown outside of Canada were not included unless corresponding values in Canada were available. Every effort was made to obtain values for Canadian-grown samples.

Requests for unpublished data were circulated to tree improvement workers, wood scientists, universities, and authors of forest biomass evaluations in Canada. For studies in which density values had not been calculated but raw data for estimating them were available, requests were made to have access to the raw data. Calculation of density and related statistics was undertaken as part of the present study.

The data are presented in Tables I and 2. Densities are usually expressed as basic density (ovendry weight/ green volume). Values based on air-dry (12% moisture content) and ovendry volumes are also given when available. A conversion formula using volumetric shrinkage to estimate density based on ovendry volume from density based on green volume is given in Appendix I, which also presents values of percent volumetric shrinkage for various species. Density variation expressed as coefficient of variation is based on either individual trees or individual specimens. In whole stem analyses, coefficient of variation is usually based on the number of trees; where density tests are made in conjunction with strength tests, coefficient of variation is usually based on individual specimens.

Table I presents values for stemwood density of softwoods and hardwoods; Table 2, for density obtained at breast height. The two values are not always comparable even for the same species. For example, the mean density derived from a whole-stem analysis of a species where density changes significantly from the butt to the top is not directly comparable to the breast-height value of that species. Also, values derived from whole disks and increment cores of a species, even if taken from the same breast height, may not be directly comparable. This is because pith-to-bark cores include juvenile wood, which may be significantly different in density from the mature wood (Jozsa and Kellogg 1986). Unless the total core density is based on the weighted average of the juvenile and mature wood density, and weighted in proportion to their volume as it occurs in the disk, the disk and the core density are not directly comparable. For this reason, methods of analysis and calculation of density have been included in this report when available.

Description of Sampling Location, Methods of Sampling, and Calculation of Density

The sampling location, methods of sampling, and calculation of density for each source of data given in the tables are presented in Appendix 2. This is intended to complement the information in the tables. The entries are listed in alphabetical order according to authors' names. Measurements had been converted to metric units in the sample descriptions.

Sampling techniques and methods of analyzing for wood density vary depending on objectives. Three methods of sampling have been generally used. They are as follows:

1. taking increment cores from standing trees at breast height;
2. felling the tree and taking whole cross sections of disks at fixed intervals along the stem; and
3. using clear wood samples in conjunction with the evaluation of strength and physical properties of wood. This method may sample from logs, planks, or dimensional lumber.

Increment core sampling is nondestructive and is generally preferred when the trees are being preserved for future use. It is a convenient method of evaluating a large number of standing trees, such as in a survey to measure geographic distribution and variation of density. Many studies (Brazier and Howell 1979; Pronin 1971; Taras and Wahlgren 1963; Wahlgren et al. 1966; Wahlgren and Fassnacht 1959) have shown a high correlation between breast-height and whole-tree densities, and it is for this reason that breast-height values are considered valid indicators of whole-tree density. In the same studies, regression equations have been developed relating breast-height core to whole-tree densities for various species. Based on these equations, whole-tree densities have been estimated from breast-height cores. In several commercial species, relative density was found to decrease generally with height in the tree (Okkonen et al. 1972). Thus, breast-height values will generally be higher than the estimated whole tree density.

Whole-stem analysis, or taking disk samples at fixed intervals along the stem, is usually done to examine the distribution of density within the stem or for a more representative sampling of the stem in the evaluation of whole-tree density. This method is used when developing a regression equation between breast-height core and whole-tree density. Sampling necessitates destruction of the tree. The disks taken from the different heights in the tree are evaluated for density, which is weighted according to the volume represented by the disks in the stem. The weighted average of these densities represents the whole-stem density.

Use of clear wood samples in conjunction with strength and physical test of wood species is a method described by the American Society for Testing and Materials (1989). The stem is cut into boles of prescribed length and one or two boles are randomly selected from each tree. The boles are cut into flitches or sticks of prescribed dimension on the cross section. Density is usually determined on samples also evaluated for shrinkage or on the same specimens tested for strength when the objective is to correlate the density with strength properties. The mean density is calculated as the arithmetic average of all individual observations. Values obtained from this method do not necessarily reflect the density of the whole stem.

When materials are obtained from sawmills or logging sites, test samples are usually cut from planks, logs, or dimension lumber, often without regard to which part of the merchantable bole the samples came from, or to the presence of knots and other defects. Because knots and injured wood tissues contribute to spurious wood density values, and wood density varies vertically and radially within a tree, sampling techniques will affect the density values obtained.

That wood density varies with geographic location, climate, age, position in the tree, and growth rate is now generally known (Chang and Kennedy 1967; Gilmore 1968; Gohre 1955; Hakkila and Panhelainen 1970; Hamilton and Knauss 1986; Heger 1974; Javadi et al. 1983; Johnstone 1970; McKimmy 1959; Sunley and Lavers 1961). Such information, important when comparing density data from different sources, is included here whenever available. When making comparisons, the reader should be aware of the factors that influenced the values presented in this report. Discussion of results of individual studies is outside the scope of this report.

ACKNOWLEDGMENTS

I wish to thank the numerous people and agencies that responded to our requests and willingly provided data: Alberta Forest Service, B.C. Ministry of Forests, New Zealand Forest Research Institute, Princes Risborough Laboratory (U.K.), G. Nepveu (France), A. Tunner of the B.C. Research Council, and many others whose contributions are acknowledged in the sources of data columns of Tables 1 and 2. I also wish to thank J. Richards and A. Sawadsky for providing technical support, C. Stieda for help in translation, R.M. Kellogg for support and encouragement, B. Britton for typing the manuscript, and (last but not least), J.M. Powell, Scientific Advisor for this project, for his support and understanding.

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Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
CEDARS									
Eastern red cedar (*Juniperus virginiana L.*)	**Canada** Ontario	16	54 (35 - 64)	18.6 (10.8 - 38.2)	9.2 (6.3 - 12.8)	437 (391 - 472)	5.3	green	Alemdag, 1984
	U.S.A. Vermont	5	------	------	------	440	---	green	Markwardt & Wilson, 1935
						490	---	ovendry	
						470	---	12% MC	
Eastern white cedar (*Thuja occidentalis L.*)	**Canada** Atlantic Provinces	(44)	------	------	------	306	11.4	green	Kennedy, *et al.*, 1968
	New Brunswick & Quebec	19 (76)	------	------	------	299	7.4	green	Jessome, 1977
		19 (38)	------	------	------	308	7.0	ovendry	Jessome, 1977
		19	------	------	------	302	---	12% MC	Jessome, 1977
	Ontario	66	97 (41 - 197)	22.7 (10.2 - 38.8)	13.0 (8.3 - 19.0)	311 (257 - 371)	7.4	green	Alemdag, 1984
	Finland Bromarv & Punkaharju	30	52.7 (52 - 53)[A]	12.3 (10 - 15)[A]	8.4 (7.6 - 9.1)[A]	328	7.1	green	Uusvaara & Pekkala, 1979
	U.S.A. Wisconsin	5	------	------	------	290	---	green	Markwardt & Wilson, 1953
						320	---	ovendry	
						310	---	12% MC	
Western red cedar (*Thuja plicata Donn*)	**Canada** British Columbia	(196)	------	------	------	345	10.1	ovendry	Hejja, 1986
		12 (407)	------	------	------	312	8.4	green	Jessome, 1977

[A] Range of site means

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
CEDARS									
Western red cedar (*Thuja plicata Donn*)	**Canada** British Columbia	12 (72)	------	------	------	338	7.8	ovendry	Jessome, 1977
		12	------	------	------	339	---	12% MC	Jessome, 1977
		50	------	------	------	329	9.1	green	Smith,1970
		65	73 (18 - 273)	21.4 (5.6 - 67.8)	13.3 (3.8 - 37.2)	342 (238 - 475)	13.6	green	Standish, 1983
	New Zealand South Island Conical Hill, Southland	12	66	28.7	28.9	320 (298 - 352)	---	green	Cown & Bigwood, 1979
	Mahinapua	6	------	------	------	315	---	green	
	Whakarewarewa	10	67	45.0	------	336	---	green	
	The Netherlands Veluwe	6	------	------	------	413	---	12% MC	Van der Zwan & Polman, 1988
	United Kingdom (9 sites)	90	(30 - 50)	------	------	320[B] (300 - 380)[A]	---	green	Brazier, 1973
	United Kingdom	10 (280)	------	------	------	310	11.3	green	Lavers, 1983
		10 (281)	------	------	------	330	10.6	12% MC	Lavers, 1983
	U.S.A. Alaska, Montana & Washington	15	------	------	------	310 340 330	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935

[A] Range of site means   [B] Calculated from site means

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Meandbh & range (cm)	Meanht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
CEDARS									
Western red cedar (*Thuja plicata Donn*)	**U.S.A.** Idaho, Montana, Oregon & Washington	504	------	53.6 (36.8 - 80.0)	------	317[c] (269 - 421)	---	green	Maeglin & Wahlgren, 1972
		34 (136)	------	62.0 (34.3 - 105.9)	------	306	8.9	green	Bendtsen, 1972
CYPRESS									
Yellow cypress (*Chamaecyparis nootka-tensis* (D. Don) Spach)	**Canada** British Columbia	(193)	------	------	------	453	9.0	ovendry	Hejja, 1986
		17 (463)	------	------	------	419	8.9	green	Jessome, 1977
		17 (102)	------	------	------	462	8.6	ovendry	Jessome, 1977
		17	------	------	------	431	---	12% MC	Jessome, 1977
		33	73 (25 - 214)	16.9 (8.2 - 42.4)	10.5 (5.2 - 30.2)	443 (239 - 544)	15.6	green	Standish, 1983
	U.S.A. Alaska & Oregon	8	------	------	------	420 460 440	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
DOUGLAS-FIR									
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	**Canada** British Columbia	24 (virgin) (894)	------	------	------	445 (323 - 615)	11.6	green	Drow, 1957
Coastal		14 (2nd growth) (357)	------	------	------	430 (313 - 557)	11.8	green	Drow, 1957
		(fast grown) 60	50 (33 - 71)	54.8 (36.6 - 75.0)	36.7 (27.5 - 47.6)	485 (405 - 550)	6.1	ovendry	Jozsa, *et al.*, 1989

c Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
DOUGLAS-FIR									
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	Canada British Columbia	(open-growth) 5	79 (76 - 81)	99.1 (94.0 - 104.1)	47.9 (42.7 - 56.7)	453 (432 - 484)	---	green	Littleford, 1961
Coastal		(1256)	------	------	------	449	---	green	McGowan, 1963
		(1156)	------	------	------	477	---	12% MC	
		42	33 (16 - 86)	22.4 (8.2 - 66.0)	16.0 (5.5 - 44.0)	421 (336 - 528)	12.0	green	Standish, 1983
	Germany	10 (2206)	(60 - 70)	------	------	524 (448 - 600)	---	ovendry	Göhre, 1955
						448 (332 - 564)	---	green	
	U.S.A. California, Oregon & Washington	37 (virgin) (1240)	------	------	------	446 (308 - 594)	11.6	green	Drow, 1957
		30	------	------	------	450	---	green	Markwardt & Wilson, 1935
						510	---	ovendry	
						480	---	12% MC	
		240 (1669)	------	------	------	443	12.4	12% MC	Snodgrass & Noskowiak, 1968
		2770	------	------	------	450 (340 - 590)	---	green	U.S. Forest Service, 1965
	Oregon & Washington	112 (2nd growth) (1142)	(65 - 150)	------	------	423 (294 - 596)	11.6	green	Drow, 1957
		36	------ (55 - 150)	44.9 (29.2 - 87.6)	36.2 (25.3 - 48.8)	438	7.0	green	McKimmy, 1959
		(2764)	------	------	------	440	---	green	Peck, 1933

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
DOUGLAS-FIR									
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	Canada								
	Alberta & British Columbia	16 (virgin) (300)	------	------	------	440 (308 - 563)	9.2	green	Drow, 1957
Interior	British Columbia	711	------	------	------	422	8.5	green	Smith, 1970
		38	86 (15 - 183)	24.9 (3.1 - 63.2)	15.8 (2.6 - 34.5)	437 (252 - 578)	14.3	green	Standish, 1983
	U.S.A.								
	Arizona, California, Colorado, Idaho, New Mexico, Oregon, Washington & Wyoming	236 (virgin) (2896)	------	------	------	423 (292 - 628)	11.2	green	Drow. 1957
	Arizona, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, Washington &Wyoming	165 (1148)	------	------	------	434	11.6	12% MC	Snodgrass & Noskowiak, 1968
	California, Idaho & Montana	15	------	------	------	410 470 440	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
	Colorado, Idaho, Montana, New Mexico, Washington, Wyoming & Utah	6363	------	------	------	450 (330 - 590)	---	green	U.S. Forest Service, 1965
	Canada								
Mixed	British Columbia	(2450)	------	------	------	490	12.3	ovendry	Hejja, 1986
		78 (2169)	------	------	------	450	11.4	green	Jessome, 1977
		78 (438)	------	------	------	510	12.3	ovendry	Jessome, 1977
		78	------	------	------	487	---	12% MC	Jessome, 1977

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
DOUGLAS-FIR									
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	**England**	170	(20 - 40)	(22.9 - 91.4)	------	421 (343 - 463)[A]	---	green	Stevens & Johnston, 1966
	Finland (South)	30	44 (41 - 46)[A]	18 (16 - 20)[A]	13.2 (12.8 - 13.5)[A]	428	6.8	green	Uusvaara & Pekkala, 1979
	Hungary Budafa Arboretum	6 (18)	21	15.1 (14.0 - 18.1)	13.6 (12.5 - 15.1)	521 (451 - 671)	11.6	ovendry	Babos, 1988
	New Zealand Canterbury	230	(22 - 53)	------	------	400[B]	---	green	Harris, 1978
	Golden Downs	100	(34 - 55)	------	------	469[B]	---	green	Walford, 1985
	Kaingaroa	400	(54 - 64)	------	------	395[B]	---	green	Walford, 1985
	Rotorua	12	35 (27 - 40)	27.5 (14.5 - 47.0)	27.6 (20.1 - 38.1)	391 (315 - 429)	8.4	green	Harris & Orman, 1958
	South Island	12	35 (24 - 50)	30.9 (24.4 - 41.1)	22.3 (14.0 - 30.5)	397 (323 - 459)	9.5	green	Harris & Orman, 1958
	Waimihia	100	(49 - 50)	------	------	405	---	green	Walford, 1985
	The Netherlands	25 (1849)	51 (25 - 91)	42.6 (27.5 - 65.5)	------	580 (480 - 690)	---	15% MC	Wisse, 1968
	Veluwe	18	61	40.2	29.6	575	---	15% MC	Van der Zwan & Polman, 1988
	United Kingdom	88	40 (36 - 49)	31.5 (21.8 - 50.1)	25.0 (12.2 - 33.5)	447 (267 - 549)	5.1[B]	12% MC	Princes Risborough Laboratory, 1959
		54 (1607)	------	------	------	410	12.0	green	Lavers, 1983
		54 (1446)	------	------	------	440	12.0	12% MC	Lavers, 1983

[A] Range of site means

[B] Calculated from site means

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
DOUGLAS-FIR									
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	**Scotland**	90	(20 - 40)	(22.9 - 91.4)	------	388 (346 - 432)[A]	---	green	Stevens & Johnston, 1966
	Wales	60	(20 - 40)	(22.9 - 91.4)	------	399 (368 - 457)[A]	---	green	Stevens & Johnston, 1966
FIRS									
Amabilis fir (*Abies amabilis*) (Dougl.) Forbes)	**Canada** British Columbia	(598)	------	------	------	409	11.7	ovendry	Hejja, 1986
		26 (843)	------	------	------	360	10.6	green	Jessome, 1977
		26 (156)	------	------	------	412	11.4	ovendry	Jessome, 1977
		26	------	------	------	389	---	12% MC	Jessome, 1977
		345	------	48.3 (12.7 - 127.0)	------	377[C]	12.2	green	Kennedy & Swann, 1969
		42	55 (22 - 167)	15.6 (6.1 - 29.8)	11.2 (4.5 - 25.8)	386 (204 - 475)	14.7	green	Standish, 1983
	U.S.A. Oregon & Washington	330	------	53.2	------	400[C] (280 - 550)	---	green	U.S. Forest Service, 1965
	Washington	6	------	------	------	350 420 380	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
Balsam fir (*Abies balsamea* (L.) Mill.)	**Canada** Alberta, Manitoba & Saskatchewan	60	------	------	------	372 (307 - 522)	10.0	ovendry	Singh, 1984
	Atlantic Provinces	571	------	------	------	329	10.6	green	Kennedy, *et al.*, 1968

[A] Range of site means

[C] Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
FIRS									
Balsam fir (*Abies balsamea* (L.) Mill.)	**Canada** Manitoba, Quebec & Saskatchewan	26 (198)	------	------	------	335	8.0	green	Jessome, 1977
		26 (51)	------	------	------	367	9.0	ovendry	Jessome, 1977
		26	------	------	------	350	---	12% MC	Jessome, 1977
	New Brunswick, Nova Scotia, Ontario & Quebec	617	77 (43 - 176)	------ (10.2 - 38.1)	------	333 (278 - 380)[D]	---	green	Hale & Prince, 1940
	Ontario	17	59 (33 - 92)	15.5 (11.5 - 21.5)	15.2 (9.0 - 18.1)	341 (299 - 370)	6.7	green	Alemdag, 1984
		(open grown) 40	25 (8 - 45)	13.8 (1.4 - 39.8)	8.6 (2.1 - 19.2)	330	---	green	Honer, 1970
	Quebec	50	------	15.8 (%CV = 25.6)	14.6 (%CV = 12.2)	319	7.8	green	Heger, 1974
		6	------	26.3 (18.0 - 36.1)	------	324 (299 - 363)	7.4	green	de Montmorency, 1965
		141	88 (35 - 164)	23.1 (9.1 - 42.4)	16.5 (7.2 - 25.3)	348	17.1	green	Ouellet, 1983
	U.S.A. Maine	206	(34 - 126)	22.1 (11.7 - 40.9)	------	339 (281 - 424)	---	green	Wahlgren, *et al.*, 1966
		2823	------	≥ 11.7	------	335[C] (269 - 487)	---	green	Wahlgren, *et al.*, 1968
	Maine, Michigan, Minnesota New Hampshire, New York, Vermont & Wisconsin	33	------	28.2 (23.4 - 36.1)	------	322 349	7.8 9.7	green 12% MC	Bendtsen, 1974

C Predicted from breast-height cores

D Range based on diameter class

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
FIRS									
Balsam fir	**U.S.A.**								
(*Abies balsamea* (L.) Mill.)	Wisconsin	364	34 (10 - 114)	18.0 (10.2 - 38.9)	------	351[C] (337 - 366)	---	green	Maeglin, 1973
		45	43 (20 - 73)	21.1 (12.7 - 29.2)	14.3 (8.5 - 19.8)	342 (306 - 378)	---	green	Maeglin, 1973 Pronin, 1971
		5	------	------	------	340 410 360	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
Grand fir (*Abies grandis* (Dougl.) Linde)	**Canada** British Columbia	36	62 (17 - 228)	24.2 (4.6 - 43.9)	17.4 (3.4 - 34.8)	359 (213 - 453)	15.3	green	Standish, 1983
	Germany (Coastal)	9 (867)	(21 - 111)	------	(14.2 - 36.1)	370 (270 - 650)	---	ovendry	Knigge, 1960
	United Kingdom	80	(30 - 50)[A]	------	------	310 (280 - 340)	---	green	Brazier, 1973
		11 trees & 20 joists (447) (435)	 ------ ------	 ------ ------	 ------ ------	 300 320	 14.0 13.4	 green 13% MC	 Lavers, 1983
	U.S.A. California, Idaho, Montana Oregon & Washington	862	------	37.2	------	350[C] (240 - 550)	---	green	U.S. Forest Service, 1965
	Montana & Oregon	10	------	------	------	370 420 400	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
Subalpine fir (*Abies lasiocarpa* (Hook.) Nutt)	**Canada** Alberta	60	------	------	------	399 (328 - 592)	12.8	ovendry	Singh, 1984

[A] Range of site means

[C] Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Characteristics of sample trees: Mean dbh & range (em)	Characteristics of sample trees: Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Wood density: Coefficient of variation (%)	Wood density: Volume basis	Source of data
FIRS									
Subalpine fir (*Abies lasiocarpa* (Hook.) Nutt)	**Canada** British Columbia	(183)	------	------	------	377	7.6	ovendry	Hejja, 1986
		11 (385)	------	------	------	331 351	10.9 ---	green 12% MC	Jessome, 1977
		97	------	------	------	329	7.0	green	Smith, 1970
		82	76 (18 - 201)	16.7 (3.5 - 44.4)	11.3 (2.2 - 27.9)	362 (268 - 541)	12.4	green	Standish, 1983
	U.S.A. Colorado	5	------	------	------	310 320 330	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
	Colorado, Idaho, Montana, Utah, Washington, Wyoming	35	------	≥ 25.4	------	305 324	10.5 11.2	green 12% MC	Bendsten, 1973
HEMLOCK									
Eastern hemlock (*Tsuga Canadensis* (L.) Carr.)	**Canada** Atlantic Provinces	166	------	------	------	355	10.7	green	Kennedy, *et al.*, 1968
	New Brunswick & Quebec	31 (1041)	------	------	------	404	9.5	green	Jessome, 1977
		31 (146)	------	------	------	447	8.3	ovendry	Jessome, 1977
		31	------	------	------	427	---	12% MC	Jessome, 1977
	Ontario	122	130 (60 - 308)	29.6 (10.2 - 51.4)	16.7 (5.2 - 26.5)	406 (366 - 677)	11.3	green	Alemdag, 1984
	Quebec	68	168 (49 - 228)	26.3 (9.5 - 46.8)	16.2 (7.8 - 23.8)	389	12.9	green	Ouellet, 1983

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
HEMLOCK									
Eastern hemlock (*Tsuga Canadensis* (L.) Carr.)	U.S.A. Maine	98	(29 - 227)	30.2 (12.4 - 52.3)	------	376 (333 - 483)	---	green	Wahlgren, *et al.*, 1966
		629	------	$\geq$ 11.7	------	391[c] (335 - 460)	---	green	Wahlgren, *et al.*, 1968
	New Hampshire, Tennessee, Vermont & Wisconsin	20	------	------	------	380 430 400	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
	Wisconsin	60	98 (42 - 140)	22.4 (11.9 - 40.4)	13.7 (6.7 - 21.3)	393 (335 - 454)	---	green	Maeglin, 1973 Pronin, 1971
		71	105 (36 - 279)	35.6 (11.9 - 86.9)	------	389[c] (328 - 452)	---	green	Maeglin, 1973
Mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.)	Canada British Columbia	31	108 (54 - 224)	21.2 (10.4 - 44.0)	11.0 (4.0 - 25.3)	542 (367 - 661)	13.0	green	Standish, 1983
	U.S.A. Alaska & Montana	10	------	------	------	430 510 470	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
Western, hemlock (*Tsuga heterophylla* (Raf.) Sarg.)	Canada British Columbia	(1782)	------	------	------	477	11.2	ovendry	Hejja, 1986
		21 (422)	------	------	------	409	9.4	green	Jessome, 1977
		21 (120)	------	------	------	470	10.9	ovendry	Jessome, 1977
		21	------	------	------	429	---	12% MC	Jessome, 1977
		605	------	43.2	(12.7 - 162.6)	427[c]	9.1	green	Kennedy & Swann, 1969

[c] Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
HEMLOCK									
Hemlock, western (*Tsuga heterophylla* (Raf.) Sarg.)	**Canada** British Columbia	Planks (43)	------	------	------	410	12.0	green	Lavers, 1983
		Planks (21)	------	------	------	450	12.0	12% MC	Lavers, 1983
		766	------	------	------	423	9.4	green	Smith, 1970
		59	66 (15 - 253)	20.5 (4.5 - 70.5)	14.8 (3.7 - 43.7)	436 (249 - 584)	13.8	green	Standish, 1983
	Germany Lower Saxony	4	108	(32 - 58)	(22 - 26)	480	---	ovendry	Sachsse, *et al.*, 1982
	The Netherlands Veluwe	10	------	------	------	508	---	15% MC	Van der Zwan & Polman, 1988
	United Kingdom	120	(30 - 50)	------	------	390 (360 - 420)	---	green	Brazier, 1973
		15 (422)	------	------	------	360	11.7	green	Lavers, 1983
		15 (408)	------	------	------	380	11.1	12% MC	Lavers, 1983
	U.S.A. Alaska	29	133 (96 - 186)	47.8 (26.4 - 74.9)	37.9 (22.3 - 53.0)	399 (370 - 440)	5.5	green	Farr, 1973
	Alaska, Oregon & Washington	18	------	------	------	380 440 420	--- --- --	green ovendry 12% MC	Markwardt & Wilson, 1935
	California, Idaho Montana, Oregon & Washington	1040	------	51.9	------	420[c] (300 - 520)	---	green	U.S. Forest Service, 1965

c Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
HEMLOCK									
Hemlock, western (*Tsuga heterophylla* (Raf.) Sarg.)	U.S.A. Oregon	(wedges) 12	116 (34 - 243)	45.4 (28.7 - 78.0)	31.1 (19.2 - 46.0)	403 (310 - 470)	11.3	green	Krahmer, 1966
		(radial strips) 12	116 (34 - 243)	45.4 (28.7 - 78.0)	31.1 (19.2 - 46.0)	380 (300 - 470)	12.1	green	Krahmer, 1966
	Oregon	40 (154)	------	------	------	383	10.5	12% MC	Krahmer & Snodgrass, 1967
	Oregon & Washington	15	------	67.2 (30.5 - 96.5)	40.8 (33.5 - 50.9)	390	---	green	Gerhards, 1965
		(1359)	------	------	------	390	---	green	Peck, 1933
LARCHES									
Tamarack (*Larix Laricina* (Du Roi) K.Koch)	Canada Alberta, Manitoba & Saskatchewan	60	------	------	------	530 (455 - 635)	7.7	ovendry	Singh, 1984
	Atlantic Provinces	47	------	------	------	454	9.8	green	Kennedy *et al.*, 1968
	Manitoba & Quebec	11 (127)	------	------	------	485	8.1	green	Jessome, 1977
		11 (39)	------	------	------	544	8.0	ovendry	Jessome, 1977
		11	------	------	------	506	---	12% MC	Jessome, 1977
	Northwest Territories	56 (414)	------	------	------	440 (340 - 555)	8.0	green	Singh, 1986
		56 (420)	------	------	------	494 (374 - 641)	8.4	ovendry	Singh, 1986

Table 1. Stemwood Density - Softwoods

			Characteristics of sample trees			Wood density			
Species	Geographic origin	No. trees (tests) & sample description	Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
LARCHES									
Tamarack (*Larix Laricina* (Du Roi) K.Koch)	Canada Ontario	60	78 (28 - 124)	20.8 (10.3 - 33.8)	19.9 (11.1 - 26.7)	494 (436 - 565)	6.3	green	Alemdag, 1984
		11	(20 - 30)	------	------	443	4.8	green	Balatinecz, 1982
		12	60 (43 - 75)	18.9 (11.0 - 26.7)	17.1 (13.1 - 22.0)	470	7.0	green	Balatinecz, 1983
	Quebec	73	62 (17 - 120)	20.9 (10.1 - 44.5)	16.6 (8.5 - 30.5)	454	10.5	green	Ouellet, 1983
	Quebec (natural)	30	47 (%CV = 14.5)	30.4 (%CV = 12.0)	19.3 (%CV = 18.7)	465	5.8	green	Doucet, *et al.*, 1983
	(plantation)	30	23 (%CV = 8.8)	22.7 (%CV = 8.3)	15.2 (%CV = 8.6)	400	6.5	green	Doucet, *et al.*, 1983
	(planation)	48	25 (22 - 30)	21.0 (18.8 - 24.8)	15.9 (14.4 - 18.2)	433 470	7.4 7.8	green 12%MC	Beaudoin, *et al.*, 1989
	U.S.A. Maine	84	(28 - 201)	23.6 (11.7 - 43.2)	------	484 (413 - 554)	---	green	Wahlgren, *et al.*, 1966
		14	------	(11.7 - 42.9)	------	483[c] (436 - 546)	---	green	Wahlgren, *et al.*, 1968
	Wisconsin	30	55 (30 - 141)	20.8 (13.0 - 30.5)	15.2 (9.4 - 19.8)	500 (421 - 600)	---	green	Maeglin, 1973 Pronin, 1971
		119	45 (15 - 133)	15.7 (10.2 - 30.0)	------	500[c] (466 - 522)	---	green	Maeglin, 1973
		5	------	------	------	490 560 530	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935

c Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
LARCHES									
Western larch	**Canada**								
(*Larix occidentalis* Nutt.)	British Columbia	17 (317)	------	------	------	549	11.9	green	Jessome, 1977
		17 (101)	------	------	------	640	13.9	ovendry	Jessome, 1977
		17	------	------	------	577	---	12% MC	Jessome, 1977
		79	------	------	------	450	10.0	green	Smith, 1970
		35	77 (23 - 159)	25.8 (8.0 - 57.5)	21.2 (7.8 - 38.5)	506 (323 - 616)	12.9	green	Standish, 1983
	U.S.A.								
	Idaho & Montana	(820)	------	------	------	450	---	green	Peck, 1933
	Idaho, Montana, Oregon & Washington	678	------	35.3	------	480[c] (380 - 540)	---	green	U.S. Forest Service, 1965
	Montana & Washington	13	------	------	------	480 590 520	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
PINES									
Eastern white pine	**Canada**								
(*Pinus strobus*)	Atlantic Provinces	27 (253)	------	------	------	323	10.8	green	Kennedy, *et al.*, 1968
	Eastern Canada	(1069)	------	------	------	365	9.4	ovendry	Hejja, 1986
	New Brunswick, Ontario & Quebec	25 (821)	------	------	------	364	11.3	green	Jessome, 1977
		25 (69)	------	------	------	384	11.8	ovendry	Jessome, 1977
		25	------	------	------	368	---	12% MC	Jessome, 1977
	Ontario	128	90 (19 - 255)	34.5 (9.9 - 68.7)	21.1 (5.4 - 35.9)	342 (237 - 447)	11.1	green	Alemdag, 1984

c Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees			Wood density			Source of data
			Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	
PINES									
Eastern white pine (*Pinus strobus*)	**Canada**								
	Quebec	43	75 (32 - 99)	25.2 (9.3 - 47.9)	18.8 (8.3 - 26.9)	376	7.5	green	Ouellet, 1983
	Hungary								
	Budafa Arboretum	6 (18)	21	17.7 (14.6 - 20.0)	16.3 (15.0 - 17.5)	367 (296 - 555)	15.0	ovendry	Babos, 1988
	United Kingdom	13 (52)	------	------	------	290 310	10.0 10.0	green 12%MC	Lavers, 1983
	U.S.A.								
	New Hampshire	75	46 (19 - 80)	31.0 (9.9 - 54.4)	14.6 (4.3 - 23.2)	338 (278 - 398)	---	green	Gammon, 1969
	Maine	202	(23 - 174)	30.5 (11.4 - 58.2)	------	331 (368 - 405)	---	green	Wahlgren, *et al.*, 1966
	Maine	176	------	------	------	324[c] (268 - 442)	---	green	Wahlgren, *et al.*, 1968
	Minnesota, New Hampshire & Wisconsin	15	------	------	------	340 370 360	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
	Minnesota	(386)	------	------	------	350	---	green	Peck, 1933
Jack pine (*Pinus banksiana* Lamb.)	**Canada**								
	Alberta, Manitoba & Saskatchewan	60	------	------	------	451 (354 - 518)	7.5	ovendry	Singh, 1984
	Atlantic Provinces	95	------	------	------	397	8.7	green	Kennedy, *et al.*, 1968
	Manitoba, New Brunswick Ontario & Saskatchewan	25 (309)	------	------	------	421	8.8	green	Jessome, 1977
		25 (84)	------	------	------	454	9.6	ovendry	Jessome, 1977
		25	------	------	------	444	---	12% MC	Jessome, 1977

[c] Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Jack pine (*Pinus banksiana* Lamb.)	Canada New Brunswick (parent trees)	442	56 (21 - 120)	21.1 (11.7 - 34.0)	17.3 (9.1 - 27.6)	396 (320 - 466)	7.1	green	Simpson, 1988
	Northwest Territories	56 (417)	------	------	------	408 (322 - 604)	10.7	green	Singh, 1986
		56 (420)	------	------	------	451 (347 - 653)	11.5	ovendry	Singh, 1986
	Ontario	69	------	16.6 (10.2 - 26.8)	17.8 (11.9 - 23.5)	418 (371 - 483)	6.2	green	Alemdag, 1984
	(planatation)	50	20	------	11.6 (9.4 - 13.3)	350[E]	4.0[E]	green	Balatinecz,1986
		20	15 (12 - 20)	7.9 (2.9 - 14.0)	5.5 (3.2 - 9.1)	327 (313 - 339)	7.8	green	Hegyi, 1969
		18	28 (22 - 30)	13.3 (5.4 - 22.0)	11.4 (10.2 - 14.9)	351 (341 - 361)	5.9	green	Hegyi, 1969
		17	62 (56 - 65)	22.2 (15.0 - 32.1)	19.8 (15.1 - 24.8)	369 (361 - 377)	4.2	green	Hegyi, 1969
	(provenance test)	42	34	13.4 (9.0 - 19.0)	16.5 (13.1 - 18.7)	390 (344 - 441)	6.0	green	Magnussen,*et al.*,1985
	Quebec	109	78 (23 - 128)	23.7 (9.6 - 41.0)	19.4 (8.4 - 27.0)	404	9.9	green	Ouellet, 1983
	Saskatchewan (parent trees)	86	54 (30 - 97)	15.7 (9.7 - 31.0)	21.9 (10.5 - 51.0)	406 (360 - 457)	5.2	green	Roddy, 1983
	U.S.A. Wisconsin	59	43 (21 - 61)	21.1 (11.7 - 31.5)	15.2 (8.8 - 20.1)	411 (354 - 493)	---	green	Maeglin, 1973 Pronin, 1971
		533	29 (9 - 78)	18.3 (10.4 - 42.4)	------	410[C] (399 - 427)	---	green	Maeglin, 1973
		5	------	------	------	390 460 430	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935

[C] Predicted from breast-height cores

[E] Calculated from family means

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Lodgepole pine (*Pinus contorta* var. Latifolia Engelm.)	Canada Alberta	36	------	10.9 (%CV = 19.5)	19.3 (%CV = 23.6)	411	12.2	green	Heger, 1974
		85	100	18.0	18.4	479 (416 - 635)	6.9	ovendry	Johnstone, 1970
		(fast growth) 30	91 (76 - 115)	37.6 (30.5 - 43.7)	25.8 (21.1 - 29.0)	368 (320 - 414)	6.0	green	Jozsa, 1989
		60	------	------	------	444 (376 - 539)	8.1	ovendry	Singh, 1984
		96	------	------	------	408	8.1	green	Smith, 1970
	Alberta & British Columbia	13 (189)	------	------	------	403	8.8	green	Jessome, 1977
		13 (65)	------	------	------	455	7.8	ovendry	Jessome, 1977
		13	------	------	------	412	---	12%MC	Jessome, 1977
	British Columbia	(fast growth) 30	85 (72 - 96)	35.7 (29.0 - 41.2)	27.2 (23.6 - 30.3)	376 (324 - 451)	6.4	green	Jozsa, 1989
		81	71 (%CV = 38.0)	7.6	9.3 (%CV=21.5)	427	8.7	green	Koch, 1987
		81	91 (%CV = 34.1)	15.2	15.6 (%CV = 16.0)	419	6.7	green	Koch, 1987
		81	107 (%CV = 36.4)	22.8	19.1 (%CV = 15.7)	407	6.4	green	Koch, 1987
		363	------	------	------	409	7.8	green	Smith, 1970
		76	79 (15 - 242)	20.7 (4.0 - 48.9)	17.7 (2.3 - 39.6)	425 (287 - 541)	12.7	green	Standish, 1983

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Characteristics of sample trees: Meandbh & range (cm)	Characteristics of sample trees: Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Wood density: Coefficient of variation (%)	Wood density: Volume basis	Source of data
PINES									
Lodgepole pine (*Pinus contorta* var. Latifolia Engehn.)	**Finland**								
	(North)	12	40	12.8	13.4	383	---	green	Hakkila & Panhelainen, 1970
	(South)	110	(29 - 43)[A]	(8.8 - 18.4)[A]	(9.6 - 18.6)[A]	433 (373 - 495)	5.5	green	
	Finland								
	(South)	199	45 (45 - 54)[A]	19 (15.8 - 24.1)[A]	18 (15.9 - 21.5)[A]	432	8.3	green	Bjorklund, 1982
	Sweden								
	(North)	55 (296)	(36 - 43)[A]	(18.3 - 21.8)[A]	(14.2 - 18.3)[A]	375[F]	8.5	green	Andersson, 1987a
	(South)	84 (235)	(39 - 43)[A]	(18.2 - 24.3)[A]	(15.5 - 22.7)[A]	426[F]	10.3	green	Andersson, 1987a
	Sweden								
	(North)	18	(34 - 39)[A]	------	------	379[G] (366 - 397)[A]	---	green	Andersson, 1987b
	(South)	35	(39 - 43)[A]	(13 - 16)[A]	(14 - 18)[A]	415[G] (398 - 449)[A]	---	green	Andersson, 1987b
	United Kingdom	41							
		(384)	------	------	------	390	13.1	green	Lavers, 1983
		(361)	------	------	------	420	14.1	13%MC	
	United Kingdom								
	Allerston, England	150 (21 - 23)[A]	23 (13.3 - 15.5)[A]	14.0 (8.4 - 11.1)[A]	9.8 (352 - 406)[A]	376	---	green	Brazier, 1980
	Beauly, Scotland	5	43	------	------	415	---	green	Brazier, 1980
	Blessington, Eire	10	28	------	------	370	---	green	Brazier, 1980
	North Wales	90	26 (22 - 30)[A]	14.3 (13.8 - 14.7)[A]	9.2 (8.1 - 10.4)[A]	362 (330 - 422)[A]	---	green	Brazier, 1980
	U.S.A.								
	California, Oregon & Washington	734	------	25.9	------	391[C] (292 - 554)	---	green	Maeglin & Wahlgren, 1972

[A] Range of site means
[G] Whole stem analysis using disks
[C] Predicted from breast-height cores
[F] Based on clear wood samples used for mechanical tests

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Lodgepole pine (*Pinus contorta* var. Latifolia Engelm.)	U.S.A. Colorado, Idaho, Montana, Utah & Wyoming	2781	------	23.0	------	379[c] (264 - 512)	---	green	Maeglin & Wahlgren, 1972
	Colorado, Montana & Wyoming	28	------	------	------	380	---	green	Markwardt & Wilson, 1935
						430	---	ovendry	
						410	---	12%MC	
	Idaho, Utah & Wyoming	44	(21 - 90)	(5.6 - 30.0)	------	392 (317 - 487)	---	green	Tackle, 1962
Ponderosa pine (*Pinus Ponderosa* Laws.)	**Canada** British Columbia	(150)	------	------	------	457	11.8	ovendry	Hejja, 1986
		17 (408)	------	------	------	438	9.0	green	Jessome, 1977
		17 (102)	------	------	------	489	9.1	ovendry	Jessome, 1977
		17	------	------	------	459	---	12%MC	Jessome, 1977
		22	------	------	------	388	6.7	green	Smith, 1970
		38	79 (15 - 164)	28.0 (5.0 - 57.6)	15.7 (3.1 - 32.7)	405 (256 - 490)	12.8	green	Standish 1983
	New Zealand (California provenance)	6 (140)	35 (34 - 36)	26.2 (12.7 - 43.9)	24.7 (19.5 - 28.7)	380	---	green	Harris & Kripas, 1959
	(British Columbia provenance)	2 (48)	33	17.7 (16.8 - 18.5)	7.3 (6.1 - 8.5)	410	---	green	Harris & Kripas, 1959
	U.S.A. Arizona	109	------	(14.2 - 51.8)	------	404	---	green	Conway & Minor, 1961
	Arizona, California, Colorado, Montana & Washington	26	------	------	------	380	---	green	Markwardt & Wilson, 1935
						420	---	ovendry	
						400	---	12%MC	

c Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees			Wood density			Source of data
			Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	
PINES									
Ponderosa pine (*Pinus Ponderosa* Laws.)	U.S.A. Arizona, Colorado, Idaho, Montana, New Mexico, S. Dakota, Utah & Wyoming	2701	------	41.2	------	375[C] (271 - 539)	---	green	Maeglin & Wahlgren, 1972
	California, Idaho & Montana	(1876)	------	------	------	370	---	green	Peck, 1933
	California, Oregon & Washington	2281	------	50.5	------	373[C] (271 - 507)	---	green	Maeglin & Wahlgren, 1972
Red pine (*Pinus resinosa* Ait.)	Canada Eastern Canada	(296)	------	------	------	419	12.2	ovendry	Hejja, 1986
	New Brunswick & Nova Scotia	7 (67)	------	------	------	356	9.4	green	Kennedy, *et al.*, 1968
	New Brunswick, Nova Scotia & Ontario	25 (687)	------	------	------	392	10.2	green	Jessome, 1977
		25 (102)	------	------	------	419	11.7	ovendry	Jessome, 1977
		25	------	------	------	401	---	12% MC	Jessome, 1977
	Ontario	94	74 (18 - 253)	29.0 (10.3 - 55.1)	18.4 (7.1 - 34.4)	372 (270 - 477)	12.1	green	Alemdag,1984
	Quebec	39	76 (35 - 97)	25.5 (10.0 - 42.4)	18.8 (7.6 - 26.6)	381	8.0	green	Ouellet, 1983
	U.S.A. New York	360	(29 - 42)[A]	$\geq$ 11.7	------	332 (323 - 340)[A]	---	green	Cody, 1972
	Maine	65	(22 - 167)	32.3 (12.2 - 52.6)	------	391 (324 - 424)	---	green	Wahlgren, *et al.*, 1966

[A] Range of site means

[C] Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Red pine (*Pinus resinosa* Ait.)	U.S.A. Maine (planatation)	100	(20 - 25)	15.9	10.4	322 (318 - 328)[A]	---	green	Baker, 1967
	Wisconsin (planatation)	66	27 (21 - 38)	15.4 (6.35 - 26.2)	10.9 (4.6 - 19.2)	341 (308 - 386)	---	green	Maeglin, 1973
	Wisconsin (planatation)	25	23 (10 - 56)	19.3 (10.7 - 46.0)	------	333[C] (322 - 402)	---	green	Maeglin, 1973
	Wisconsin (planatation)	54	(14 - 37)	------	------	344 (286 - 428)	8.5	green	Pillow, 1952
	Wisconsin (natural)	101	42 (17 - 93)	27.7 (11.2 - 51.8)	------	373[C] (299 - 430)	---	green	Maeglin, 1973
	Wisconsin (natural)	50	51 (13 - 82)	21.3 (11.9 - 46.7)	15.5 (7.0 - 23.5)	377 (319 - 449)	---	green	Maeglin, 1973 Pronin, 1971
	Wisconsin	5	------	------	------	440 510 480	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
Shore pine (*Pinus contorta* var. contorta)	**Canada** British Columbia	35	37 (17 - 55)	16.9 (7.8 - 32.1)	12.8 (5.8 - 20.5)	466 (386 - 591)	9.3	green	Standish, 1983
Western white pine (*Pinus monticola* Dougl.)	**Canada** British Columbia	(107)	------	------	------	404	9.7	ovendry	Hejja, 1986
		17 (614)	------	------	------	355	7.6	green	Jessome, 1977
		17 (102)	------	------	------	398	7.5	ovendry	Jessome, 1977
		17	------	------	------	366	---	12% MC	Jessome 1977
		39	52 (16 - 175)	19.1 (3.7 - 52.4)	13.8 (2.5 - 37.8)	398 (304 - 496)	12.7	green	Standish, 1983

A Range of site means

C Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Western white pine (*Pinus monticola* Dougl.)	**U.S.A.**								
	California, Idaho, Montana, Oregon & Washington	34	------	49.8 (26.4 - 71.6)	------	347 378	9.9 12.0	green 12% MC	Bendtsen, 1972
	California, Oregon & Washington	108	------	53.2	------	355[c] (288 - 448)	---	green	Maeglin & Wahlgren, 1972
	Idaho	36	------	≥ 25.4	------	346	---	green	Gernert, *et al.*, 1980
		(1179)	------	------	------	360	---	green	Peck, 1933
	Idaho & Montana	184	------	38.0	------	356[c] (300 - 433)	---	green	Maeglin & Wahlgren, 1972
		5	------	------	------	360 420 380	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
SPRUCES									
Black spruce (*Picea mariana* (Mill.) B.C.P.)	**Canada**								
	Alberta, Saskatchewan & Manitoba	58	------	------	------	457 (387 - 584)	7.4	ovendry	Singh, 1984
	Atlantic Provinces	34 (318)	------	------	------	400	9.0	green	Kennedy, *et al.*, 1968
	British Columbia	55	120 (47 - 222)	16.2 (3.5 - 38.4)	13.9 (2.9 - 30.1)	455 (331 - 546)	10.9	green	Standish, 1983
	Manitoba, New Brunswick, Quebec & Saskatchewan	32 (216)	------	------	------	406	9.4	green	Jessome, 1977
		32 (66)	------	------	------	445	9.3	ovendry	Jessome, 1977
		32	------	------	------	428	---	12% MC	Jessome, 1977
	New Brunswick (parent trees)	430	64 (26 - 208)	22.0 (12.5 - 36.5)	18.0 (10.5 - 25.0)	404 (304 - 520)	7.2	green	Simpson, 1988

[c] Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
Black spruce (*Picea mariana* (Mill.) B.C.P.)	Canada New Brunswick, Nova Scotia & Ontario	784	103 (26 - 226)[D]	------ (10.2 - 35.6)	------	435 (356 - 564)[D]	---	green	Hale & Prince, 1940
	Northwest Territories	51 (348)	------	------	------	454 (353 - 625)	10.6	green	Singh, 1986
		51 (351)	------	------	------	514 (400 - 723)	10.9	ovendry	Singh, 1986
	Nova Scotia (parent trees)	94	76 (50 - 144)	22.2 (12.7 - 33.2)	15.3 (8.3 - 20.5)	421 (359 - 495)	6.3	green	Mullin, 1987 Sebastian, 1984
	Ontario	39	------	13.4 (9.4 - 22.2)	13.4 (8.2 - 18.9)	437 (367 - 520)	8.5	green	Alemdag, 1984
	Quebec Forestville	11	------	22.5 (14.2 - 29.2)	------	450 (400 - 512)	8.0	green	de Montmorency, 1965
	Quebec	50	------	16.2 (%CV = 16.2)	15.3 (%CV = 15.4)	427	7.5	green	Heger, 1974
	Quebec	568	125 (54 - 281)	16.4 (9.0 - 32.9)	14.7 (5.7 - 22.8)	421	12.7	green	Ouellet, 1983
		5 (316)	------ (70 - 80)	17.5 (14.2 - 19.8)	13.8 (13.1 - 15.2)	380 (332 - 442)	5.8	green	Risi & Zeller, 1960
	Finland Punkaharju	10	47	14	8.8	411	---	green	Uusvaara & Pekkala, 1973
	U.S.A. Maine	105	------ (24 - 222)	23.9 (12.2 - 40.9)	------	412 (336 - 497)	---	green	Wahlgren, *et al.*, 1966
	Maine	59	------	(11.7 - 32.8)	------	420[C] (368 - 499)	---	green	Wahlgren, *et al.*, 1968

C Predicted from breast-height cores

D Range based on diameter class

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
Black spruce (*Picea mariana* (Mill.) B.C.P.)	**U.S.A.** New Hampshire	5	------	------	------	380 430 400	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
	Wisconsin	122	45 (16 - 124)	14.7 (10.2 - 30.5)	------	420 (378 - 450)	---	green	Maeglin, 1973
	Wisconsin	30	55 (32 - 93)	20.8 (13.5 - 32.3)	14.9 (10.7 - 18.0)	406 (370 - 483)	---	green	Maeglin, 1973 Pronin, 1971
Engelmann spruce (*Picea engelmannii* Parry)	**Canada** British Columbia	11 (181)	------	------	------	375	8.6	green	Jessome, 1977
		11 (66)	------	------	------	425	9.6	ovendry	Jessome, 1977
		11	------	------	------	395	---	12%MC	Jessome, 1977
		608	------	------	------	355	8.7	green	Smith, 1970
		41	94 (21 - 253)	24.3 (4.9 - 57.6)	17.5 (3.2 - 40.8)	403 (266 - 518)	13.0	green	Standish, 1983
	Finland Punkaharju	10	46	18	14.8	388	---	green	Uusvaara & Pekkala, 1979
	U.S.A. Arizona, Colorado, Idaho, Montana, New Mexico, Utah & Wyoming	1704	------	39.2	------	346[c] (258 - 507)	---	green	Maeglin & Wahlgren, 1972
	Arizona, Colorado, Idaho New Mexico, Oregon, Utah & Washington	50 (200)	------	≥ 22.9	------	325 352	8.9 8.7	green 12% MC	Bendtsen & Wahlgren, 1970
	Colorado	10	------	------	------	310 350 330	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935

c Predicted from breast-height cores

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
Engelmann spruce (*Picea engelmannii* Parry)	U.S.A. Colorado & Wyoming	89	------	>30.5	------	314 (264 - 439)	8.1	green	Bodig, 1969
	Oregon & Washington	85	------	39.3	------	361[C] (293 - 444)	---	green	Maeglin & Wahlgren, 1972
Red spruce (*Picea rubens* Sarg.)	**Canada** Atlantic Provinces	42 (382)	------	------	------	380	---	green	Kennedy, *et al.*, 1968
	New Brunswick & Nova Scotia	114	74 (47 - 180)[D]	(12.7 - 25.4)	------	378 (331 - 408)[D]	---	green	Hale & Prince, 1940
		13 (106)	------	------	------	380	6.3	green	Jessome, 1977
		13 (33)	------	------	------	425	6.9	ovendry	Jessome, 1977
		13	------	------	------	401	---	12%MC	Jessome, 1977
	Quebec	50	135 (61 - 340)	24.4 (10.3 - 43.5)	16.5 (10.7 - 21.2)	380	9.6	green	Ouellet, 1983
	U.S.A. Maine	2444	------	------	------	381[C] (326 - 427)	---	green	Maeglin, *et al.*, 1968
	Maine	106	(22 - 227)	26.9 (11.7 - 45.7)	------	381 (339 - 449)	---	green	Wahlgren, *et al.*, 1966
	New Hampshire & Tennessee	11	------	------	------	380	---	green	Markwardt & Wilson, 1935
						410	---	ovendry	
						410	---	12%MC	

[C] Predicted from breast-height cores

[D] Range based on diameter class

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
Sitka spruce (*Picea sitchensis* (Bong.) Carr.)	**Canada** British Columbia	(167)	------	------	------	417	11.4	ovendry	Hejja, 1986
		14 (737)	------	------	------	347	10.1	green	Jessome, 1977
		14 (84)	------	------	------	394	11.9	ovendry	Jessome, 1977
		14	------	------	------	387	---	12%MC	Jessome, 1977
		34	31 (15 - 78)	17.6 (5.3 -45.1)	11.2 (4.6 - 22.5)	412 (320 - 568)	15.4	green	Standish, 1983
	Finland Bromarv	10	39	17	13.1	410	---	green	Uusvaara & Pekkala, 1979
	Norway West Coast	41	48 (29 - 57)	29.7 (21.3 - 38.7)[A]	21.2 (15.2 - 24.9)[A]	325[B] (313 - 337)[A]	---	green	Okstad, 1987
						390 (317 - 450)	8.8	12%MC	
	West Coast	56 (372)	------	------	------	389	3.3	12%MC	Ishengoma & Nagoda, 1987
	United Kingdom	55 trees 50 joists	------	------	------	330	12.1	green	Lavers, 1983
						340	12.9	12%MC	
	England	60	34 (30 - 37)	23.5 (21.0 - 28.6)	10.3 (5.4 - 15.5)	337 (285 - 396)[H]	---	green	Broughton, 1962 Sunley & Lavers, 1961
	England	160	(20 - 40)	(22.9 - 91.4)	------	406 (351 - 454)[A]	---	green	Stevens & Johnston, 1966
	England, Scotland & Wales	97	33 (22 - 40)	26.8 (24.4 - 29.9)[A]	------ (12.1 - 19.0)[A]	344[G] (263 - 422)	9.1	green	Brazier, *et al.*, 1976
		102	(22 - 40)	(24.4 - 29.9)[A]	(12.1 - 19.0)[A]	326[F]	---	green	Brazier, *et al.*, 1976

[A] Range of site means
[G] Whole stem analysis using disks
[B] Calculated from site means
[H] Values obtained from graph
[F] Based on clear wood samples used for mechanical tests

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
Sitka spruce (*Picea sitchensis* (Bong.) Carr.)	**United Kingdom** Ireland	24	20	------	(10.2 - 14.8)	349 (310 - 414)	8.9	green	Javadi, *et al.*, 1983
	Scotland	60	33 (31 - 36)	22.8 (20.3 - 29.8)	9.6 (5.6 - 13.9)	330 (255 - 425)[H]	---	green	Broughton, 1962 Sunley & Lavers, 1961
	Scotland	120	(20 - 40)	(22.9 - 91.4)	------	367 (335 - 405)[A]	---	green	Stevens & Johnston, 1966
	Wales	20	30	56.4 (43.2 - 86.4)	15.9 (13.3 - 18.4)	329	8.8	green	Princes Risborough Laboratory, 1958
	Wales	39	(21 - 31)[A]	------	------	332[I] (275 - 395)	---	green	MacGregor, 1952
						304[J] (242 - 382)	---	green	
	Wales	60	34 (31 - 36)	24.7 (21.6 - 29.8)	10.7 (7.2 - 15.6)	327 (266 - 378)[H]	---	green	Broughton, 1962 Sunley & Lavers, 1961
	Wales	60	(20 - 40)	(22.9 - 91.4)	------	384 (358 - 414)[A]	---	green	Stevens & Johnston, 1966
	U.S.A. Alaska	35	129 (75 - 180)	50.3 (28.4 - 72.4)	38.7 (23.5 - 55.5)	380 (340 - 440)	6.8	green	Farr, 1973
	Alaska, Oregon & Washington	25	------	------	------	370 420 400	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
	Oregon & Washington	(658)	------	------	------	360	---	green	Peck, 1933

[A] Range of site means
[H] Values obtained from graph
[I] Values at .3 m above ground
[J] Values at 6.4 m above ground

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
White spruce (*Picea glauca* (Moench) Voss.)	Canada Alberta	13	------	------	------	355	---	green	Taylor, *et al.*, 1982 Wang & Micko, 1984
		24	------	------	------	410	---	ovendry	Jozsa & Powell,1987
	Alberta, Manitoba, New Brunswick, Quebec & Saskatchewan	43 (510)	------	------	------	354	10.2	green	Jessome, 1977
		43 (125)	------	------	------	393	11.8	ovendry	Jessome, 1977
		43	------	------	------	372	---	12%MC	Jessome, 1977
	Alberta, Manitoba & Saskatchewan	59	------	------	------	404 (313 - 527)	9.2	ovendry	Singh, 1984
	Atlantic Provinces	22 (204)	------	------	------	353	11.8	green	Kennedy, *et al.*, 1968
	British Columbia	998	------	------	------	360	8.9	green	Smith, 1970
		94	76 (19 - 245)	19.5 (3.6 - 57.6)	17.4 (2.2 - 39.3)	401 (257 - 540)	12.6	green	Standish, 1983
	Manitoba	100	133	44.5	------	343	---	green	Hale & Fensom, 1931
		100	87	37.1	------	329	---	green	Hale & Fensom, 1931
	New Brunswick (northwestern)	20	89 (39 - 185)	37.0 (28.6 - 50.1)	19.1 (9.6 - 24.1)	353 (301 - 390)	5.8	green	Caron, 1980
	New Brunswick, Nova Scotia, Ontario & Quebec	282	82 (35 - 189)[D]	------ (10.2 - 38.1)	------	368 (312 - 484)[D]	---	green	Hale & Prince, 1940
	Northwest Territories	61 (456)	------	------	------	411 (288 - 651)	15.0	green	Singh, 1986
		61 (457)	------	------	------	460 (305 - 694)	15.3	ovendry	Singh, 1986

[D] Range based on diameter class

Table 1. Stemwood Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
White spruce (*Picea glauca* (Moench) Voss.)	**Canada** Ontario	56	------	20.8 (10.3 - 33.8)	19.9 (11.1 - 26.7)	383 (314 - 476)	9.1	green	Alemdag, 1984
	Ontario (Petawawa) (plantation)	52	14	6.5 (4.3 - 8.6)	4.9 (3.8 - 5.6)	320[E]	4.2[E]	green	Balatinecz, 1986
	Ontario (southern)	232	30 (17 - 41)	17.9 (4.3 - 28.2)	10.6 (5.6 - 17.5)	335 (270 - 422)	8.0	green	Chang & Kennedy, 1967
	Quebec	56	103 (59 - 220)	24.5 (9.5 - 43.5)	17.3 (10.1 - 26.3)	353	12.1	green	Ouellet 1983
	Quebec Forestville	5	------	41.0 (28.7 - 50.3)	------	354 (323 - 368)	5.2	green	de Montmorency, 1965
	Saskatchewan	200	95	32.0	------	343	---	green	Hale & Fensom, 1931
	Saskatchewan (parent trees)	28	90 (65 - 133)	38.1 (28.4 - 49.9)	26.7 (19.0 - 33.0)	341 (310 - 369)	5.1	green	Roddy, 1986
	Finland Bromarv & Punkaharju	20	46	17.5	18.2	367	5.5	green	Uusvaara & Pekkala, 1979
	U.S.A. Alaska, New Hampshire & Wisconsin	10	------	------	------	370 450 400	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
	Maine	119	------ (16 - 159)	26.9 (11.4 - 49.0)	------	358 (290 - 452)	---	green	Wahlgren, *et al.*, 1966
	Maine	216	------	(11.7 - 53.1)	------	365[C] (306 - 433)	---	green	Maeglin, 1968
	Wisconsin	30	44 (26 - 63)	21.3 (13.0 - 34.3)	14.3 (8.8 - 18.9)	350 (299 - 413)	---	green	Maeglin, 1973 Pronin, 1971
	Wisconsin	38	38 (17 - 64)	21.3 (10.2 - 48.3)	------	365[C] (312 - 455)	---	green	Maeglin, 1973

[C] Predicted from breast-height cores

[E] Calculated from family means

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
ALDER									
Red alder (*Alnus rubra* Bong.)	Canada British Columbia	6 (103)	------	------	------	373	6.9	green	Jessome, 1977
		6 (36)	------	------	------	422	6.1	ovendry	Jessome, 1977
		6	------	------	------	409	6.1	12%MC	Jessome, 1977
		40	18 (5 - 48)	13.2 (5.8 - 33.3)	11.4 (6.1 - 23.8)	395 (333 - 603)	12.7	green	Standish, 1983
	U.S.A. Washington	6	------	------	------	370 430 410	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
ASHES									
Black ash (*Fraxinus nigra* Marsh.)	Canada Ontario	18	74 (40 - 120)	18.3 (10.1 - 33.1)	15.1 (9.2 - 20.3)	545 (509 - 571)	2.9	green	Alemdag, 1983
		5 (27)	------	------	------	468	8.5	green	Jessome, 1977
		5 (16)	------	------	------	539	8.3	ovendry	Jessome, 1977
		5	------	------	------	494	---	12% MC	Jessome, 1977
	U.S.A. Michigan & Wisconsin	6	------	------	------	450 530 490	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
Green ash (*Fraxinus pennsylvanica* var. subintegerrima (Vahl) Fern.)	Canada Manitoba	2 (28)	------	------	------	486	7.6	green	Jessome, 1977

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
ASHES									
Green ash (*Fraxinus pennsylvanica* var. subintegerrima (Vahl) Fern.)	Canada Manitoba	2 (19)	------	------	------	556	10.5	ovendry	Jessome, 1977
		2	------	------	------	506	---	12% MC	Jessome, 1977
	U.S.A. Louisiana & Missouri	10	------	------	------	530 610 560	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
Red ash (*Fraxinus pennsylvanica* Marsh.)	Canada Ontario	24	61 (35 - 89)	23.3 (12.0 - 40.2)	19.7 (13.5 - 26.7)	555 (500 - 608)	5.2	green	Alemdag, 1983
White ash (*Fraxinus americana* L.)	Canada New Brunswick & Ontario	13 (148)	------	------	------	570	8.4	green	Jessome, 1977
		13 (30)	------	------	------	650	8.7	ovendry	Jessome, 1977
		13	------	------	------	506	---	12% MC	Jessome, 1977
	Ontario	64	70 (37 - 145)	26.3 (10.7 - 53.7)	18.8 (11.8 - 26.9)	594 (483 - 664)	6.6	green	Alemdag, 1983
	U.S.A. Arkansas, Massachusetts, New York, Vermont & West Virginia	23	------	------	------	550 640 600	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
BASSWOOD									
Basswood (*Tilia americana* L.)	Canada Ontario	62	70 (23 - 112)	30.8 (12.3 - 54.8)	19.6 (10.0 - 26.1)	428 (354 - 597)	11.0	green	Alemdag, 1983

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
BASSWOOD									
Basswood (*Tilia americana* L.)	**Canada** Quebec	4 (34)	------	------	------	360	10.6	green	Jessome, 1977
		4 (17)	------	------	------	423	14.6	ovendry	Jessome, 1977
		4	------	------	------	417	---	12% MC	Jessome, 1977
	U.S.A. Pennsylvania & Wisconsin	8	------	------	------	320 400 370	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
BEECH									
Beech (*Fagus grandifolia* Ehrh.)	**Canada** New Brunswick & Quebec	17 (206)	------	------	------	590	5.2	green	Jessome, 1977
		17 (51)	------	------	------	705	6.0	ovendry	Jessome, 1977
		17	------	------	------	667	---	12%MC	Jessome, 1977
	Ontario	63	97 (40 - 148)	27.8 (10.5 - 44.1)	19.9 (9.7 - 26.5)	607 (540 - 692)	5.1	green	Alemdag, 1983
	U.S.A. Indiana, Pennsylvania & Vermont	17	------	------	------	560 670 640	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
BIRCHES									
White birch (*Betula papyrifera* Marsh.)	**Canada** Alberta, Manitoba & Saskatchewan	60	------	------	------	607 (512 - 693)	7.4	ovendry	Singh, 1984

Table 1. Stemwood Density - Hardwoods

			Characteristics of sample trees			Wood density			
Species	Geographic origin	No. trees (tests) & sample description	Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
BIRCHES									
White birch (*Betula papyrifera* Marsh.)	**Canada** British Columbia	40	47 (7 - 142)	15.0 (4.5 - 30.6)	13.9 (5.3 - 22.7)	519 (406 - 653)	9.6	green	Standish, 1983
	Manitoba, New Brunswick & Saskatchewan	16 (168)	------	------	------	506	5.7	green	Jessome, 1977
		16 (35)	------	------	------	588	7.1	ovendry	Jessome, 1977
		16	------	------	------	571	---	12%MC	Jessome, 1977
	Ontario	44	72 (46 - 90)	21.3 (13.3 - 32.7)	19.6 (14.9 - 22.3)	539 (490 - 583)	3.7	green	Alemdag, 1983
	U.S.A. New Hampshire & Wisconsin	10	------	------	------	480	---	green	Markwardt & Wilson, 1935
						600	---	ovendry	
						550	---	12%MC	
Western white birch (*Betula papyrifera var. comutata* (reg) Fern.)	**Canada** British Columbia	18 (234)	------	------	------	508	6.0	green	Jessome, 1977
		18 (80)	------	------	------	605	6.9	ovendry	Jessome, 1977
		18	------	------	------	564	---	12%MC	Jessome, 1977
(*Betula papyrifera var. neoalaskana* (Sarg.) Raup.)	**Finland** Punkaharju	10	47	14	14.2	469	---	green	Uusvaara & Pekkala, 1979
	U.S.A. Alaska	10	------	------	------	490	---	green	Markwardt & Wilson, 1935
						590	---	ovendry	
						550	---	12%MC	

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
BIRCHES									
Yellow birch (*Betula alleghaniensis Britton (Betula lutea* Michx. f.)	**Canada** New Brunswick, Nova Scotia & Quebec	25 (295)	------	------	------	559	5.4	green	Jessome, 1977
		25 (56)	------	------	------	649	5.9	ovendry	Jessome, 1977
		25	------	------	------	608	---	12%MC	Jessome, 1977
	Ontario	83	107 (37 - 210)	37.2 (10.4 - 70.3)	20.5 (10.0 - 25.6)	596 (512 - 686)	6.2	green	Alemdag, 1984
	U.S.A. Pennsylvania, Vermont & Wisconsin	17	------	------	------	550	---	green	Markwardt & Wilson, 1935
						660	---	ovendry	
						620	---	12%MC	
CHERRY									
Black cherry (*Prunus serotina* Ehrh.)	**Canada** Ontario	64	55 (26 - 91)	26.1 (9.5 - 49.6)	18.6 (8.4 - 25.9)	569 (494 - 647)	5.1	green	Alemdag, 1983
		5 (88)	------	------	------	510	6.9	green	Jessome, 1977
		5 (21)	------	------	------	623	8.0	ovendry	Jessome, 1977
		5	------	------	------	551	---	12%MC	Jessome, 1977
	U.S.A. Pennsylvania	5	------	------	------	470	---	green	Markwardt & Wilson, 1935
						530	---	ovendry	
						500	---	12%MC	

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
CHESTNUT									
Chestnut (*Castanea dentata* (Marsh.) Borkh.)	**Canada** Ontario	5 (54)	------	------	------	423	8.0	green	Jessome, 1977
		5 (20)	------	------	------	466	9.8	ovendry	Jessome, 1977
		5	------	------	------	449	---	12% MC	Jessome, 1977
	U.S.A. Maryland & Tennessee	10	------	------	------	400 450 430	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
ELMS									
Rock elm (*Ulnus thomasii* Sarg.)	**Canada** Ontario	13 (632)	------	------	------	625	10.3	green	Jessome, 1977
		13 (78)	------	------	------	732	14.2	ovendry	Jessome, 1977
		13	------	------	------	661	---	12% MC	Jessome, 1977
	U.S.A. Wisconsin	5	------	------	------	570 660 630	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
Slippery elm (*Ulnus rubra* Muhl)	**Canada** Ontario	5 (48)	------	------	------	547	12.9	green	Jessome, 1977
		5 (20)	------	------	------	643	11.5	ovendry	Jessome, 1977
		5	------	------	------	602	---	12%MC	Jessome, 1977

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
ELMS									
White elm (*Ulnus americana* L.)	**Canada** Manitoba, Ontario & Quebec	23 (510)	------	------	------	524	9.6	green	Jessome, 1977
		23 (83)	------	------	------	617	9.2	ovendry	Jessome, 1977
		23	------	------	------	562	---	12% MC	Jessome, 1977
	Ontario	68	63 (26 - 129)	23.0 (11.3 - 55.2)	14.6 (8.0 - 23.2)	580 (512 - 676)	7.2	green	Alemdag, 1983
	U.S.A. New Hampshire, Pennsylvania & Wisconsin	12	------	------	------	460 550 500	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
HICKORY									
Hickory (*Carya* spp.)	**Canada** Ontario	67	63 (24 - 110)	23.5 (10.0 - 46.6)	21.3 (11.6 - 29.4)	616 (550 - 673)	3.9	green	Alemdag, 1983
Bitternut hickory (*Carya cordiformis* (Wang.) K. Koch)	**Canada** Ontario	5 (21)	------	------	------	628	6.8	green	Jessome, 1977
		5 (20)	------	------	------	760	9.5	ovendry	Jessome, 1977
		5	------	------	------	675	---	12% MC	Jessome, 1977
	U.S.A. Ohio	11	------	------	------	600 660	--- ---	green 12% MC	Markwardt & Wilson, 1935

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Meandbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
HICKORY									
Shagbark hickory (*Carya ovata* (Mill.) K. Koch)	**Canada** Ontario & Quebec	11 (108)	------	------	------	654	6.5	green	Jessome, 1977
		11 (42)	------	------	------	788	6.7	ovendry	Jessome, 1977
		11	------	------	------	724	---	12% MC	Jessome, 1977
	U.S.A. Mississippi, Ohio Pennsylvania & West Virginia	24	------	------	------	640 720	--- ---	green 12% MC	Markwardt & Wilson, 1935
IRONWOOD									
Ironwood (*Ostrya virginiana* (Mill.) K. Koch)	**Canada** Quebec	6 (29)	------	------	------	652	3.5	green	Jessome, 1977
		6 (16)	------	------	------	786	4.8	ovendry	Jessome, 1977
		6	------	------	------	728	---	12% MC	Jessome, 1977
	U.S.A. Wisconsin	5	------	------	------	630 760 700	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
MAPLES									
Broadleaf maple (*Acer macrophyllum* Pursh.)	**Canada** British Columbia	6 (78)	------	------	------	466	4.7	green	Jessome, 1977
		6 (36)	------	------	------	530	5.3	ovendry	Jessome, 1977
		6	------	------	------	507	---	12% MC	Jessome, 1977

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
MAPLES									
Broadleaf maple	**U.S.A.**								
(*Acer macrophyllum*	Washington	5	------	------	------	440	---	green	Markwardt & Wilson, 1935
Pursh.)						510	---	ovendry	
						480	---	12%MC	
Manitoba maple	**Canada**								
(*Acer negundo* L.)	Manitoba	6 (73)	------	------	------	416	7.8	green	Jessome, 1977
		6 (28)	------	------	------	501	8.8	ovendry	Jessome, 1977
		6	------	------	------	457	---	12% MC	Jessome, 1977
Red maple	**Canada**								
(*Acer rubrum* L.)	Ontario	36	71 (32 - 122)	28.1 (13.5 - 45.2)	20.0 (10.8 - 25.4)	588 (521 - 655)	5.1	green	Alemdag, 1983
		6 (76)	------	------	------	516	5.2	green	Jessome, 1977
		6 (24)	------	------	------	586	4.4	ovendry	Jessome, 1977
		6	------	------	------	545	---	12%MC	Jessome, 1977
	U.S.A.								
	New Hampshire,	14	------	------	------	490	---	green	Markwardt & Wilson, 1935
	Pennsylvania					550	---	ovendry	
	& Wisconsin					540	---	12%MC	
Silver maple	**Canada**								
(*Acer saccharinum* L.)	Ontario	31	41 (28 - 58)	27.4 (13.3 - 45.3)	22.0 (14.2 - 26.4)	480 (421 - 528)	5.0	green	Alemdag, 1983
		5 (58)	------	------	------	461	6.6	green	Jessome, 1977

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
MAPLES									
Silver maple (*Acer saccharinum* L.)	**Canada**								
	Ontario	5 (20)	------	------	------	509	5.2	ovendry	Jessome, 1977
		5	------	------	------	478	---	12%MC	Jessome, 1977
	U.S.A.								
	Wisconsin	5	------	------	------	440	---	green	Markwardt & Wilson, 1935
						510	---	ovendry	
						470	---	12%MC	
Sugar maple (*Acer saccharum* Marsh.)	**Canada**								
	New Brunswick, Ontario & Quebec	19 (310)	------	------	------	597	5.2	green	Jessome, 1977
		19 (71)	------	------	------	702	5.3	ovendry	Jessome, 1977
		19	------	------	------	659	---	12%MC	Jessome, 1977
	Ontario	86	80 (34 - 139)	31.4 (10.0 - 57.8)	19.7 (9.9 - 26.4)	616 (518 - 672)	5.2	green	Alemdag, 1983
	U.S.A.								
	Indiana, Pennsylvania, Vermont & Wisconsin	17	------	------	------	560	---	green	Markwardt & Wilson, 1935
						680	---	ovendry	
						630	---	12%MC	
OAKS									
Black oak (*Quercus velutina Lam.*)	**Canada**								
	Ontario	5 (51)	------	------	------	597	3.9	green	Jessome, 1977
		5 (31)	------	------	------	677	4.5	ovendry	Jessome, 1977
		5	------	------	------	621	---	12%MC	Jessome, 1977

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
OAKS									
Black oak (*Quercus velutina Lam.*)	**U.S.A.** Arkansas & Wisconsin	8	------	------	------	560	---	green	Markwardt & Wilson, 1935
						670	---	ovendry	
						610	---	12%MC	
Bur oak (*Quercus macrocarpa* Michx.)	**Canada** Manitoba	6 (34)	------	------	------	599	6.7	green	Jessome, 1977
		6 (21)	------	------	------	694	8.1	ovendry	Jessome, 1977
		6	------	------	------	653	---	12%MC	Jessome, 1977
	U.S.A. Wisconsin	5	------	------	------	580	---	green	Markwardt & Wilson, 1935
						670	---	ovendry	
						640	---	12%MC	
Red oak (*Quercus rubra* L.)	**Canada** Ontario	100	70 (35 - 101)	25.6 (10.1 - 53.3)	16.6 (9.9 - 23.0)	590 (468 - 690)	6.1	green	Alemdag, 1983
	Ontario & Quebec	11 (136)	------	------	------	581	5.1	green	Jessome, 1977
		11 (50)	------	------	------	655	6.7	ovendry	Jessome, 1977
		11	------	------	------	612	---	12%MC	Jessome, 1977
	United Kingdom	8 (40)	------	------	------	570	6.0	green	Lavers, 1983
						640	6.3	12%MC	
	U.S.A. Arkansas, Indiana, Louisiana, New Hampshire & Tennessee	33	------	------	------	560	---	green	Markwardt & Wilson, 1935
						660	---	ovendry	
						630	---	12%MC	

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
OAKS									
White oak (*Quercus alba* L.)	**Canada** Ontario	49	81 (17 - 127)	28.5 (9.9 - 74.3)	13.0 (5.0 - 21.5)	646 (600 - 709)	3.7	green	Alemdag, 1983
		5 (75)				654	4.2	green	Jessome, 1977
		5 (21)				775	6.0	ovendry	Jessome, 1977
		5	------	------	------	676	---	12%MC	Jessome, 1977
	U.S.A. Arkansas, Indiana & Louisiana	20	------	------	------	600 710 680	--- --- ---	green ovendry 12% MC	Markwardt & Wilson 1935
POPLARS									
Balsam poplar (*Populus balsamifera* L.)	**Canada** Alberta	30	58 (29 - 103)	26.0 (18.1 - 39.0)	18.4 (13.8 - 22.6)	337 (286 - 399)	7.7	green	Kellogg & Swan, 1986
	Alberta, Manitoba & Saskatchewan	60	------	------	------	409 (324 - 516)	9.8	ovendry	Singh, 1984
	Manitoba & Ontario	10 (88)	------	------	------	372	8.7	green	Jessome, 1977
		10 (36)	------	------	------	416	6.4	ovendry	Jessome, 1977
		10	------	------	------	415	---	12%MC	Jessome, 1977
	Northwest Territories	56	------	------	------	387 (255 - 499)	10.8	green	Singh, 1986
		56	------	------	------	433 (313 - 575)	11.0	ovendry	Singh, 1986

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
POPLARS									
Balsam poplar (*Populus balsamifera* L.)	**Canada** Ontario	87	42 (24 - 90)	25.5 (10.0 - 53.2)	18.8 (8.7 - 27.0)	354 (304 - 412)	5.4	green	Alemdag, 1983
	U.S.A. Alaska & Vermont	10	------	------	------	300 350 330	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
Black cottonwood (*Populus balsamifera L. Subsp. trichocarpa* Terr. & Gray)	**Canada** British Columbia	7 (167)	------	------	------	295	9.2	green	Jessome, 1977
		7 (42)	------	------	------	334	10.5	ovendry	Jessome, 1977
		7	------	------	------	320	---	12%MC	Jessome, 1977
		30	52 (26 - 77)	45.9 (19.1 - 72.5)	34.3 (21.3 - 44.5)	338 (272 - 432)	11.3	green	Kellogg & Swan, 1986
		34	19 (8 - 45)	15.9 (5.6 - 31.5)	13.6 (6.9 - 25.4)	378 (229 - 564)	15.7	green	Standish, 1983
	U.S.A. Oregon & Washington	120	------	58.1	------	310[c] (280 - 400)	---	green	U.S. Forest Service, 1965
	Washington	5	------	------	------	320 370 350	--- --- ---	green ovendry 12% MC	Markwardt & Wilson, 1935
Eastern cottonwood (*Populus deltoides* Bartr.)	**Canada** Ontario	5 (121)	------	------	------	352	10.7	green	Jessome, 1977
		5 (20)	------	------	------	386	10.8	ovendry	Jessome, 1977
		5	------	------	------	386	---	12%MC	Jessome, 1977

[c] Predicted from breast-height cores

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
POPLARS									
Eastern cottonwood (*Populus deltoides* Bartr.)	U.S.A. Missouri	5	------	------	------	370 430 400	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
	Illinois	(900) dimension lumber	------	------	------	430	2.0[K]	ovendry	Peterson, *et al.*, 1959
Largetooth aspen (*Populus grandidentata* Michx.)	Canada Ontario	11	59 (55 - 81)	25.4 (15.3 - 39.2)	18.8 (14.1 - 23.0)	388 (376 - 404)	2.3	green	Alemdag, 1983
		10 (69)	------	------	------	390	9.4	green	Jessome, 1977
		10 (30)	------	------	------	431	8.4	ovendry	Jessome, 1977
		10	------	------	------	401	---	12%MC	Jessome, 1977
	U.S.A. Vermont & Wisconsin	10	------	------	------	350 410 390	--- --- ---	green ovendry 12%MC	Markwardt & Wilson, 1935
	Wisconsin	497	37 (13 - 94)	21.3 (10.2 - 53.8)	------	370[C] (337 - 396)	---	green	Maeglin, 1973
	Wisconsin	100	41 (33 - 50)	24.1 (13.5 - 39.9)	21.6 (12.8 - 27.7)	380 (329 - 444)	---	green	Maeglin, 1973 Pronin, 1971
Trembling aspen (*Populus tremuloides* Michx.)	Canada Alberta, Manitoba & Saskatchewan	57	------	------	------	424 (360 - 497)	7.9	ovendry	Singh, 1984

[C] Predicted from breast-height cores [K] Standard error

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
POPLARS									
Trembling aspen (*Populus tremuloides* Michx.)	**Canada** British Columbia	(233)	------	------	------	416	10.0	ovendry	Hejja, 1986
		33	44 (7 - 92)	18.1 (6.0 - 34.8)	15.7 (5.4 - 25.6)	415 (304 - 519)	11.3	green	Standish, 1983
	Manitoba, New Brunswick & Saskatchewan	20 (181)	------	------	------	374	6.4	green	Jessome, 1977
		20 (34)	------	------	------	424	6.8	ovendry	Jessome, 1977
		20	------	------	------	408	---	12%MC	Jessome, 1977
	Northwest Territories	56	------	------	------	388 (306 - 521)	7.3	green	Singh, 1986
		56	------	------	------	432 (351 - 589)	7.2	ovendry	Singh, 1986
	Ontario	28	50 (20 - 90)	21.8 (10.3 - 41.8)	20.1 (14.3 - 26.8)	387 (313 - 469)	11.6	green	Alemdag, 1983
	U.S.A. New Mexico & Wisconsin	11	------	------	------	350	---	green	Markwardt & Wilson, 1935
						400	---	ovendry	
						380	---	12%MC	
	Wisconsin	2213	33 (9 - 89)	18.8 (10.2 - 45.5)	------	390[c] (359 - 437)	---	green	Maeglin, 1973
		105	39 (28 - 45)	23.9 (12.2 - 34.3)	18.3 (11.3 - 24.1)	401 (336 - 450)	---	green	Maeglin, 1973 Pronin, 1971
WALNUTS									
Black walnut (*Juglans nigra*)	**Canada** Ontario	3 (104)	------	------	------	546	6.1	green	Jessome, 1977

c Predicted from breast-height cores

Table 1. Stemwood Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
WALNUTS									
Black walnut (*Juglans nigra*)	**Canada** Ontario	3 (23)	------	------	------	626	5.8	ovendry	Jessome, 1977
		3	------	------	------	594	---	12% MC	Jessome, 1977
	U.S.A. Kentucky	5	------	------	------	510	---	green	Markwardt & Wilson, 1935
						560	---	ovendry	
						550	---	12% MC	
Butternut (*Juglans Cinerla* L.)	**Canada** Ontario	5 (46)	------	------	------	368	9.2	green	Jessome, 1977
		5 (19)	------	------	------	399	9.7	ovendry	Jessome, 1977
		5	------	------	------	388	---	12% MC	Jessome, 1977
	U.S.A. Tennessee & Wisconsin	10	------	------	------	360	---	green	Markwardt & Wilson, 1935
						400	---	ovendry	
						380	---	12% MC	

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees			Wood density			Source of data
			Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	
CEDARS									
Eastern red cedar (*Juniperus virginiana L.*)	**Canada** Ontario	16 (disks)	54 (35 - 64)	18.6 (10.8 - 38.2)	9.2 (6.3 - 12.8)	440 (397 - 493)	6.3	green	Alemdag, 1984
Eastern white cedar (*Thuja occidentalis L.*)	**Canada** Manitoba	6 (cores)	------	------	------	425	14.6	green	Micko, *et al.*, 1984
	Ontario	66 (disks)	97 (41 - 197)	22.7 (10.2 - 38.8)	13.0 (8.3 - 19.0)	304 (247 - 406)	10.4	green	Alemdag, 1984
	U.S.A. Wisconsin	136 (cores)	62 (16 - 154)	19.5 (10.7 - 39.9)	------	320 (241 - 494)	---	green	Maeglin, 1973
Western red cedar (*Thuja plicata Donn*)	**Canada** British Columbia (parent trees)	47 (cores)	107 (49 - 232)	66.2 (37.2 - 103.7)	34.1 (24.0 - 50.0)	278[A] (212 - 342)	12.1	green	Gonzalez, 1987
	New Zealand North Island	15 (cores)	73	20.0	------	341	---	green	Cown & Bigwood, 1979
	U.S.A. Idaho, Montana, Oregon & Washington	504 (cores)	------	53.6	------	328 (269 - 421)	---	green	Maeglin & Wahlgren, 1972
CYPRESS									
Yellow cypress (*Chamaecyparis nootka-tensis* (D. Don) Spach)	**Canada** British Columbia (parent & dominant trees)	13 (cores)	270 (175 - 500)	58.1 (45.0 - 82.7)	32.8 (23.0 - 40.0)	426[A] (373 - 466)	7.4	green	Gonzalez, 1987

[A] Outer-half of pith-to-bark core

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
DOUGLAS-FIR									
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	Canada								
	British Columbia (fast growth)	60 (cores)	50 (33 - 71)	54.8 (36.6 - 75.0)	36.7 (27.5 - 47.6)	534 (444 - 615)	7.1	ovendry	Jozsa, *et al.*, 1989
Coastal	British Columbia Mesachie Lake	30 (cores)	70	40.0 (30.0 - 60.8)	36.2 (25.2 - 47.1)	505 (440 - 610)	---	green	Robertson, *et al.*, 1989
	U.S.A.								
	California, Oregon & Washington	3532 (cores)	------	66.0	------	484 (462 - 548)[B]	---	green	U.S. Forest Service, 1965
	Hawaii	14 (cores)	26 (25 - 27)	34.1	15.1	404	5.0	green	Skolmen, 1963
	Canada								
Interior	British Columbia (parent trees)	1490 (cores)	------	------	------	456[A] (329 - 592)	8.5	green	Gonzalez, 1987
		1466 (cores)	------	------	------	418[C] (319 - 589)	7.3	green	Gonzalez, 1987
	Alberta								
	Didsbury (parent trees)	10 (cores)	79 (61 - 80)	35.4 (29.4 - 45.8)	20.4 (18.4 - 22.1)	415[D] (386 - 451)	5.1	green	Yanchuck, 1987
	Sundre (parent trees)	16 (cores)	76 (60 - 94)	29.9 (25.2 - 36.4)	20.8 (16.1 - 28.2)	441[D] (383 - 540)	8.9	green	Yanchuck, 1987
	U.S.A.								
	Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, Washington & Wyoming	5,601 (cores)	------	39.9	------	455 (423 - 478)[B]	---	green	U.S. Forest Service, 1965

[A] Outer-half of pith-to-bark core
[B] Range of mean values for survey units, sites or stands
[C] Inner half of pith-to-bark core
[D] Weighted average of juvenile (rings 1-20), intermediate (rings 21-50) and mature (rings 50+) wood density

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
DOUGLAS-FIR									
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	**USSR**[E] Baltic Region	229							
	Estonia		≥ 60	29.9 (23.5 - 32.5)	24.8 (21.9 - 26.8)	534 (496 - 572)	9.1	ovendry	Veveris, *et al.*, 1982
	Kaliningrad Oblast		≥ 60	50.0 (43.8 - 54.5)	33.2 (31.7 - 35.2)	588 (583 - 592)	7.0	ovendry	Veveris, *et al.*, 1982
	Latvia		≥ 60	23.7 (22.1 - 25.2)	22.3 (22.0 - 22.5)	525 (522 - 527)	8.9	ovendry	Veveris, *et al.*, 1982
	Lithuania		≥ 60	32.4 (19.6 - 39.0)	21.2 (15.2 - 27.7)	536 (509 - 574)	10.4	ovendry	Veveris, *et al.*, 1982
	France Dordogne	1433 (cores)	14	------	------	479[F]	---	12 to 15 % MC	Bastien, *et al.*, 1985
	Guebwiller	31 (cores)	60	------	------	486[G] 564[H]	7.5 6.4	10% MC 10% MC	Keller & Thoby, 1977
	Saint-Just-D'Avray	20 (cores)	62	------	------	409[G] 506[H]	7.4 7.8	10% MC 10% MC	Keller & Thoby, 1977
	Verreries de Moussans	30 (cores)	30	------	------	435[G] 471[H]	6.2 9.9	10% MC 10% MC	Keller & Thoby, 1977
	(specific site not given)	20 (cores)	50	------	------	442[H]	---	green	Polge, 1984
	New Zealand Canterbury	230 (cores)	34 (22 - 53)[B]	32.4[J] (24 - 42)[B]	------	443[H] (383 - 520)[B]	---	10% MC	Harris, 1978
	Golden Downs	100 (cores)	32 (34 - 55)[B]	------	------	469[I]	---	green	Walford, 1985
	Kaingaroa	400 (cores)	58 (54 - 64)[B]	------	------	432[I]	---	green	Walford, 1985

[B] Range of mean values for survey units, sites or stands
[E] Sampling at BH and ovendry-volume basis assumed
[F] Five rings closest to the bark
[G] Juvenile wood: 10 rings closest to the pith
[H] Mature wood: 10 rings closest to the bark
[I] 50-mm section closest to the bark
[J] Calculated from site means

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
DOUGLAS-FIR									
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	**New Zealand** North & South Islands	1900 (cores)	------ (34 - 40)[B]	35.9 (30.0 - 47.8)[B]	------	456[H] (407 - 520)[B]	---	10%MC	Harris, 1978
	Waimihia	100 (cores)	50 (49 - 50)[B]	------	------	448[I]	---	green	Walford, 1985
FIRS									
Amabilis fir (*Abies amabilis*) (Dougl.) Forbes)	**Canada** British Columbia (natural range)	345 (cores)	------	------	------	386	11.9	green	Kennedy & Swann, 1968
	(parent & dominant trees)	439 (cores)	------	------	------	346[A] (244 - 486)	9.7	green	Gonzalez, 1987
	U.S.A. Oregon & Washington	330 (cores)	------	53.1	------	414 (409 - 461)[B]	---	green	U.S. Forest Service, 1965
Balsam fir (*Abies balsamea* (L.) Mill.)	**Canada** Alberta, Manitoba & Saskatchewan	60 (disks)	------	------	------	370	---	ovendry	Singh, 1984
	Ontario	44 (disks)	55 (33 - 92)	15.5 (11.5 - 21.5)	15.2 (9.0 - 18.1)	353 (289 - 428)	8.1	green	Alemdag, 1984
	U.S.A. Maine	2823 (cores)	------	(11.7 - 53.3)	------	341 (244 - 567)	---	green	Wahlgren, *et al.*, 1968
	Wisconsin	364 (cores)	34 (10 - 114)	18.0 (10.2 - 38.9)	------	340 (232 - 474)	---	green	Maeglin, 1973
	Wisconsin	45 (cores)	(20 - 73)	21.1 (12.7 - 29.2)	14.3 (8.5 - 19.8)	320 (268 - 397)	---	green	Maeglin, 1973 Pronin, 1971

[A] Outer-half of pith-to-bark core
[I] 50-mm section closest to the bark
[B] Range of mean values for survey units, sites or stands
[H] Mature wood: 10 rings closest to the bark

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
FIRS									
Grand fir (*Abies grandis* (Dougl.) Linde)	**Canada** British Columbia (parent & dominant trees)	87 (cores)	------	------	------	379[A] (311 - 459)	7.2	green	Gonzalez, 1987
	U.S.A. California, Idaho, Montana, Oregon & Washington	862 (cores)	------	37.1	------	392 (364 - 470)	---	green	U.S. Forest Service, 1965
Subalpine fir (*Abies lasiocarpa* (Hook.) Nutt)	**Canada** Alberta, Manitoba & Saskatchewan	60 (disks)	------	------	------	410	---	ovendry	Singh, 1984
HEMLOCK									
Eastern hemlock (*Tsuga Canadensis* (L.) Carr.)	**Canada** Ontario	122 (disks)	130 (60 - 308)	29.6 (10.2 - 51.4)	16.7 (5.2 - 26.5)	417 (286 - 771)	16.9	green	Alemdag, 1984
	U.S.A. Maine	629 (cores)	------	(11.7 - 53.3)	------	415 (330 - 558)	---	green	Wahlgren, *et al.*, 1968
	Wisconsin	71 (cores)	105 (36 - 279)	35.6 (11.9 - 86.9)	------	410 (343 - 508)	---	green	Maeglin, 1973
	Wisconsin	60 (cores)	98 (42 - 140)	22.3 (11.9 - 40.4)	13.7 (6.7 - 21.3)	386 (312 - 505)	---	green	Maeglin, 1973 Pronin, 1971
Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.)	**Canada** British Columbia (natural range)	605 (cores)	------	------	------	439	9.1	green	Kennedy & Swann, 1968
	(parent & dominant trees)	1027 (cores)	------	------	------	408[A] (310 - 517)	5.8	green	Gonzalez, 1987

[A] Outer-half of pith-to-bark core

Table 2. Breast-Heigbt Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
HEMLOCKS									
Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.)	U.S.A. Alaska	29 (cores)	133 (96 - 186)	47.8 (26.4 - 74.9)	37.9 (22.3 - 53.0)	446 (360 - 590)	9.9	green	Farr, 1973
		29 (wedges)	133 (96 - 186)	47.8 (26.4 - 74.9)	37.9 (22.3 - 53.0)	425 (380 - 490)	6.4	green	Farr, 1973
	California, Idaho, Montana, Oregon & Washington	1040 (cores)	------	51.8	------	448 (437 - 499)[B]	---	green	U.S. Forest Service, 1965
LARCHES									
Tamarack (*Larix Laricina* (Du Roi) K.Koch)	Canada Alberta	10 (disks & cores)	------	------	------	445 516	9.3 7.6	green ovendry	Singh, 1987
Forest-tundra & forest grassland transition	Manitoba	25 (disks & cores)	------	------	------	473 537	7.6 8.5	green ovendry	Singh, 1987
	Saskatchewan	30 (disks & cores)	------	------	------	450 505	8.4 9.9	green ovendry	Singh, 1987
	Alberta, Manitoba & Saskatchewan (Boreal forest region)	60 disks	------	------	------	530	---	ovendry	Singh, 1984
	Alberta, central (parent trees)	4 (cores)	89 (70 - 115)	26 (22.5 - 33.0)	21 (19.2 - 23.4)	472[D] (447 - 491)	3.6	green	Yanchuk, 1987
	New Brunswick (parent trees)	176 (cores)	55 (9 - 104)	25.5 (10.8 - 43.0)	21.4 (8.0 - 31.0)	460 (364 - 553)	7.0	green	Simpson, 1988
	(comparison trees)	130 (cores)	56 (9 - 112)	24.3 (10.7 - 36.5)	19.8 (7.4 - 27.7)	447 (381 - 520)	6.6	green	Simpson, 1988
	Ontario	60 (disks)	78 (28 - 124)	20.8 (10.3 - 33.8)	19.9 (11.1 - 26.7)	512 (436 - 591)	8.3	green	Alemdag, 1984

[B] Range of mean values for survey units, sites or stands

[D] Weighted average of juvenile (rings 1-20), intermediate (rings 21-50) and mature (rings 50+) wood density

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Characteristics of sample trees: Mean dbh & range (cm)	Characteristics of sample trees: Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Wood density: Coefficient of variation (%)	Wood density: Volume basis	Source of data
LARCHES									
Tamarack (*Larix Laricina* (Du Roi) K.Koch)	**Canada** Ontario	60 (cores) (acetone-extracted)	46 (18 - 80)	14.3	12.7	460[K] 480[L]	--- ---	green green	Bond, 1985
	Ontario	240 (cores) (acetone-extracted)	59	17.6	14.2	430[K]	8.3	green	Yang & Hazenberg, 1987
	Quebec (plantation)	30 (cores)	23 (%CV = 8.8)	22.7 (%CV = 8.3)	15.2 (%CV = 8.6)	377	6.9	green	Doucet, *et al.*, 1983
	(natural stand)	30 (cores)	47 (%CV = 14.5)	30.4 (%CV = 12.0)	19.3 (%CV = 18.7)	440	6.6	green	Doucet, *et al.*, 1983
	U.S.A. Maine	14 (cores)	------	(11.7 - 42.9)	------	502 (402 - 613)	---	green	Wahlgren, *et al.*, 1968
	Wisconsin	119 (cores)	45 (15 - 133)	15.7 (10.2 - 30.0)	------	480 (341 - 583)	---	green	Maeglin, 1973
		30 (cores)	55 (30 - 141)	20.8 (13.0 - 30.5)	15.2 (9.4 - 19.8)	474 (402 - 573)	---	green	Maeglin, 1973 Pronin, 1971
Western larch (*Larix occidentalis* Nutt.)	**Canada** British Columbia (parent trees)	39 (cores) (solvent-extracted)	(30 - 90)	------	------	464[U] (420 - 512)	5.3	green	Gonzalez, 1989
						447[V] (389 - 537)	7.6	green	Gonzalez, 1989
	U.S.A. Idaho, Montana Oregon & Washington	678 (cores)	------	35.3	------	537 (514 - 546)[B]	---	green	U.S. Forest Service, 1965
PINES									
Eastern white (*Pinus strobus*)	**Canada** Nova Scotia	19 (cores)	61 (40 - 87)	32.3 (24.6 - 80)	20.6 (14.0 - 25.5)	348 (299 - 467)	12.3	green	Sebastian, 1986 Mullin, 1987

B Range of mean values for survey units, sites or stands
U Mature wood: excluding 15 rings closest to the pith
K Juvenile wood: 20-26 rings closest to the pith
V Juvenile wood: 15 rings closest to the pith
L Mature wood: excluding 20-26 rings closest to the pith

Table 2. Breast-Height Density - Softwoods

			Characteristics of sample trees			Wood density			
Species	Geographic origin	No. trees (tests) & sample description	Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Eastern white (*Pinus strobus*)	Canada Ontario	129 (disks)	90 (19 - 255)	34.5 (9.9 - 68.7)	21.1 (5.4 - 35.9)	349 (246 - 523)	12.8	green	Alemdag, 1984
	U.S.A. Illinois	240 (cores)	13 (5 - 36)	------	9.2 (4.9 - 24.7)	304 (274 - 347)	5.3	green	Gilmore, 1968
	Maine	176 (cores)	------	(11.7 - 53.3)	------	339 (242 - 548)	---	green	Wahlgren *et al.*, 1968
	New Hampshire	75 (cores)	46	------	------	338 (278 - 398)	---	green	Gammon, 1969
	Georgia, N. Carolina & Tennessee	559 (cores)	48	38.9	------	350 (250 - 540)	9.4	green	Saucier & Taras, 1969
	Wisconsin	175 (cores)	47 (9 - 124)	34.0 (13.7 - 77.2)	------	350 (229 - 463)	---	green	Maeglin, 1973
		60 (cores)	56 (24 - 88)	21.6 (12.7 - 35.1)	------	338 (288 - 398)	---	green	Maeglin, 1973
Jack pine (*Pinus banksiana* Lamb.)	Canada Alberta, Manitoba & Saskatchewan (boreal forest region)	60 (disks)	------	------	------	470	---	ovendry	Singh, 1984
Forest-tundra & forest grassland transition	Alberta	8 (disks & cores)	------	------	------	432 481	6.4 7.1	green ovendry	Singh, 1987
	Manitoba	110 (disks & cores)	------	------	------	415 467	13.2 14.1	green ovendry	Singh, 1987
	Saskatchewan	91 (disks & cores)	------	------	------	414 462	12.1 12.3	green ovendry	Singh, 1987

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Jack pine (*Pinus banksiana* Lamb.)	Canada								
	Manitoba (plantation)	251 (disks)	16	5.7 (SD = 1.1)	------	359	6.6	green	Chapman, 1989
	New Brunswick (parent trees)	146 (cores)	55 (30 - 88)	22.9 (12.9 - 34.6)	19.7 (5.8 - 27.3)	404 (328 - 526)	7.6	green	Simpson, 1988
	(comparison trees)	146 (cores)	55 (30 - 88)	22.1 (12.8 - 32.1)	18.5 (11.7 - 25.6)	401 (318 - 469)	5.5	green	Simpson, 1988
	Ontario	69 (disks)	------	16.6 (10.2 - 26.8)	17.8 (11.9 - 23.5)	438 (367 - 528)	7.6	green	Alemdag, 1984
		310 (disks)	(20 - 90)	------	------	405	---	green	Balatinecz, 1982
	(parent trees)	1042 (disks)	(25 - 90)	------	------	390[M] 440[N]	--- ---	green green	Buchert, 1987
	(progeny test)	611 (whole disks)	20	9.5 (3.5 - 17.9)	10.5 (4.5 - 14.6)	372 (310 - 472)	6.6	green	Keith & Chauret, 1989
	(progeny test)	60 (cores)	22	13.5 (11.5 - 17.0)	------	374 (334 - 423)	4.9	green	Villeneuve, *etal.*, 1987
	Saskatchewan (parent trees)	74 (cores)	52 (31 - 90)	15.7 (9.7 - 28.2)	14.7 (9.8 - 21.6)	382[G] (315 - 457)	7.2	green	Roddy, 1983
	(parent trees)	74 (cores)	52 (31 - 90)	15.7 (9.7 - 28.2)	14.7 (9.8 - 21.6)	419[O] (358 - 500)	6.8	green	Roddy, 1983
	(parent trees)	86 (cores)	52 (31 - 90)	15.7 (9.7 - 28.2)	14.7 (9.8 - 21.6)	405[Q] (349 - 460)	6.3	green	Roddy, 1983
	(parent trees)	91 (disks)	54 (30 - 97)	15.7 (9.7 - 31.0)	21.9 (10.5 - 51.0)	420 (360 - 490)	6.1	green	Roddy, 1983
	U.S.A.								
	Minnesota	450 (cores)	39 (26 - 59)[B]	>10.2	------	387[H] (280 - 520)	36[P]	green	Grigal & Sucoff, 1966

B Range of mean values for survey units, sites or stands
M Juvenile wood: 20 rings closest to the pith
P Standard deviation
G Juvenile wood: 10 rings closest to the pith
N Mature wood: excluding 20 rings closest to the pith
Q Weighted average of juvenile and mature wood density
H Mature wood: 10 rings closest to the bark
O Mature wood: excluding 10 rings closest to the pith

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Jack pine (*Pinus banksiana* Lamb.)	U.S.A. Wisconsin	533 (cores)	29 (9 - 78)	18.3 (10.4 - 42.4)	------	400 (300 - 554)	---	green	Maeglin, 1973
		59 (cores)	43 (21 - 61)	21.1 (11.7 - 31.5)	15.2 (8.8 - 20.1)	404 (318 - 499)	---	green	Maeglin, 1973 Pronin, 1971
		120 (disks)	(35 - 39)[B]	(10.7 - 17.5)[B]	(11.1 - 16.1)[B]	414 (399 - 436)[B]	---	green	Wilde, *et al.*, 1951
Lodgepole pine (*Pinus contorta* var. Latifolia Engelm.)	Canada Alberta (Kananaskis Forest Res. Stn.)	85 (disks)	100	18.0	18.5	488 (382 - 617)	8.0	ovendry	Johnstone, 1970
	Alberta (west central)	30 (cores) (solvent-extracted)	91 (76 - 115)	37.6 (30.5 - 43.7)	25.8 (21.1 - 29.0)	365 (322 - 408)	6.9	green	Jozsa, 1989
	Alberta (natural range)	60 (cores) (solvent-extracted)	90	28.7	20.3	370[R]	11.1	green	Taylor, *et al.*. 1982
	Alberta (N-S gradient) (boreal forest region)	60 (disks)	------	------	------	440	---	ovendry	Singh, 1984
	Alberta (central) (parent trees)	62 (cores & disks)	99.6 (45 - 138)	26.0 (17.6 - 36.2)	24.2 (19.8 - 29.0)	420[D] (349 - 520)	7.6	green	Yanchuk, 1987
	Alberta (southeast) (parent trees)	5 (cores & disks)	90 (88 - 94)	29.0 (22.9 - 34.3)	21.1 (19.5 - 23.2)	402[D] (351 - 457)	8.7	green	Yanchuk, 1987
	British Columbia (parent trees)	1000 (cores) (solvent-extracted)	------	------	------	409[A] (315 - 532)	---	green	Gonzalez, 1987
						368[C] (280 - 478)	---	green	

[A] Outer-half of pith-to-bark core
[D] Weighted average of juvenile (rings 1-20), intermediate (rings 21-50) and mature (rings 50+) wood density
[B] Range of mean values for survey units, sites or stands
[R] Excluding 30 rings closest to the pith
[C] Inner half of pith-to-bark core

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Characteristics of sample trees: Mean dbh & range (cm)	Characteristics of sample trees: Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Wood density: Coefficient of variation (%)	Wood density: Volume basis	Source of data
PINES									
Lodgepole pine (*Pinus contorta* var. Latifolia Engelm.)	Canada British Columbia (southeast) (fast growth)	30 (cores) (solvent-extracted)	85 (72 - 96)	35.7 (29.0 - 42.1)	27.2 (22.8 - 30.3)	385[S] (339 - 457)	6.2	green	Jozsa, 1989
	Sweden North	65 (cores)	(36 - 43)[B]	------	------	372	7.8	green	Andersson, 1987a
	South	93 (cores)	(39 - 43)[B]	------	------	426	10.1	green	Andersson, 1987a
	U.S.A. California, Colorado Idaho, Montana, Oregon, Utah & Wyoming	3516 (cores)	------	23.6	------	412 (264 - 554)	---	green	Maeglin & Wahlgren, 1972
	Idaho, Utah & Wyoming (dominant trees)	44 (cores)	(21 - 90)[T]	(5.6 - 30.0)[B]	------	386 (315 - 482)	---	green	Tackle, 1962
		44 (disks)	(21 - 90)[T]	(5.6 - 30.0)[B]	------	396 (331 - 486)	---	green	Tackle, 1962
Red pine (*Pinus resinosa* Ait.)	Canada Ontario	94 (disks)	74 (18 - 253)	29.0 (10.3 - 55.1)	18.4 (7.1 - 34.4)	392 (226 - 543)	15.2	green	Alemdag, 1984
	U.S.A. Illinois (plantation)	300 (cores)	13 (6 - 29)	------	7.4 (3.7 - 15.5)	342 (296 - 394)	5.8	green	Gilmore, 1968
	Maine	9 (cores)	------	(11.7 - 42.9)	------	428 (329 - 491)	---	green	Wahlgren, *et al.*, 1968
	(plantation)	100 (cores)	(20 - 25)	15.9	10.4	331 (322 - 350)	---	green	Baker, 1967

B Range of mean values for survey units, sites or stands

S Weighted by ring width

T Range of stand age class

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
PINES									
Red pine (*Pinus resinosa* Ait.)	U.S.A. Wisconsin (natural range)	101 (cores)	42 (17 - 93)	27.7 (11.2 - 51.8)	------	390 (249 - 539)	---	green	Maeglin, 1973
	(natural range)	50 (cores)	51 (13 - 82)	21.3 (11.9 - 46.7)	15.5 (7.0 - 23.5)	380 (329 - 449)	---	green	Maelin, 1973 Pronin, 1971
	(plantation)	66 (cores)	26 (20 - 38)	15.2 (6.4 - 26.2)	10.9 (4.6 - 19.2)	342 (296 - 406)	---	green	Maeglin, 1973
	(plantation)	25 (cores)	23 (10 - 56)	19.3 (10.7 - 46.0)	------	350 (295 - 423)	---	green	Maeglin, 1973
SPRUCES									
Black spruce (*Picea mariana* (Mill.) B.C.P.)	Canada Alberta (central) (parent trees)	16 (disks & cores)	82 (54 - 112)	23.6 (19.0 - 34.1)	21.1 (17.2 - 25.6)	398[D] (340 - 520)	7.5	green	Yanchuk 1987
	Alberta, Manitoba & Saskatchewan (Boreal forest region)	58 (disks)	------	------	------	450	---	ovendry	Singh, 1984
Forest-tundra & forest grassland transitions	Alberta	140 (disks & cores)	------	------	------	453 511	10.9 10.8	green ovendry	Singh, 1987
	Manitoba	349 (disks & cores)	------	------	------	467 532	10.3 10.8	green ovendry	Singh, 1987
	Saskatchewan	209 (disks & cores)	------	------	------	460 525	10.2 10.4	green ovendry	Singh, 1987
	Newfoundland (central) (dominant & co-dominant trees)	>600 (cores)	(10 - 95)[B]	(5.0 - 20.9)[B]	(4.3 - 16.1)[B]	405 (385 - 419)[B]	5.8	green	Hall, 1984

[B] Range of mean values for survey units, sites or stands

[D] Weighted average of juvenile (rings 1-20), intermediate (rings 21-50) and mature (rings 50+) wood density

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
Black spruce (*Picea mariana* (Mill.) B.C.P.)	**Canada** New Brunswick (parent trees)	84 (cores)	63 (32 - 103)	22.2 (15.8 - 29.5)	18.8 (11.8 - 24.0)	408 (322 - 475)	6.2	green	Simpson, 1988
	(comparison trees)	84 (cores)	64 (35 - 130)	21.2 (14.8 - 29.4)	17.4 (11.6 - 21.4)	404 (364 - 457)	4.5	green	Simpson, 1988
	Nova Scotia (parent trees)	138 (cores)	70 (47 - 150)	21.9 (12.9 - 34.0)	15.4 (10.5 - 21.0)	413 (317 - 503)	6.9	green	Sebastian, 1986 Mullin, 1986
	Ontario (natural range)	39 (disks)	------	13.4 (9.4 - 22.2)	13.4 (8.2 - 18.9)	440 (370 - 536)	9.5	green	Alemdag, 1984
	Ontario, (Marks Lake) (parent trees)	30 (cores)	~60	20.4	18.2	413[M] 385[N]	9.7 7.3	green green	Meilleur, 1987
	Ontario (progeny tests)	59 (cores)	20	11.3 (9.2 - 14.2)	------	395[S] (349 - 461)	4.7	green	Villeneuve, *et al.*, 1987
	U.S.A. Alaska (Interior)	77 (cores)	------	≥12.7	------	423	8.3	green	Bom, 1966
	Maine	59 (cores)	------	(11.7 - 32.8)	------	441 (355 - 572)	---	green	Wahlgren, *et al.*, 1968
	Wisconsin	122 (cores)	45 (16 - 124)	14.7 (10.2 - 30.5)	------	420 (314 - 572)	---	green	Maeglin, 1973
		30 (cores)	55 (32 - 92)	20.8 (13.5 - 32.3)	14.9 (10.7 - 18.0)	387 (334 - 477)	---	green	Maeglin, 1973 Pronin, 1971
Red spruce (*Picea rubens* Sarg.)	**Canada** Nova Scotia (parent trees)	228 (cores)	67 (37 - 107)	24.2 (16.8 - 39.8)	19.2 (14.5 - 27.0)	394 (309 - 488)	7.6	green	Sebastian, 1986 Mullin, 1986

[M] Juvenile wood: 20 rings closest to the pith [N] Mature wood: excluding 20 rings closest to the pith [S] Weighted by ring width

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
Red spruce (*Picea rubens* Sarg.)	**U.S.A.** Maine	2444 (cores)	------	(11.7 - 53.1)	------	404 (287 - 603)	---	green	Wahlgren, *et al.*, 1968
Sitka spruce (*Picea sitchensis* (Bong.) Carr.)	**Canada** British Columbia (parent & dominant trees)	25 (cores)	(92 - 250)	------	------	361[A] (307 - 413)	7.2	green	Gonzalez, 1987
		73 (cores)	(50 - 60)	------	------	319[A] (279 - 393)	7.8	green	Gonzalez, 1987
	Ireland (1.9 m x 1.9 m spacing)	10 (cores)	30	22.2	19	419	---	12%MC	Savill & Sandels, 1983
	(2.4 m x 2.4 m spacing)	8 (cores)	23	22.8	17.5	372 (351 - 425)	8.9	green	Gardiner & O'Sullivan, 1978
	(4.5 m x 4.5 m spacing)	8 (cores)	23	28.6	16.0	325 (284 - 401)	10.6	green	Gardiner & O'Sullivan, 1978
		30 (cores)	(35 - 44)	(26 - 36)	(19 - 25)	365 (301 - 471)	11.0	green	Carminati, 1986
		30 (blocks)	(35 - 44)	(26 - 36)	(19 - 25)	422 (362 - 580)	11.0	12.5%	Carminati, 1986
	U.S.A. Alaska (Interior)	16 (cores)	------	$\geq$ 12.7	------	400	11.0	green	Bom, 1966
	Alaska	35 (cores)	129 (75 - 180)	50.3 (28.4 - 72.4)	38.7 (23.5 - 55.5)	392 (320 - 470)	10.0	green	Farr, 1973
		35 (wedges)	129 (75 - 180)	50.3 (28.4 - 72.4)	38.7 (23.5 - 55.5)	378 (320 - 450)	9.0	green	Farr, 1973

[A] Outer-half of pith-to-bark core

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
White spruce (*Picea glauca* (Moench) Voss.)	**Canada**								
	Alberta Edson & Footner Lake	40 (cores & disks) (solvent-extracted)	(62 - 86)[B]	(30.6 - 33)[B]	(19.5 - 24.5)[B]	338	6.5	green	Taylor, *et al*, 1982
	Slave Lake	34 (cores & disks) (solvent-extracted)	46	------	------	364 (331 - 441)	7.1	green	Wang & Micko, 1984
	Alberta (parent trees) (Footner Lake)	114 (disks)	104 (53 - 178)	41.8 (25.3 - 74.5)	30.2 (20.7 - 44.0)	335[D] (270 - 463)	8.7	green	Yanchuk, 1987
	(Lac La Biche)	83 (disks)	100 (54 - 130)	36.1 (24.9 - 49.9)	29.6 (21.0 - 37.0)	349[D] (302 - 395)	6.3	green	Yanchuk, 1987
	Alberta, Manitoba & Saskatchewan (Boreal forest region)	59 (disks)	------	------	------	398	8.9	ovendry	Singh, 1984
	British Columbia (Interior) (parent trees and dominant trees)	1206 (cores)	------	------	------	328[A] (256 - 429)	7.8	green	Gonzalez, 1987
Forest-tundra & forest grassland transition	Manitoba	22 (cores & disks)	------	------	------	380 424	12.9 12.8	green ovendry	Micko, *et al*.,, 1984
	New Brunswick (Northwestern)	20 (disks)	89 (39 - 185)	37.0 (28.6 - 50.1)	19.1 (9.6 - 24.1)	355 (300 - 393)	7.0	green	Caron, 1980
		20 (cores)	89 (39 - 185)	37.0 (28.6 - 50.1)	19.1 (9.6 - 24.1)	343 (304 - 391)	6.9	green	Caron, 1980
	New Brunswick (parent trees)	247 (cores)	60 (21 - 142)	30.6 (10.6 - 53.5)	21.5 (7.5 - 32.5)	350 (286 - 442)	8.0	green	Simpson, 1988
	(comparison trees)	247 (cores)	61 (18 - 151)	29 (12.2 - 46.2)	19.6 (6.6 - 28.9)	349 (306 - 428)	6.9	green	Simpson, 1988

[A] Outer-half of pith-to-bark core

[B] Range of mean values for survey units, sites or stands

[D] Weighted average of juvenile (rings 1-20), intermediate (rings 21-50) and mature (rings 50+) wood density

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
White spruce (*Picea glauca* (Moench) Voss.)	Canada Northwest Territories (Southwestern)	57 (disks)	------	------	------	439	14.5	ovendry	Singh, 1987
	Nova Scotia (parent trees)	247 (cores)	55 (33 - 80)	23.7 (2.7 - 48)	18.6 (12.7 - 29.3)	381 (306 - 454)	7.1	green	Sebastian, 1986 Mullin, 1986
	Ontario	56 (disks)	------	16.7 (9.9 - 35.8)	13.9 (6.2 - 23.2)	386 (310 - 495)	9.5	green	Alemdag, 1984
	Quebec (provenance test)	207 (disks)	20	9.6 (6.7 - 12.3)	8.2 (5.7 - 11.0)	344 (283 - 417)	7.0	green	Beaulieu & Corriveau, 1985
	Quebec	377 (cores)	39 (20 - 97)	30.4 (9 - 65.6)	14.5 (4 - 29.4)	353[V]	13.9	green	Corriveau *et al.*., 1987
		377 (cores)	39 (20 - 97)	30.4 (9 - 65.6)	14.5 (4 - 29.4)	328[U]	11.9	green	Corriveau *et al.*., 1987
	Quebec (Val Cartier Experimental Station)	780 (cores)	18	13.3 (8.8 - 18.9)	8.7 (6.1 - 11.8)	329	6.9	green	Corriveau, *et al.*, 1988
	Saskatchewan (parent trees)	31 (cores)	90 (65 - 133)	38.1 (28.4 - 49.9)	26.7 (19.0 - 33.0)	342[G] (273 - 403)	9.1	green	Roddy, 1986
						336[O] (292 - 374)	5.9	green	Roddy, 1986
		31 (disks)	90 (65 - 133)	38.1 (28.4 - 49.9)	26.7 (19.0 - 33.0)	339 (311 - 382)	4.9	green	Roddy, 1986
		28 (cores)	90 (65 - 133)	38.1 (28.4 - 49.9)	26.7 (19.0 - 33.0)	335[Q] (297 - 370)	5.7	green	Roddy, 1986
	U.S.A. Alaska (Interior)	567 (cores)	------	≥ 12.7	------	400	11.9	green	Born, 1966

G Juvenile wood: 10 rings closest to the pith
U Mature wood: excluding 15 rings closest to the pith
O Mature wood: excluding 10 rings closest to the pith
V Juvenile wood: 15 rings closest to the pith
Q Weighted average of juvenile and mature wood density

Table 2. Breast-Height Density - Softwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & range (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
SPRUCES									
White spruce (*Picea glauca* (Moench) Voss.)	U.S.A. Maine	216 (cores)	------	(11.7 -53.1)	------	379 (278 - 494)	---	green	Wahlgren, *et al.*, 1968
	Wisconsin	38 (cores)	38 (17 - 64)	21.3 (10.3 - 48.3)	------	370 (273 - 505)	---	green	Maeglin, 1973
		30 (cores)	44 (26 - 63)	21.3 (13.0 - 34.3)	14.3 (8.8 - 18.9)	341 (269 - 408)	---	green	Maeglin, 1973 Pronin, 1971

Table 2. Breast-Height Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & rnage (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
ALDER									
Red alder (*Alnus rubra* Bong.)	**Canada** Alberta	21 (disks & cores)	------	------	------	392 442	13.3 11.3	green ovendry	Singh, 1987
	Manitoba	25 (disks & cores)	------	------	------	437 499	18.7 20.0	green ovendry	Singh, 1987
	Saskatchewan	22 (disks & cores)	------	------	------	422 494	12.3 12.0	green ovendry	Singh, 1987
	U.S.A. Washington	56 (cores)	52 (35 - 73)[B]	29.5 (27.2 - 32.5)[B]	26.2 (21.9 - 29.2)[B]	390 (300 - 460)	---	green	Debell & Wilson, 1978 Harrington & Debell, 1980
ASHES									
Black ash (*Fraxinus nigra* Marsh.)	**Canada** Ontario	18 (disks)	74 (40 - 120)	18.3 (10.1 - 38.2)	15.1 (9.2 - 20.3)	546 (513 - 590)	4.4	green	Alemdag, 1984
	U.S.A. Wisconsin	263 (cores)	61 (18 - 160)	20.2 (10.2 - 42.4)	------	515 (403 - 691)	---	green	Maeglin, 1973
Green ash (*Fraxinus pennsylvanica* var. subintegerrima (Vahl) Fern.)	**Canada** Alberta & Manitoba	20 (disks & cores)	------	------	------	527 609	15.9 17.5	green ovendry	Singh, 1987
	U.S.A. Wisconsin	22 (cores)	37 (14 - 90)	20.1 (11.4 - 36.6)	------	554 (503 - 630)	---	green	Maeglin, 1973
Red ash (*Fraxinus, pennsylvanica* Marsh.)	**Canada** Ontario	24 (disks)	61 (35 - 89)	23.3 (12.0 - 40.2)	19.7 (13.5 - 26.7)	562 (505 - 643)	6.7	green	Alemdag, 1984

[B] Range of mean values for survey units, sites or stands

Table 2. Breast-Height Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Meandbh & range (cm)	Mean ht. & rnage (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
ASHES									
White ash (*Fraxinus americana* L.)	**Canada** Ontario	64 (disks)	70 (37 - 145)	26.3 (10.7 - 53.7)	18.8 (11.8 - 26.9)	598 (348 - 706)	9.0	green	Alemdag, 1984
	U.S.A. Wisconsin	16 (cores)	41 (31 - 56)	21.0 (12.2 - 33.0)	------	563 (479 - 632)	---	green	Maeglin, 1973
BASSWOOD									
Basswood (*Tilia americana* L.)	**Canada** Ontario	62 (disks)	70 (23 - 112)	30.8 (12.3 - 54.8)	19.6 (10.0 - 26.1)	436 (341 - 621)	13.7	green	Alemdag, 1984
	U.S.A. Wisconsin	174 (cores)	43 (13 - 126)	22.7 (10.7 - 43.9)	------	333 (250 - 490)	---	green	Maeglin, 1873
BEECH									
Beech (*Fagus grandifolia* Ehrh.)	**Canada** Ontario	63 (disks)	97 (40 - 148)	27.8 (10.5 - 44.1)	19.9 (9.7 - 26.5)	613 (523 - 699)	7.2	green	Alemdag, 1984
	U.S.A. Wisconsin	7 (cores)	54 (33 - 68)	31.5 (25.1 - 42.7)	------	548 (317 - 696)	---	green	Maeglin, 1973
BIRCHES									
White birch (*Betula papyrifera* Marsh.)	**Canada** Alberta, Manitoba & Saskatchewan (Boreal forest region)	60 (disks)	------	------	------	620	---	ovendry	Singh, 1984

Table 2. Breast-Height Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & rnage (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
BIRCHES									
White birch	**Canada**								
(*Betula papyrifera* Marsh.)	Alberta	12 (disks & cores)	------	------	------	512 598	12.6 12.6	green ovendry	Singh, 1987
Forest-tundra & forest grassland transition	Manitoba	26 (disks & cores)	------	------	------	470 535	12.9 14.6	green ovendry	Singh, 1987
	Saskatchewan	40 (disks & cores)	------	------	------	479 598	11.3 12.6	green ovendry	Singh, 1987
	Ontario	44 (disks)	72 (46- 90)	21.3 (13.3 - 32.7)	19.6 (14.9 - 22.3)	543 (495 - 596)	3.7	green	Alemdag, 1984
	U.S.A.								
	Alaska	296 (cores)	------	≥ 12.7	------	508	10.2	green	Born, 1966
	Wisconsin	433 (cores)	39 (10 - 91)	17.5 (10.2 - 36.3)	------	517 (392 - 653)	---	green	Maeglin, 1973
Yellow birch	**Canada**								
(*Betula alleghaniensis* Britton (*Betula lutea* Michx. f.)	Ontario	83 (disks)	107 (37 - 210)	37.2 (10.4 - 70.3)	20.5 (10.0 - 25.6)	596 (435 - 695)	8.5	green	Alemdag, 1984
	U.S.A.								
	Wisconsin	31 (cores)	56 (11 - 164)	23.4 (10.2 - 39.6)	------	548 (489 - 619)	---	green	Maeglin, 1973
CHERRY									
Black cherry	**Canada**								
(*Prunus serotina* Ehrh.)	Ontario	64 (disks)	55 (26 - 91)	26.1 (9.5 - 49.6)	18.6 (8.4 - 25.9)	564 (238 - 654)	9.8	green	Alemdag, 1984

Table 2. Breast-Height Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & rnage (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
ELM									
White elm (*Ulnus americana* L.)	**Canada** Alberta & Manitoba	20 (disks & cores)	------	------	------	503 600	13.2 12.5	green ovendry	Singh, 1987
	Ontario	68 (disks)	63 (26 - 129)	23.0 (11.3 - 55.2)	14.6 (8.0 - 23.2)	586 (513 - 708)	7.7	green	Alemdag, 1984
	U.S.A. Wisconsin	339 (cores)	45 (7 - 155)	25.0 (10.2 - 74.2)	------	567 (429 - 726)	---	green	Maeglin, 1973
HICKORY									
Hickory (*Carya* spp.)	**Canada** Ontario	67 (disks)	63 (24 - 110)	23.5 (10.0 - 46.6)	21.3 (11.6 - 29.4)	618 (541 - 696)	5.5	green	Alemdag, 1984
Shagbark hickory (*Carya ovata* (Mill.) K. Koch)	**U.S.A.** Wisconsin	39 (cores)	55 (11 - 109)	23.4 (12.2 - 37.3)	------	642 (529 - 728)	---	green	Maeglin, 1973
	Mid-South U.S.A.	30 (cores)	82	27.5	24.3	650[N]	---	green	Taylor, 1977
MAPLES									
Manitoba maple (*Acer negundo* L.)	**Canada** Manitoba	18 (disks & cores)	------	------	------	470 529	14.6 19.4	green ovendry	Singh, 1987
Red maple (*Acer rubrum* L.)	**Canada** Ontario	36 (disks)	71 (32 - 122)	28.1 (13.5 - 45.2)	20.0 (10.8 - 25.4)	602 (510 - 682)	6.6	green	Alemdag, 1984
	U.S.A. Wisconsin	171 (cores)	42 (11 - 93)	18.7 (10.4 - 40.4)	------	530 (413 - 662)	---	green	Maeglin, 1973

[N] Mature wood: excluding 20 rings closest to the pith

Table 2. Breast-Height Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & rnage (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
MAPLES									
Silver maple (*Acer saccharinum* L.)	**Canada** Ontario	31 (disks)	41 (28 - 58)	27.4 (13.3 - 45.3)	22.0 (14.2 - 26.4)	485 (428 - 552)	6.6	green	Alemdag, 1984
	U.S.A. Wisconsin	4 (cores)	42 (22 - 63)	22.9 (19.1 - 26.2)	------	465 (445 - 597)	---	green	Maeglin, 1973
Sugar maple (*Acer saccharum* Marsh.)	**Canada** Ontario	86 (disks)	80 (34 - 139)	31.4 (10.0 - 57.8)	19.7 (9.9 - 26.4)	614 (498 - 716)	7.8	green	Alemdag, 1984
	U.S.A. Wisconsin	863 (cores)	50 (18 - 140)	21 (10.2 - 54.1)	------	638 (456 - 799)	---	green	Maeglin, 1973
OAKS									
Bur oak (*Quercus macrocarpa* Michx.)	**Canada** Alberta & Manitoba	35 (disks & cores)	------	------	------	584 678	15.0 16.9	green ovendry	Singh, 1987
	U.S.A. Wisconsin	69 (cores)	61 (19 - 139)	24.4 (11.9 - 47.0)	------	645 (532 - 802)	---	green	Maeglin, 1973
Red oak (*Quercus rubra* L.)	**Canada** Ontario	100 (disks)	70 (35 - 101)	25.6 (10.1 - 53.3)	16.6 (9.9 - 23.0)	590 (413 - 746)	8.3	green	Alemdag, 1984
	U.S.A. Wisconsin	820 (cores)	51 (8 - 114)	25.6 (10.2 - 51.6)	------	582 (480 - 710)	---	green	Maeglin, 1973

Table 2. Breast-Height Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees			Wood density			Source of data
			Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & rnage (m)	Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	
OAKS									
White oak (*Quercus alba* L.)	**Canada** Ontario	49 (disks)	81 (17 - 127)	28.5 (9.9 - 74.3)	13.0 (5.0 - 21.5)	647 (587 - 701)	5.0	green	Alemdag, 1984
	U.S.A. Wisconsin	125 (cores)	67 (19 - 123)	26.1 (11.2 - 50.3)	------	657 (576 - 737)	---	green	Maeglin, 1973
POPLARS									
Balsam poplar (*Populus balsamifera* L.)	**Canada**								
Boreal forest region	Alberta, Manitoba & Saskatchewan	60 (disks)	------	------	------	390	---	ovendry	Singh, 1984
Forest-tundra & forest grassland transition	Alberta, Manitoba & Saskatchewan	39 (disks & cores)	------	------	------	386 436	13.3 15.6	green ovendry	Singh, 1987
	Ontario	87 (disks)	42 (24 - 90)	25.5 (10.0 - 53.2)	18.8 (8.7 - 27.0)	351 (286 - 452)	7.8	green	Alemdag, 1984
	U.S.A. Alaska	35 (cores)	------	≥ 12.7	------	345	13.7	green	Bom, 1966
	Wisconsin	16 (cores)	36 (14 - 81)	22.0 (11.2 - 36.3)	------	339 (217 - 424)	---	green	Maeglin, 1973
Largetooth aspen (*Populus grandidentata* Michx.)	**Canada** Ontario	11 (disks)	59 (55 - 81)	25.4 (15.3 - 39.2)	18.8 (14.1 - 23.0)	411 (388 - 436)	3.3	green	Alemdag, 1984

Table 2. Breast-Height Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Mean dbh & range (cm)	Mean ht. & rnage (m)	Wood density: Wood density & range (kg/m³)	Coefficient of variation (%)	Volume basis	Source of data
POPLARS									
Largetooth aspen (*Populus grandidentata* Michx.)	U.S.A. Wisconsin	100 (cores)	41 (33 - 50)	24.1 (13.5 - 39.9)	21.6 (12.8 - 27.7)	398 (300 - 486)	---	green	Maeglin, 1973 Pronin, 1971
		497 (cores)	37 (13 - 94)	21.3 (10.2 - 53.8)	------	390 (283 - 564)	---	green	Maeglin, 1973
Trembling aspen (*Populus tremuloides* Michx.)	**Canada** Alberta, Manitoba & Saskatchewan (Boreal forest region)	57 (disks)	------	------	------	430	---	ovendry	Singh, 1984
Forest-tundra & forest granssland transition	Alberta	22 (disks & cores)	------	------	------	397 451	7.7 7.9	green ovendry	Singh, 1987
	Manitoba	175 (disks & cores)	------	------	------	401 458	11.7 13.9	green ovendry	Singh, 1987
	Saskatchewan	19 (disks & cores)	------	------	------	408 461	9.5 11.0	green ovendry	Singh, 1987
	Ontario	28 (disks)	50 (20 - 90)	21.8 (10.3 - 41.8)	20.1 (14.3 - 26.8)	390 (311 - 487)	11.3	green	Alemdag, 1984
	U.S.A. Alaska	74 (cores)	------	≥ 12.7	------	374	9.2	green	Born, 1966
	Michigan & Wisconsin	225 (cores)	36 (23 - 44)[B]	19.7 (15.7 - 24.4)[B]	16.9 (13.6 - 20.6)[B]	391 (365 - 433)	4.7	green	Einspahr & Benson, 1967
	Wisconsin	2213 (cores)	33 (9 - 89)	18.8 (10.2 - 45.5)	------	400 (297 - 554)	---	green	Maeglin, 1973
		105 (cores)	39 (28 - 45)	23.9 (12.2 - 34.3)	18.3 (11.3 - 24.1)	412 (358 - 464)	---	green	Maeglin, 1973 Pronin, 1971
		45 (disks)	(39 - 56)[B]	22.8 (17.5 - 30.7)	------	372 (325 - 421)	---	green	Wilde & Paul, 1959

B Range of mean values for survey units, sites or stands

Table 2. Breast-Height Density - Hardwoods

Species	Geographic origin	No. trees (tests) & sample description	Characteristics of sample trees: Mean age & range (yr)	Meandbh & range (cm)	Meanht. & rnage (m)	Wood density: Wood density & range (kg/m^3)	Coefficient of variation (%)	Volume basis	Source of data
WILLOW									
Willow	Canada								
(*Salix* spp.)	Alberta	39	------	------	------	457	11.1	green	Singh, 1987
		(disks & cores)				513	11.3	ovendry	
Forest-tundra & forest	Manitoba	100	------	------	------	463	10.1	green	Singh, 1987
grassland transition		(disks & cores)				524	11.0	ovendry	
	Saskatchewan	19	------	------	------	465	10.2	green	Singh, 1987
		(disks & cores)				527	9.2	ovendry	

APPENDIX 1

VOLUMETRIC SHRINKAGE OF WOODS GROWN IN CANADA AND THE UNITED STATES

Formula for converting basic density (based on green volume) to density based on ovendry volume:

$$\text{Density, based on ovendry volume} = \frac{\text{Basic density}}{100 - \text{volumetric shrinkage (\%)}} \times 100$$ (Kollmann and Cote 1968)[1]

Volumetric shrinkage of woods grown in Canada and the United States

Species	Shrinkage (%) from green to ovendry moisture content, based on green dimensions	
	Canadian-grown[A]	United States-grown[B]
Softwoods		
Cedar:		
Eastem red cedar	---	7.8
Eastem white cedar	6.4	7.2
Westem red cedar	7.8	6.8
Yellow cypress	9.4	---
Douglas-fir	11.9	12.4 (coast) 10.7 (interior north) 11.8 (interior west)
Fir:		
Amabilis fir	12.5	13.0
Balsam fir	10.7	11.2
Grand fir	---	11.0
Subalpine fir	---	9.4
Hemlock:		
Eastem hemlock	11.2	9.7
Mouintain hemlock	---	11.1
Westem hemlock	13.0	12.4
Larch:		
Tamarack	11.2	13.6
Westem larch	14.0	14.0
Pine:		
Eastem white pine	8.2	8.2
Jack pine	9.6	10.3
Lodgepole pine	11.4	11.1
Ponderosa pine	10.5	9.7
Red pine	9.6	11.3
Shore pine	---	---
Westem pine	10.7	11.8
Spruce:		
Black spruce	11.1	11.3
Engelmann spruce	11.6	11.0
Red spruce	11.7	11.8
Sitka spruce	11.7	11.5
White spruce	11.3	---

[A] Source: Jessome, A.P. 1977. Strength and related properties of woods grown in Canada. Environ. Can., Can. For. Serv. For. Prod. Lab., Ottawa, Ontario. For. Tech. Rep. 21.

[B] Source: U.S. Dept. of Agriculture. 1974. Wood handbook: Wood as an engineering material. Forest Service Agricultural Handbook No. 72. U.S. Dept. of Agriculture, For. Prod. Lab., Madison, Wisconsin.

[1] Kollman, F.F.P.; Cote, W. 1968. Principles of wood science and technology. I. Solid wood. Springer-Verlag New York Inc., New York, N.Y.

Volumetric shrinkage of woods grown in Canada and the United States (continued)

Species	Shrinkage (%) from green to ovendry moisture content, based on green dimensions	
	Canadian-grown[A]	United States-grown[B]
Hardwoods		
Red alder	11.7	12.6
Ash:		
Black ash	13.8	15.2
Green ash	11.4	12.5
Red ash	---	---
White ash	13.1	13.3
Basswood	18.4	15.8
Beech	17.3	17.2
Birch:		
White birch	13.8	---
Western white birch	16.0	16.2
Yellow birch	15.1	16.8
Black Cherry	12.7	11.5
Chestnut	10.0	11.6
Elm:		
Rock elm	14.8	14.9
Slippery elm	15.5	13.8
White elm	15.2	14.6
Hickory:		
Bitternut hickory	17.8	---
Shagbark hickory	17.2	16.7
Ironwood	18.2	---
Maple:		
Broadleaf maple	12.1	11.6
Manitoba maple	14.8	---
Red maple	12.4	12.6
Silver maple	12.8	12.0
Sugar maple	15.7	14.7
Oak:		
Black oak	13.2	15.1
Bur oak	13.7	12.7
Red oak	12.0	13.7 (Northern red)
		16.1 (Southern red)
White oak	16.6	16.3
Poplar:		
Balsam poplar	11.6	10.5
Black cottonwood	11.7	12.4
Eastern cottonwood	11.8	13.9
Largetooth aspen	11.7	11.8
Trembling aspen	11.8	11.5
Walnut:		
Black walnut	13.8	12.8
Butternut	9.6	10.6

[A] Source: Jessome, A.P. 1977. Strength and related properties of woods grown in Canada. Environ. Can., Can. For. Serv. For. Prod. Lab., Ottawa, Ontario. For. Tech. Rep. 21.

[B] Source: U.S. Dept. of Agriculture. 1974. Wood handbook: Wood as an engineering material. Forest Service Agricultural Handbook No. 72. U.S. Dept. of Agriculture, For. Prod. Lab., Madison, Wisconsin.

APPENDIX 2

DESCRIPTIONS OF SAMPLING LOCATIONS, METHODS OF SAMPLING, AND DENSITY CALCULATIONS

A

Alemdag, I.S. 1984. Wood density variation of 28 tree species from Ontario. Environ. Can., Can. For. Serv., Petawawa Natl. For. Inst., Chalk River, Ontario. Inf. Rep. PI-X-45.

Sampling Location: Full range of sites in Ontario.

Method of Sampling: Four disks, 3-4 cm thick, were taken from each tree: at breast height, at one-third up, two-thirds up, and top of the merchantable stem, which had a minimum diameter of 9.1 cm. From each disk, a pie-shaped sector was obtained for density measurement. Test samples were free of knots and other visible defects.

Method of Density Calculation: Basic density was determined on the pie-shaped sector from each of the four disks. Green volumes of the sectors were determined by water displacement method (TAPPI Method 258 OS-76)[1]. Merchantable stem-wood density was calculated as the weighted average of the wood density of each pie-shaped sector, the weighting factor being the square of the inside-bark diameter of the disks.

For this report, a species average at breast height was calculated.

Andersson, E. 1987a. *Pinus contorta*—strength. The properties of trees and wood. Swedish Univ. Agric. Sci., Dep. For. Prod. Uppsala, Sweden. Rep. 185.

Sampling Location: Eight experimental stands in Sweden ranging from the Province of Vasterbotten in the north to the Province of Smaland in the south.

Method of Sampling: Test samples were obtained from various sizes of lumber that were also being tested for strength. Each piece of lumber was cut across from one end, producing blocks with the following dimensions on the cross section: 35 × 95 mm, 45 × 95 mm, and 45 × 120 mm. All samples measured 50 mm along the grain.

Method of Density Calculation: Densities were measured on the green volumes and ovendry weights of the samples. Green volume was determined by taking exact measurements of the width, length, and thickness of the blocks. Their weights were taken after drying in an oven at 100°-105°C.

Andersson, E. 1987b. *Pinus contorta*. The properties of trees and wood. Swedish Univ. Agric. Sci., Dep. For. Prod. Uppsala, Sweden. Rep. 186.

Sampling Location: Eight experimental stands in Sweden ranging from the Province of Vasterbotten in the north to the Province of Smaland in the south.

Method of Sampling: Five-cm thick disks were obtained at 1%, 10%, 30%, 50%, 70%, and 80% of the total tree height.

Method of Density Calculation: Basic densities of the disks were determined by the water displacement method. Samples were dried to constant weight at 105°C. Whole-stem density was calculated as the average of the disk densities weighted by the volume represented by the disks in the stem.

[1] Technical Association of the Pulp and Paper Industry. 1976. TAPPI standard method T258 OS-76. Norcross, Georgia.

B

Babos, K. 1988. Budapest, Hungary. Personal communication.

Sampling Location: Kiscsehi-Budafa Arboretum, Hungary, at 200 m above sea level. Thickness of the surface soil: 130 cm of loamy brown forest soil. Natural forest association: hornbeam and beech grove.

Method of Sampling: Two-metre log sections were cut off from the stems above the breast height. Eighteen test samples were obtained from the sections. No further description was given.

Method of Density Calculation: Density was based on ovendry weight and green volume.

Baker, G. 1967. Estimating specific gravity of plantation-grown red pine. For. Prod. J. 107(8):21-24.

Sampling Location: A single-age plantation (20–25 years) in Maine. Two parallel areas with tree spacings of 0.6 to 3 m by 0.6-m intervals. In one area, trees originally spaced 0.6 × 0.6 m had been thinned to 1.2 × 1.2 m, and trees originally spaced 1.2 × 1.2 m had been thinned to 2.4 × 2.4 m. In the other area, no thinning had been done.

Method of Sampling: Ten dominant and codominant trees were selected from each spacing block in each area. Each tree was sampled for two breast-height increment cores at 90 degrees to each other, the compass direction of the first core being randomly selected. Trees were also felled and cut into bolts 1.3 m long. A disk 6-cm thick was cut from the top of each bolt.

Method of Density Calculation: Densities were determined on both cores and disks based on the ovendry weights and green volumes of the samples. The core volumes were estimated from their length and diameter; the disk volumes were measured by the water immersion method. Ovendry weights were obtained in an oven at 105°C. The cores provided values at breast height; the disks provided values for calculating whole stem density. Disk densities were weighted in proportion to the volume represented by the disks in the stem.

Balatinecz, J.J. 1982. Wood quality of young eastern larch from Ontario. Report prepared for the Ontario Ministry Natural Resources Forest Research Branch, Toronto, Ontario.

Balatinecz, J.J. 1983. Properties and utilization of larch—an overview. Pages 65-80 *in* C.M. Graham, H.L. Farintash, and B.J. Graham, eds. Larch symposium: potential for the future. Ontario Minist. Nat. Resour., Toronto, Ontario.

Sampling Location: Kemptville-Brockville, North Bay, and Kapuskasing, Ontario.

Method of Sampling: A total of 11 young tamarack trees (Balatinecz 1982) were sampled: four trees each from North Bay and Kapuskasing, and three from Kemptville-Brockville. Disks were obtained at three height levels of each tree: at stump height, at 3 m above ground, and at 6 m above ground. A total of 12 older tamarack trees (Balatinecz 1983) were sampled: four trees from each of the three sites. A disk was taken at stump height and at every 3 m interval up the stem to a height of 12 m above ground.

Method of Density Calculation: Basic wood density was determined on pith–to–bark strip sawn from each disk. The stem–wood density was the arithmetic mean of the densities determined on the strip at each height level.

Balatinecz, J.J. 1986 Wood quality studies in commercially important conifers. Report prepared for Canadian Forestry Service, Ottawa, Ontario.

Sampling Location: Petawawa National Forestry Institute experimental plantations, Ontario. Jack pine was sampled from a plantation established in 1964 at the Sturgeon Lake Road site.

Method of Sampling: Jack pine: five trees were sampled from 10 families. Disks of 5–cm thickness were obtained at five height levels: at butt height, 1.5 m, 3 m, 6 m, and 9 m above ground. White spruce: four trees were sampled from 13 families. Disks of 5–cm thickness were cut from the tree at 0.5–m intervals.

Method of Density Calculation: Basic density was determined on pith–to–bark strip sawn from each disk. The stem–wood density was calculated as the arithmetic mean of the densities of the strip at each height level.

Bastien, J.C.; Roman–Amat, B.; Vonnet, G. 1985. Natural variability of some wood internal traits of coastal Douglas–fir in a French progeny test. Paper presented at the IUFRO S2.02-05 Working Party. Meeting, Vienna, Austria, June 1985.

Sampling Location: A Douglas–fir progeny test at Cendrieux, Dordogne, France, at 220 m elevation with an annual rainfall of 85 cm. Four–year–old seedlings (Washington State, U.S.A. IUFRO provenances) were outplanted in 1971, in single–tree plots and incomplete block design. Pruning was done up to a height of 2.5 m at the end of 1979.

Method of Sampling: Ten fast–growing provenances were selected, six being late flushing and four early flushing. Ten trees per progeny were selected. Bark–to–bark cores were obtained at breast height.

Method of Density Calculation: Density was measured by an x–ray method on the last five rings closest to the bark at both ends of the core. Each ring was scanned radially and spot density was measured on 0.0251 mm–wide segments contiguous to each other. The mean breast–height density for each tree was the weighted density of the 10 rings measured on each diametric core, weighted by ring width.

Beaudoin, M.; Masanga, B.O.; Poliquin, J.; Beauregard, R.L. 1989. Physical and mechanical properties of plantation–grown tamarack. For. Prod. J. 39(6):5-10.

Sampling Location: Sixteen tamarack plantations, 22–30 years old on former agricultural lands in southeastern Quebec. Soils were sandy to clayey and drainage varied from good to bad. Spacing was anywhere from 1.8 × 1.8 m to 2.7 × 2.7 m. Artificial pruning was done on some plantations.

Method of Sampling: Fifty trees with dbh not less than 20 cm were randomly selected. Each tree was cut in 2.5-m bolts. A bolt was randomly selected from each tree. A boxed-pith flitch 70 mm thick was cut bark to bark from each selected bolt. Four 70-mm square samples were cut from the flitch, two on either side of the pith. Two samples were cut near the pith and two were cut near the bark.

Method of Density Calculation: Density was determined on both green-volume and 12% moisture content bases. All weights were taken on ovendry samples. Green volumes were determined by water displacement.

Beaulieu, J.; Corriveau, A. 1985. Variabilité de la densité du bois et de la production des provenances d'épinette blanche, 20 ans après plantation. Can. J. For. Res. 15:833-838.

Sampling Location: White spruce provenance test at Harrington Forest Farm, Quebec, 150 m elevation. Annual mean temperature was 4°C; annual mean precipitation was 1010 mm.

Method of Sampling: Three trees per block, 3 blocks per provenance, and 23 provenances were sampled. Trees were approximately 20 years old. One disk, 3-4 cm thick, was taken at breast height from each tree.

Method of Density Calculation: The whole disk, cleared of knots, was analyzed for basic wood density. Green volume was measured by water displacement method. Ovendried weights were determined after 72 hours in an oven at 105°C.

Bendtsen, B.A. 1972. Important structural materials of four western softwoods: white pine, sugar pine, western redcedar, and Port-Orford cedar. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 191.

Sampling Location: Thirty-four white pine trees were sampled: 1 in California, 20 in Idaho, 2 in Montana, 4 in Oregon, and 7 in Washington. Thirty-four Western red cedars were sampled: 5 in Idaho, 1 in Montana, 11 in Oregon, and 17 in Washington. Sampling locations were selected by random procedures involving three stages: selection of states, counties or survey units, and sample locations within survey units. Volume estimates of growing stock were used as basis of selection.

Method of Sampling: Sound trees with no more than 15° lean and no less than 22.9 cm dbh were selected. Stems were cut at 1.5-m intervals to a minimum top diameter of 22.9 cm. A bolt was randomly selected from each tree and kept green under spray storage. A bark-to-bark flitch, 6.4 cm wide, was sawn from each selected bolt. Test specimens, 6.4 cm^3, were randomly located and obtained from each flitch. Four samples from each were tested for density.

Method of Density Calculation: Densities were determined from ovendry weights and green volumes of the samples. Green volumes were based on the cube dimensions. Mean density for the species was the arithmetic average of the individual observations.

Bendtsen, B.A. 1973. Mechanical properties and specific gravity of randomly sampled subalpine fir. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 197.

Sampling Location: Thirty-five trees from the growth range of subalpine fir in the United States selected by random procedure from Colorado, Idaho, Montana, Oregon, Utah, Washington, and Wyoming.

Method of Sampling: See Bendtsen and Wahlgren (1970).

Method of Density Calculation: See Bendtsen and Wahlgren (1970).

Bendtsen, B.A. 1974. Specific gravity and mechanical properties of black, red, and white spruce and balsam fir. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 237.

Sampling Location: Growth range of the species in the U.S. selected by random procedures that involved selection of states, counties, and sample locations within counties, based on estimates of growing stock volume.

Method of Sampling: See Bendtsen (1972).

Method of Density Calculation: See Bendtsen (1972).

Bendtsen, B.A.; Wahlgren, H.E. 1970. Mechanical properties and specific gravity of a randomly selected sample of Engelmann spruce. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 128.

Sampling Location: The entire growth range of Engelmann spruce in the U.S.

Method of Sampling: Random procedures were used in the selection of sample locations, trees, bolts and sticks, with probability approximately proportional to volume at each stage of sampling. A detailed description of the random sampling techniques used is given in Bendtsen and Wahlgren (1970). Each tree was cut into bolts 1.5 m in length from stump to a top diameter of 20.3 cm. A single bolt was randomly selected from each tree, with probability of selection proportional to the squared end diameter of the bolt (approximately proportional to volume). The selected bolt was sawn into the maximum possible number of 6.4 cm square sticks with the annual rings oriented parallel to one face of the stick. Two sticks were selected at random. One was used for green test, the other for air-dry test.

Method of Density Calculation: Density was calculated in two ways: 1) ovendry weight divided by green volume; 2) ovendry weight divided by volume at 12% moisture content (air-dry condition).

Bjorkland, T. 1982. Technical properties of lodgepole pine. Folia For. 522:1-25.

Sampling Location: Nine forest stands in south Finland. Seed origins were Alberta and British Columbia. Stand density ranged from 375 to 2200 trees/ha.

Method of Sampling: Disks were sawn at 0.5 m, 1.3 m, 2 m, 4 m, and 6 m heights from each tree.

Method of Density Calculation: Density was calculated from the green volume and ovendry weight of each sample from the disks. Drying of the samples was at 103°C.

Bodig, J. 1968. Mechanical properties of Engelmann spruce grown in Colorado and Wyoming. For. Prod. J. 19(10):53-59.

Sampling Location: Fifteen counties in Colorado and five in Wyoming national forests, sampled in proportion to the species' growing stock volume estimates by the U.S. Forest Service. Elevation ranged from 2500 to 3600 m above sea level.

Method of Sampling: The volume of each tree up to 30 cm top diameter was determined and divided into bolts 1.2 m long. A number was assigned to each bolt proportional to its percentage of the tree volume. From the total, a number was randomly drawn and the bolt corresponding to that number was used for the preparation of 5.7 by 5.7 cm cross sections. These were mixed randomly within a bolt and clear specimens were selected for static bending tests, which were also used for density measurements.

Method of Density Calculation: Basic density was determined according to the American Society for Testing and Materials[2].

Bond, J.E.J. 1985. Sapwood thickness, growth rate, and specific gravity of tamarack in northern Ontario. M.S. thesis. Fac. For., Lakehead Univ., Thunder Bay, Ontario.

Sampling Location: Two stands in Timmins, Fort Frances, and Moosonee in northern Ontario.

Method of Sampling: Ten trees were sampled per stand in which 40% of the trees were tamaracks. Increment cores, 12 mm in diameter, were obtained from the western and southern direction of each tree at breast height. The cores were divided into juvenile wood (26 rings closest to the pith) and mature wood (26 rings closest to the bark).

Method of Density Calculation: Basic densities using the maximum-moisture-content method[3] were determined separately for juvenile and mature wood. Core samples were pre-extracted with 60% acetone.

Born, J.D. 1966. Specific gravity of increment cores from Interior Alaska. U.S. For. Serv., North. For. Exp. Stn., Juneau, Alaska. Note NOR-19.

Sampling Location: Locations were randomly selected over the commercial forest lands of interior Alaska, including all of the mainland to the north and west of Anchorage.

2 American Society for Testing and Materials. 1989. Standard methods of testing smallclear specimens of timber. D-143-83. Am. Soc. Test. Mater. 4:35-76.

3 Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

Method of Sampling: Trees selected were at least 12.7 cm in dbh and within 10 m of each of 10 points systematically spaced over a half-acre location. The number of trees selected for a species in a location depended on the stand composition. A single core through the pith was taken at breast height with a core borer having an inside diameter of 4.3 mm.

Method of Density Calculation: Basic densities were determined on the cores. Green volumes were computed using the inside diameter of the core borer and the length of the core. After drying in a convection oven at 105°C for 48 hours, the cores were weighed to the nearest 0.001 gram.

Brazier, J.D. 1973. Wood properties of the minor softwood species. Paper presented at the joint Forestry Commission/Princes Risborough Seminar held at the Building Research Establishment, Princes Risborough Lab., Aylesbury, U.K., April 11, 1973.

Sampling Location: United Kingdom. The following number of sites were sampled: Grand fir—8; Western hemlock—12; Western red cedar—9.

Method of Sampling: Two disks per tree; 10 trees per site.

Method of Density Calculation: Ovendry weight/green volume.

Brazier, J.D. 1980. A report on the effects of provenance on the timber properties of Lodgepole pine. Pages 181-207 *in* Proceedings of the IUFRO Working Party Meeting 1980 on *Pinus Contorta* Provenances (S2.02-06) in Norway and Sweden. Swedish Dep. Agric. Sci. Res. Note 30.

Sampling Location: Lodgepole pine provenance trials established from 1930 to 1938 in North Wales (mainly Clocaenog Forest) and from 1938 to 1940 in Yorkshire, England (mainly Allerston Forest).

Method of Sampling: Two 60-cm-long bolts were taken at positions corresponding to one-eighth and one-quarter of the tree height. A full cross-section disk was sawn from the bottom of each bolt.

Method of Density Calculation: Basic density was estimated on each disk. Procedure for measuring green volume was not given. Average density for each stand was given. For this report, a straight arithmetic average of the stand means was calculated and reported as the species average.

Brazier, J.D.; Priest, D.T.; Lavers, G.M.; White, N.C. 1976. An evaluation of home-grown Sitka spruce. Build. Res. Establ., Watford, U.K. Curr. Pap. CP 20/76.

Sampling Location: Nine sites in Wales and Scotland (Tarenig, Glenbranter, Dovey, South Strome, Drumtochty, Glengarry, Radnor, Achnashellach, and Castle O'er), covering a range of yield classes from 10 to 18 m^3/ha per year.

Method of Sampling: Twelve trees were selected from each site, two from each of six different basal area classes. Five classes were recognized within each site, each representing one-fifth of the stand basal area for the trees yielding log lengths of 8 m or more to a stem diameter of 18 cm outside bark. The sixth class consisted of trees that failed to meet this requirement. Each stem was divided into two sections: from butt to 18 cm dob (diameter outside bark), and from 18 cm dob to 7 cm dob. From the first section, disks were cut at about one-twelfth, three-twelfth, five-twelfth, seven-twelfth, nine-twelfth, and 11-twelfth of the section length, avoiding knot whorls. The second section was cut into half and disk samples were obtained at the midpoints of the halves.

Method of Density Calculation: Basic densities were determined on the disks. Volume of the water-saturated disks was estimated by water displacement; ovendry weights of the disks were obtained after drying at 103°C for 48 hours. Whole-stem density was calculated as the weighted average of the disk densities weighted by the proportion of volume represented by the disks in the stem.

Broughton, J.A.H. 1962. Properties of 30-37 year old Sitka spruce timber. Princes Risborough Lab., Princes Risborough, Aylesbury, U.K. For Prod. Res. Bull. 48.

Sampling Location: Samples were taken from six zones which contain a substantial acreage of Sitka spruce: north and west Scotland, northwest and southwest England, north and south Wales. Stands were restricted to those of 30-37 years of age. Seeds were from the Queen Charlotte Islands, British Columbia.

Method of Sampling: Sampling was done to represent all quality classes from all six zones. Ten trees were sampled from each of 18 sites from the six zones, for a total of 180 trees. Two 90-cm long bolts were taken at random from that part of the tree between 60 cm from the butt to the point where stem diameter was 15 cm. A 5-cm thick disk was cut from the bottom of each bolt.

Method of Density Calculation: Density was based on ovendry weight and green volume of each disk. The disks were machined to exact thickness. The volume of the disks was estimated from the thickness and the surface area, which was measured with a planimeter. The disks were dried to constant weight at 102°C.

Buchert, G. 1987. Ontario Tree Improve. For. Biomass Inst. Maple, Ontario. Personal communication.

Sampling Location: The following districts in Ontario were sampled: Kirkland Lake, Chapleau, Gogama, Kapuskasing, Hearst, and Ignace.

Method of Sampling: Plus trees selected were either dominant or codominant. Disks were taken at breast height from each tree. A pie-shaped sector was obtained from each disk. The sector was separated into juvenile (first 20 rings from the pith) and mature wood (ring 21 to bark).

Method of Density Calculation: Basic density was determined on the juvenile and mature wood of each sector. Green volume was achieved by soaking the samples in water until they sank. Green volume was measured by the water immersion method.

C

Carminati, M. 1986. Etude du comportement mécanique du bois soumis a différentes sollicitations en relation avec quelques-unes de ses caractéristiques physiques. Application à l'épicea de Sitka (*Picea sitchensis* (Bong.) Carr.). Centre de recherches de Nancy, Station de recherches sur la qualité des bois, Nancy, France.

Sampling Location: Ireland

Method of Sampling: Core and block samples were taken from a l-m bolt. The first 15 rings from the pith were excluded from analysis. The bolt was cut up into planks and cube samples sawn from near the edge of the planks.

Method of Density Calculation: The core samples were saturated in water for 4 days. The blocks were conditioned to about 12% moisture content. The volumes of the samples were estimated from their precise dimensions. Ovendry weights were obtained after drying at 102°C.

Caron, E.G. 1980. A study of specific gravity variation in white spruce from northwestern New Brunswick. Undergraduate thesis. Fac. For., Univ. New Brunswick, Fredericton, New Brunswick.

Sampling Location: Restigouche County, New Brunswick; fully open-grown, black spruce-balsam fir stand with admixture of white spruce.

Method of Sampling: Sample trees were dominant or codominant, with fully developed crown, and regular shape. Disks, 2.5-5.0 cm thick, were taken at breast height, and at 5-m intervals. Two pie-shaped sectors, with included angle of 30°, were obtained from each disk from the north and south directions. Two breast-height increment cores at 90° intervals, one from north position, were also taken.

Method of Density Calculation: Basic density was determined on each sector. Green volumes of the sectors were determined by water displacement. Increment cores were analyzed by the maximum-moisture-content method[4]. Total stem-wood density was calculated as the weighted average of the disk (sector) densities at each height level, the weighting factor being the inside bark diameter of the disks.

Chang, C.I.; Kennedy, R.W. 1967. Influence of specific gravity and growth rate on dry wood production in plantation-grown white spruce. For. Chron. 43(2):165-173.

Sampling Location: Southern Ontario; 29 plots in six localities of white spruce plantations.

Method of Sampling: Dbh distribution within plots was determined and plotted with class intervals of 5.0 cm. One tree was randomly selected per dbh class within plots. Additional tree was selected from class of highest frequency. Trees were felled at stump height (15 cm above ground). Disks, 2.5-5.0 cm thick, were cut from base upwards at 1.2-m intervals. One sector (included angle = 45°, 90° for small sectors) was obtained from an area of average growth of each disk, free of knots, resins, and other defects.

[4] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

Method of Density Calculation: Basic density was determined on each sector. Green volume of each sector was measured by water displacement method[5]. Total-stem density was the weighted average of the disk (sector) densities at each height level, the weighting factor being the volume of the stem segment represented by the disk.

Chapman, P. 1989. For. Can., North. For. Cent., Edmonton, Alberta. Personal communication.

Sampling Location: Four family test plantations of jack pine in the Belair and Sandilands provincial forests in southeastern Manitoba, planted at 1.8-m spacing in four-tree plots.

Method of Sampling: The plantations were thinned to the two best trees in the plot. Disk samples were taken at breast height from 251 trees from the 60 best families.

Method of Density Calculation: Densities were determined on whole disks using green volumes and ovendry weights[6].

Cody, J.B. 1972. Some wood characteristics and properties of plantation-grown red pine in New York state, N.Y. State Univ., Coll. For., Syracuse, New York. AFRI Res. Rep. 9.

Sampling Location: Twelve red pine plantations (representing two age groups: 25–55 years and over 55 years) in each of the Department of Environmental Conservation Forest Districts 1 to 5 in New York state. Elevations ranged from 300 to 715 m. Plantations selected were in need of thinning, free of wind and snow damage, and of defects such as root and stem rots.

Method of Sampling: Six trees were systematically selected in each plantation and treated as random samples. All selected trees were interior-grown (none from the edge of plantations or open areas) and were free of defects such as cankers, conks, swollen knots, excessive crook, and forked tops. Trees were cut 15 cm above ground. Disks 5 cm thick were cut from the stem at 3-m interval sections starting from 3 m above the butt to top dib (diameter inside bark) of 10 cm. Disks 15 cm in diameter were kept intact and processed whole. Pie-shaped wedges (at least 30° arc) were cut from each disk with a diameter larger than 15 cm.

Method of Density Calculation: Densities were based on ovendry weights and green volumes. Green volumes were determined by the water immersion technique. Ovendry weights were obtained after drying to constant weight at 105°C. Stem-wood density was the weighted average of the disk densities, weighted by the proportion of volume represented by the disks in the stem.

Conway, E.M.; Minor, C.O. 1961. Specific gravity of Arizona Ponderosa pine pulpwood. U.S. For. Serv., Rocky Mt. For. Range Exp. Stn., Fort Collins, Colorado. Res. Note 54.

Sampling Location: Flagstaff, Arizona.

[5] Brown, H.P.A.; Panshin, J.; Forsaith, C.C. 1952. Textbook of wood technology. Vol. 1, First ed. McGraw-Hill Co. Ltd., New York, N.Y.

[6] Technical Association of the Pulp and Paper Industry. 1953. TAPPI standard method T18M-53. Norcross, Georgia. This measures volume by water immersion method, and ovendry weight after drying the disks at 105°C to constant weight.

Method of Sampling: Breast-height cores were taken from 109 pulpwood-sized trees. Cores were also extracted at stump height and at 1.2-m intervals to the merchantable top (top diameter not given).

Method of Density Calculation: Densities were determined on the cores using ovendry weights and green volumes estimated from the cores' length and diameter. Whole-tree density was estimated from the average of the cores taken at fixed intervals from the stem. Using cores from the same trees, a regression equation was established relating dbh to whole-tree density. Using this equation, whole-tree density was predicted for the other cores taken at breast height.

Corriveau, A.; Beaulieu, J.; Mothe, F. 1987. Wood density of natural white spruce populations in Quebec. Can. J. For. Res. 17:675-682.

Sampling Location: Eighty different white spruce populations in Quebec.

Method of Sampling: One 5-mm increment core per tree was obtained at breast height. The cores were screened for compression wood and divided into juvenile (first 15 rings from pith) and mature (ring 16 to bark) wood segments.

Method of Density Calculation: Basic density was determined on the cores by the maximum-moisture-content method. Maximum moisture was achieved by immersing samples in water under vacuum for 5 days.

Cown, D.J.; Bigwood, S.R. 1979. Some wood characteristics of New Zealand-grown western redcedar (*Thuja plicata* D. Don). N.Z. J. For. 24(1):125-132.

Sampling Location: One-half hectare block in Compartment 19, Whakarewarewa State Forest; a 73-year old unthinned plantation in Compartment 11, Waiotapu State Forest, 20 km from Whakarewarewa; Mahinapua State Forest, Westland Conservancy; and Conical Hill State Forest, Southland, New Zealand.

Method of Sampling: Whakarewarewa: disks were obtained from the top and bottom ends of 5-m long logs. The disks were reduced to small blocks of 10 growth rings from the pith outwards along two radii. Waiotapu: two pith-to-bark core samples were taken at breast height from 15 dominant and codominant trees. Mahinapua and Conical Hill: disks were obtained from butt logs.

Method of Density Calculation: Density estimates were based on ovendry and green-volume samples. Volume of the block samples was determined by the water immersion method. The cores were analyzed by the maximum-moisture-content method[7].

[7] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

D

DeBell, D.S.; Wilson, B.C. 1978. Natural variation in red alder. Pages 193-208 *in* D.G. Briggs, D.S. DeBell, and W.A. Atkinson, comps. Utilization and management of alder. Proceedings of a symposium held at Ocean Shores, Washington, April 25–27, 1977. U.S. For. Serv., Pac. Northwest Exp. Stn., Portland, Oregon. Gen. Tech. Rep. PNW-70.

Sampling Location: Seven naturally regenerated stands west of Olympia, Washington, covering a range of site conditions in the area. Elevation ranged from about 90 to 550 m above sea level. Site index ranged from 20 to 31 m on a 50-year basis.

Method of Sampling: Disks 3–5 cm thick were cut at breast height from eight randomly selected trees in each stand. A 2-cm wide strip was cut through each disk so that the length of the piece was nearly equal the average diameter of the disk. The strip was separated at the pith and wood beyond the 25th growth ring was discarded.

Method of Density Calculation: Density was calculated from green volume and ovendry weight. Drying of the samples was done at 105°C.

De Montmorency, W.H. 1965. The relationship of wood characteristics to mechanical pulping. Pulp Pap. Mag. Can. 66(6):T325-348.

Sampling Location: Forestville, Quebec. Black spruce was sampled in an uneven aged (60–140 years old) stand of pure black spruce with few trees from a low marshy area. Balsam fir and white spruce ranging from 50 to 130 years old were obtained from a mixed stand not too far away on a hillside with about 15% slope facing east. White spruce was also sampled from a mixed stand along the Labrieville road 37 km northeast of Forestville[8].

Method of Sampling: Fifty-two black spruce, 21 white spruce, and 52 balsam fir trees were cored and their densities analyzed. Based on the predetermined densities, the trees were selected to cover a wide range of density values while maintaining a minimum of diameter to provide sufficient material for the whole study. Knot-free disks were cut from each tree at 0.6 m, 1.8 m, 3.0 m, 4.3 m, and 5.5 m from the stump for density determination.

Method of Density Calculation: Basic density was determined on the whole disks. Mean stem density was the arithmetic average of the disk densities, and species average was the arithmetic mean of the stem densities.

Doucet, J.; Poliquin, J.; Verville, A. 1983. Density variation in plantation grown larch and the suitability of larch for waferboard. Pages 81–113 *in* C.M. Graham, H.L. Farintash, and B.J. Graham, eds. Larch symposium: potential for the future. Ontario Minist. Nat. Resour., Toronto, Ontario.

Sampling Location: Plantation and natural stands in Quebec.

Method of Sampling: Test trees were codominant or dominant, with no visible sign of rodent damage, with at least 20 cm dbh. Disks were taken at breast height (1.2 m), and at

[8] Keen, R.E. 1963. Weights and centres of gravity involved in handling pulpwood trees. Pulp Pap. Inst. Can., Pointe Claire, Que. Woodlands Res. Index 147.

1.5-m intervals to the top, which had a minimum diameter of 10 cm. A pie-shaped sector (included angle of 45°) was cut from each disk.

Method of Density Calculation: Basic density was determined on the sectors. Green volumes of the sectors were measured by water displacement method. Total stem-wood density was the weighted average of the disk (sector) densities at each height level, the weighting factor being the volume of the stem segment represented by the disk.

Drow, J.T. 1957. Relationship of locality and rate of growth to density and strength of Douglas-fir. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2078.

Sampling Location: Coastal samples from virgin forests in Canada were obtained from Abbotsford, Comox, Kissinger, and Cowichan Lake, all in B.C. Coastal samples from second-growth forests were obtained from Port Moody and Whonock, B.C. Interior samples from virgin forests in Canada were obtained from Morley, Alberta, and Golden and Shuswap Lake, B.C. In the U.S., samples were taken from the Wenatchee forest on the eastern slope of the Cascades in Washington State, the Trinity forest in northern California, and the Umatilla forest in northeastern Oregon. Second-growth materials were obtained from western Oregon and Washington. Interior materials came from Montana, Idaho, Wyoming, Oregon, New Mexico, Arizona, and Colorado.

Method of Sampling: Clear wood blocks were obtained in accordance with ASTM method D143[9].

Method of Density Calculation: Density was based on green volume and ovendry weight determined in accordance with ASTM Method D143[10]. Each tree was given equal weighting in the calculation of the mean density for the species. Major sources of data were the U.S. Madison Forest Products Laboratory strength and specific gravity tests, and the Canadian Forest Products Laboratories.

E

Einspahr, D.W.; Benson, M.K. 1967. Geographic variation of quaking aspen in Wisconsin and upper Michigan. Silvae Genet. 16(3):106-112.

Sampling Location: Five locations in Wisconsin and upper Michigan. The stands ranged from 23 to 44 years of age and were limited to medium and light textured upland soils with water table levels at about 2 m in depth.

Method of Sampling: The following selection resulted in a total of 225 trees: 3 trees per clone, 3 clones per stand, and 5 stands per location. Four 10-mm breast-height increment cores taken at right angles to each other were obtained from each tree.

Method of Density Calculation: Basic densities were determined on the cores. The core volumes were estimated using the inside diameter of a calibrated increment borer

[9], [10] American Society for Testing and Materials. 1989. Standard methods of testing small clear specimens of timber. D-143-83. Am. Soc. Test. Mater. 4:35-76.

and the length of the cores. The mean breast-height density for each tree was the arithmetic mean of four increment cores. Each tree had equal weighting in the calculation of the overall mean.

F

Farr, W.A. 1973. Specific gravity of western hemlock and Sitka spruce in southeast Alaska. Wood Sci. 6(1):9-13.

Sampling Location: Even-aged stands of western hemlock and Sitka spruce in southeast Alaska.

Method of Sampling: Two western hemlock and two Sitka spruce dominant and codominant trees were sampled from each of 20 even-aged stands. One increment core to the pith and one 5-cm thick wedge were obtained from each tree at breast height. Additional wedges were obtained at the top of each 3-m section from stump height to the top of the tree.

Method of Density Calculation: Basic densities of the wedges and the cores were determined. Stem density was the average of the wedge densities, each weighted by the volume proportion represented by the wedge in the stem. Breast-height densities were estimated from both core and wedge samples.

G

Gammon, G.L. 1969. Specific gravity and wood moisture variation of white pine. U.S. For. Serv., Northeast. For. Exp. Stn., Upper Darby, Pennsylvania. Res. Note NE-99.

Sampling Location: Durham, New Hampshire.

Method of Sampling: Seventy-five trees were selected. Each was cut into 2.4-m sawlogs and 1.2-m pulp bolts. A 2.5-cm thick cross-sectional disk was cut from the base of each section and at the top of the merchantable stem limit.

Method of Density Calculation: The basic density of each disk was determined. Stem density was the average of the disk densities, weighted by the proportion of volume represented by the disks in the stem.

Gardiner, J.J.; O'Sullivan, P. 1978. The effect of wide espacement on wood density in Sitka spruce. Ir. For. 35(1):45-51.

Sampling Location: Two stands at Drumhierney Plantations, Co. Leitrim, Ireland, established in 1954 at spacings of 2.4 × 2.4 m and 4.5 × 4.5 m. The stands had never been thinned, but all stems had been pruned consistently since early age to leave approximately two-thirds of the live crown. Basal areas per hectare were 54.5 m^3 and 27.9 m^3, respectively, for the two stands.

Method of Sampling: Two trees from each of the four diameter classes in each stand were sampled for a pith-to-bark 5-mm increment core at breast height from the south side of the tree.

Method of Density Calculation: Whole cores were analyzed for basic density using the water displacement method.

Gerhards, C.C. 1965. Strength and related properties of western hemlock. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 28.

Sampling Location: Clatsop and Lane counties in Oregon, and Pierce County in Washington.

Method of Sampling: A single 2.4-m bolt was selected from random heights in five trees from each county. The bolts were cut into planks measuring 7.6 × 20.3 cm on the cross section. Four planks were randomly chosen from each bolt and cut into specimens for testing according to ASTM methods[11].

Method of Density Calculation: Densities were measured on the green volumes and ovendry weights of the samples according to ASTM methods[12].

Gernert, G.L.; Hofstrand, A.; Lowery, D.P. 1980. Comparison of percent shrinkage and specific gravity for three types of western white pine wood. U.S. For. Serv., Intermt. For. Range Exp. Stn., Ogden, Utah. Int-276.

Sampling Location: Twelve areas throughout the species range in north Idaho.

Method of Sampling: Three trees (per area), with a minimum diameter of 25.4 cm at a height of 9.75 m, were selected to represent the widest range of the species distribution. A sample section, 20.3 cm thick, was cut above the first log (9.75 m long). Samples for wood density measuring 5.1 × 5.1 cm on the cross section and 15.2 cm along the grain were obtained from this section.

Method of Density Calculation: Basic densities were measured on the samples by the water immersion method. Samples were dried at 100°C.

Gilmore, A.R. 1968. Geographic variations in specific gravity of white pine and red pine in Illinois. For. Prod. J. 18(11):49-51.

Sampling Location: Forty-eight white pine plantations and 60 red pine plantations throughout Illinois. Site index at age 25 years ranged from 8.5 to 24.4 m for white pine and from 6.4 to 15 m for red pine.

Method of Sampling: Increment cores were extracted from the west side of five dominant trees in each plot with a 4.5-mm borer.

Method of Density Calculation: Densities were estimated from the ovendry weights and green volumes of the cores. The volumes of the cores were calculated from their diameter and length, which was measured from the pith to the last ring closest to the bark.

[11, 12] American Society for Testing and Materials. 1989. Standard method of testing small clear specimens of timber. D-143-83. Am. Soc. Test. Mater. 4:35-76.

Gohre, K. 1955. Die rohwichte des Douglasienholzes, ihre Verteilung im Stamm und Abhangigkeit von Abstand vom Mark, Jahrringbreite und Spatholzanteil. Arch. Forstwes. Bd. 4, H. 7/8, S. 639/660.

Sampling Location: North Germany, near the coast.

Method of Sampling: The trees were the first Douglas-fir trees planted in Germany and not necessarily representative. Disks were cut from each tree at 0.3 and 1.3 m and at intervals of 4 m thereafter up the tree. Each disk was divided into samples measuring $2 \times 2 \times 3$ cm following a north-south and east-west cruciform pattern. All samples were analyzed for density.

Method of Density Calculation: Density was calculated from the ovendry weight and ovendry volume of each block. The mean densities for each disk, stem, and species were successively calculated by straight arithmetic average.

Gonzalez, J.S. 1985. Density evaluation of lodgepole pine trees. Report prepared for the Canadian Forestry Service, Ottawa, Ontario.

Gonzalez, J.S. 1987. Wood density of tree species in British Columbia. Report prepared for the Canadian Forestry Service, Ottawa, Ontario.

Sampling Location: British Columbia.

Method of Sampling: Parent trees were selected by the B.C. Ministry of Forests and Lands. Age ranged from 50 to 150 years, mostly between 50 and 100 years. At the start, associated dominant trees were also selected. This was discontinued later in the program when results showed that although dominant trees had a tendency to have higher relative density than plus trees, the differences were not consistently significant statistically[13].

Two pith-to-bark increment cores were taken at breast height of the tree, usually at 180° intervals. In the case of lodgepole pine, disks were taken at breast height. Two pith-to-bark strips, preferably at 180° intervals, were sawn from the disks. The final dimensions of the strips were 5 mm on the transverse surface and 5 mm along the grain.

The cores and strips were divided into outer- and inner-half segments. The outer-half segment was the portion from the bark to half the length of the entire core. The inner half was the remaining portion closer to the pith.

Method of Density Calculation: The two segments were analyzed separately for relative density using the maximum-moisture-content method[14]. The inner half of the core was analyzed only for interior Douglas-fir and lodgepole pine to obtain an estimate

[13] Gonzalez, J.S. and Kellogg, R.M. 1978. Evaluating wood specific gravity in a tree improvement program. Forintek Can. Corp., West. For. Prod. Lab., Vancouver, B.C. Inf. Rep. VP-X-183.

[14] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

of the juvenile wood relative density. Western hemlock, the spruces, and the true firs do not have density values for the inner half. Lodgepole pine samples were pre-extracted with alcohol- benzene, alcohol, and hot water. Species average was the arithmetic mean of all individual trees (based on two cores per tree).

Gonzalez, J.S. 1989. Wood density of field-selected western larch plus trees. Report prepared for the B.C. Ministry of Forests, Victoria, B.C.

Sampling Location: Southeastern British Columbia.

Method of Sampling: See Gonzalez 1985, 1987.

Method of Density Calculation: Basic wood densities were determined separately on the juvenile and mature wood portions of the core using the maximum-moisture-content method[15]. The samples were pre-extracted with cyclohexane-ethyl alcohol and hot water. Juvenile wood consisted of the first 15 rings from the pith. Mature wood excluded these first 15 rings.

Grigal, D.F.; Sucoff, E.I. 1966. Specific variation among thirty jack pine plots. TAPPI 49(11):497-498.

Sampling Location: Hubbard County, Minnesota; all sites were within a 15-mile wide circle of almost continuous mixed pine forest, undisturbed for at least 10 years, on level and well-drained ground.

Method of Sampling: Increment cores were removed from trees with dbh not less than 10.2 cm and soaked in water to achieve green volume. A segment containing the last 10 years of growth was cut from each core and analyzed for density.

Method of Density Calculation: Basic density was determined from the ovendry weight and green volume of the segment. The green volume of the segment was calculated from its length and diameter. The length of the segment containing the last 10 years of growth was measured on an Addo-X tree-ring machine. The diameter was the inside diameter of the increment core borer.

H

Hakkila, P.; Panhelainen, A. 1970. On the wood properties of *Pinus contorta* in Finland. Commun. Inst. For. Fenn. 73.1.

Sampling Location: Twenty-four stands on experimental forest land owned by the National Board of Forestry: 2 in north Finland (above 66° latitude) and 22 in the south (below 62° latitude). The growing stock was pure lodgepole pine. The seeds were from Alberta and British Columbia. In four stands, the seeds were of unknown provenance.

[15] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

Method of Sampling: Five trees were selected from each of the stands in the south, six trees from each of the stands in the north. From each tree, 5-cm thick disks were sawn at intervals of I m from the butt up to the crown.

Method of Density Calculation: Whole disks including knots were analyzed for basic wood density using a xylometer to measure green volume. To obtain average stem density, the disk densities were weighted by their respective diameters.

Hale, J.D.; Fensom, K.G. 1931. The rate of growth and density of the wood of white spruce. Can. Dep. Inter., For. Serv., Ottawa, Ontario. Circ. 30.

Sampling Location: Two stands in the Pasquia National Forest of Saskatchewan and two stands in the Riding Mountain Forest of Manitoba.

Method of Sampling: One hundred white spruce trees were collected from each stand. This number was considered a fair sample of the wood in the locality. Cross-sectional disks, 7.6 cm thick, were taken at 3.7-m intervals along the stem from 0.3 m above ground to the top. In larger trees, the disks were obtained at 4.9-m intervals.

Large disks (first three from the bottom) were sampled by taking a pie-shaped sector about one-tenth the volume of the disk. Each sector was subdivided further into three sections by the following procedure: two distances from the pith were measured along the radius. The first was equal to half the radius; the second was from the pith to 0.707 times the radius. The sector was cut at these points along the curvature of the growth rings to produce three sections. These sections were used to determine the average density of the disk.

Method of Density Calculation: Basic density was determined for each disk, using the water immersion method to measure the green volume of the samples. Smaller disks were analyzed whole. To obtain the densities of the larger disks, the three sections from each pie-shaped sector were analyzed separately and density weighted by the volume fraction represented by each in the disk. The first and second sections closest to the pith were each given a weighting factor of 1/4. The third section closest to the bark was given a factor of 1/2.

To obtain the average density for each stem, the disk densities were weighted by the volume fraction represented by the disks in the stem.

Hale, J.D.; Prince, J.B. 1940. Density and rate of growth in the spruces and balsam fir of Eastern Canada. Can. Dep. Mines Res., Dom. For. Serv., Ottawa, Ontario.

Sampling Location: Seventy stands distributed over a wide range of territory from near Kenora in western Ontario to the coastal regions of New Brunswick and Nova Scotia in the extreme east of Canada.

Method of Sampling: Selection of trees was done to represent all the significant diameter classes in the stands sampled. Disks, 5.1 cm thick, were cut from each tree at stump height and at intervals of 2.4 m up the tree to the "smallest usable top diameter".

Method of Density Calculation: Mean basic density values were given for each diameter class. For the purpose of the present report, the mean density for each of the species examined was calculated from the average values given for each diameter class, weighted by the number of trees. The range of parameter values presented in the present report was also based on the average values given for each of the diameter classes sampled.

Hall, J.P. 1984. Relationship between wood density and growth rate and the implications for the selection of black spruce plus trees. Environ. Can., Can. For. Serv., Newfoundland For. Res. Cent., St. John's, Newfoundland. Inf. Rep. N-X-224.

Sampling Location: Twelve stands in central Newfoundland.

Method of Sampling: From 50 to 100 trees were sampled per stand. They were dominant or codominant trees, straight stems, narrow crowns, and free from insects and diseases. A single core, pith-to-bark, 12 mm in diameter, was taken at breast height from the west side of the tree.

Method of Density Calculation: Basic densities of the cores were determined by the water displacement method. Species average was calculated for this report by taking the arithmetic mean of the given stand mean densities.

Harris, J.M. 1978. Effects of site and silviculture on wood density of Douglas-fir grown in Canterburn conservancy. N.Z. For. Serv, For. Res. Inst., Rotorua, N.Z. For. Prod. Div. Rep., WQ. 21. Unpublished report A.

Harris, J.M. Undated. A survey of the wood density of Douglas-fir grown in New Zealand. Unpublished report B.

Sampling Location: New Zealand.
(A) Seven sites from the plains to the high country of Arthurs Pass in Canterbury conservancy. Elevation of sites ranged from 60 to 700 m. Three stands had been unthinned, two stands had been thinned, one was a species trial, and one was a regeneration in an area of ornamentals.
(B) Nineteen sites in the north and south islands of New Zealand using spacements of 1.2×1.2 m in three stands, and 2.4×2.4 m in 12 stands. Eleven stands had been unthinned, two had had light thinning, and one had been heavily thinned.

Method of Sampling:
(A) Five trees from each site to represent highly contrasting conditions were sampled at breast height.
(B) A total of 100 trees from each of 19 sites were sampled at breast height.

Method of Density Calculation: Both methods used 10-mm increment cores and beta-ray densitometer to measure densities of the 10 outer growth rings closest to the bark. Density is based on 10% moisture content.

Harris, J.M.; Kripas, S. 1959. Notes on the physical properties of Ponderosa pine, Monticola pine, western red cedar, and Lawson cypress grown in New Zealand. N.Z. For. Serv., For. Res. Inst., Rotorua, N.Z. Res. Note 16.

Sampling Location: Compartments 1016, 1074, and 1093 in Kaingaroa Forest, New Zealand. The last two compartments were within 18 m of each other.

Method of Sampling: One dominant, one codominant, and one suppressed tree of ponderosa pine were taken from each of compartments 1016 and 1074. A dominant and a codominant tree were taken from compartment 1093. Sample disks were cut from the butt and from every fifth internode to a 15.2-cm top diameter. North and south sectors were cut from each disk.

Method of Density Calculation: Basic density was analyzed on the two sectors from each disk. Mean density for each tree was given but no weighting by volume was specified. For this report, the mean density and coefficient of variation for ponderosa pine were calculated based on the given mean densities of the individual trees.

Harris, J.M.; Orman, H.R. 1958. The physical and mechanical properties of New Zealand-grown Douglas-fir. N.Z. For. Serv., For. Res. Inst., Rotorua, N.Z. Tech. Pap. 24.

Sampling Location: New Zealand. Twelve trees were sampled in 4 sites in the Rotorua area on the north island and twelve from 7 sites on the south island. Two sites in the Rotorua area were planted at a spacing of 2.4 × 2.4 m; two at 1.8 × 1.8 m. On the south island, three sites were planted at 1.2 × 1.2 m spacing; two sites at 2.4 × 2.4 m, and the rest had mixed spacings. The sites on the south island had extremely contrasting environments.

Method of Sampling: A dominant, codominant, and intermediate tree were sampled in each of the four sites in Rotorua. A dominant and/or codominant tree was sampled on the south island. Sample disks were cut from every fifth internode from the stump; north and south sectors were cut from each disk.

Method of Density Calculation: Basic density was determined on the sectors from each disk. Species average and coefficient of variation were calculated based on the mean density given for the individual trees.

Heger, L. 1974. Longitudinal variation of specific gravity in stems of black spruce, balsam fir, and lodgepole pine. Can. J. For. Res. 4:321-326.

Sampling Location: Black spruce and balsam fir were sampled from 20 plots in even-aged natural stands in Quebec. Lodgepole pine samples were from Prince George, British Columbia.

Method of Sampling: Five dominant or codominant trees were sampled from each plot. For black spruce and balsam fir, 10 disks were obtained from each stem at intervals of 10% of total tree height beginning at the 90% mark. For the lodgepole pine, disks were cut at 2-m intervals above stump.

Method of Density Calculation: Basic densities of the disks were determined by the water displacement method. Green volume was achieved by soaking disks in water for at least 20 hours.

Hegyi, F. 1969. A study of basic density variation in jack pine. Can. Dep. Fish. For., Can. For. Serv., For. Res. Lab., Sault Ste. Marie, Ontario. Intern. Rep. 0-17.

Sampling Location: Rectangular, 0.2-acre, semipermanent sample plots from 12 stands, representing a range of natural forest conditions in Wells township, Algoma District, Ontario.

Method of Sampling: Dbh classes (grouped by 2.5–5.0 cm diameter class) were determined for each plot. One tree per diameter class, per plot, was randomly selected. Disks, 2.5-5.0 cm thick, were cut at points representing 10% of total height of tree.

Method of Density Calculation: Basic densities were determined on the disks by water displacement using the micrometer-head method of measuring the amount of water displaced[16]. Ovendry weights of the disks were taken after air-drying for 2–3 weeks and drying in an oven at 105°C to constant weight. The stem density was calculated as the weighted average of the disk densities, the weighting factor being the stem volume represented by each disk.

Hejja, A. 1986. Procedures used in the Canadian Ingrade Testing Program. Report prepared for the Canadian Wood Council, Ottawa, Ontario.

Sampling Location: Various sawmills from across Canada.

Method of Sampling: Clear wood blocks from dimension lumber of different grades and sizes used in the ingrade compression strength tests.

Method of Density Calculation: Density was calculated as the ratio of ovendry weight to ovendry volume. Ovendry volume was determined by water immersion. For this report, species average was calculated as the arithmetic mean of all blocks tested for a species.

Honer, T.G. 1970a. Bole weight to volume ratio: balsam fir. Can.Dep. Fish. For., Can. For. Serv., Ottawa, Ontario. Notes: 26(4):37.

Honer, T.G. 1970b. Dimensional relationships in open-grown balsam fir trees. Can. Dep. Fish. For., Can. For. Serv., For. Manage. Inst., Ottawa, Ontario. Inf. Rep. FMR-X-24.

Sampling Location: Open-grown plantation at the Petawawa Forest Experiment Station, Chalk River, Ontario.

Method of Sampling: Forty trees were randomly selected, none less than 7.6 cm at dbh. The trees were cut at stump height (15 cm above ground) and sectioned into 1.2-m bolts. Smaller trees were sectioned into bolts 0.6 m long.

Method of Density Calculation: The boles from each tree were debarked and weighed green. A disk, 3.8 cm in thickness, was removed from the midportion of each bole,

[16] Carmichael, A. 1967. Annual report. Ont. Dep. Lands. For., Res. Branch, Toronto, Ontario.

weighed green, and ovendried at 104°C to constant weight for determination of percent dry weight. From this, the ovendry weights of the individual boles was determined. The volume of each bole was determined by the Smalian formula, using the large- and small-end diameters of the bole and its length. The total volume and ovendry weight of each whole stem were obtained by summing up the individual bole values. To calculate stem density, total ovendry weight was divided by the total volume for each stem.

I

Ishengoma, R.C.; Nagoda, L. 1987. Strength properties of small clear wood specimens of Sitka spruce (*Picea sitchensis* Carr.) Medd. Nor. Inst. Skogforsk. 40.6.

Sampling Location: Thirty-one locations in five districts in western and northern Norway: Rogaland, Hordaland, Sogn og Fjordane, Nordland, and More og Romsdal.

Method of Sampling: Fifty-six trees were cut into 234 planks of size 50 × 150 mm, 74 planks of size 50 ×200 mm, and 64 of size 75 ×200 mm. A total of 372 small clear specimens were prepared for testing.

Method of Density Calculation: The samples used for testing bending strength were used for density measurements. Densities of the samples were determined from their ovendry weights and from their volumes after conditioning in a room at 65% relative humidity and 20°C. The volumes of the samples were determined from their width, length, and thickness. Final values of density were corrected to 12% moisture content.

J

Javadi, Z.; MacSuirtain, M.; Gardiner, J.J. 1983. The effect of tree espacement upon wood density in Sitka spruce (*Picea sitchensis* (Bong.) Carr.). Ir. For. 40(2):92-97.

Sampling Location: Forest and Wildlife Service spacing trial 11/63 established in 1963 on a clayey soil at Doneraile Forest, Co. Cork, Ireland. The experimental design was a randomized block with four replications and five spacing treatments.

Method of Sampling: Trees were selected on the basis of the mean diameter at breast height in the selected spacings. Eight trees were selected from each of three espacements: 1.2, 2.4, and 3.0 m. The trees were felled and disks 2-cm thick were cut from the stem at heights corresponding to 3.5%, 15%, 30%, 45%, 60%, and 80% of the total height. A rectangular section was sawn from the center of the disk, boxing the pith. From this section, groups of annual rings were split off for wood density determination.

Method of Density Calculation: Basic density was calculated by the water displacement method. No description was given for calculating individual whole tree density. Spacing had no effect on wood density; the data for all trees were therefore pooled to calculate the mean density and coefficient of variation.

Jessome, A.P. 1977. Strength and related properties of woods grown in Canada. Environ. Can., Can. For. Serv. East. For. Prod. Lab., Ottawa, Ontario. For. Tech. Rep. 21.

Kennedy, E.I. 1965. Strength and related properties of woods grown in Canada. Can. Dep. For., For. Prod. Res. Branch, Ottawa, Ontario. Publ. 1104.

Sampling Location: Various sawmills from across Canada.

Method of Sampling: The sampling procedure used was as described in Jessome's report, *Laboratory processing of the specimens* (1965). (See also Kennedy et al. 1968.) Each specimen was taken from a plank, board, or log. Samples were cut 30 cm from the end of a freshly cut plank or board taken from the green chain, about 8 cm long in whatever widths were being cut. Alternately, disks about 8 cm thick were cut from a log. Pith-to-bark sections were taken from these disks, or in the case of small disks, sections extended across the whole diameter.

Method of Density Calculation: Basic densities were determined on the test samples by the water displacement method.

Johnstone, W.D. 1970. Some variations in specific gravity and moisture content of 100-year-old lodgepole pine trees. Can. Dep. Fish. For., Can. For. Serv., For. Res. Lab., Calgary, Alberta. Inf. Rep. A-X-29.

Sampling Location: Two square, 1/10-acre plots at Kananaskis Forest Research Station, Alberta.

Method of Sampling: Trees were from even-aged (100 years old) stands: one undisturbed, the other thinned in 1938 with no apparent effect on wood density. Disks, about 2.5 cm thick, were cut at about 30 cm above ground (stump height), at 1.4 m and 2.7 m, and at 2.4-m intervals to the top. A sector containing a line of mean radius of the disk was obtained. No screening was done for knots and other defects.

Method of Density Calculation: Density was determined as the ratio of ovendry weight to ovendry volume. Method B-11 Designation D2395-65T[17] was used. Stem density was calculated as the weighted average of the disk (sector) densities, the weighting factor being the volume of the stem represented by the disks. Stem volume was calculated by the Smalian formula[18].

Jozsa, L.A. 1989. Properties of second-growth lodgepole pine. Forintek Can. Corp., Vancouver, B.C. Personal communication.

Sampling Location: Thirty trees of fast-growth lodgepole pine were sampled in Alberta and 30 trees in southeastern British Columbia. In Alberta, the three sites sampled had an average of 600 trees/ha. In British Columbia, the sites were in active logging areas with 605 trees/ha and 836 trees/ha in two of the sites.

Method of Sampling: See Jozsa et al. (1989).

Method of Density Calculation: See Jozsa et al. (1989).

[17] American Society for Testing and Materials. 1967. Tentative methods of test for specific gravity of wood and wood-base materials. Method B-11. D2395-65T. Am. Soc. Test. Mater. 16:781-792.

[18] Chapman, H.H.; Meyer, W.H. 1949. Forest mensuration. McGraw-Hill Book Co., New York, N.Y.

Jozsa, L.; Powell, J.M. 1987. Some climatic aspects of biomass productivity of white spruce stem wood. Can. J. For. Res. 17:1075-1079.

Sampling Location: Alberta. Four sampling sites transected Alberta north to south, close to 115 °longitude. All sites were even-aged (110 years), well-drained, level terrain in mature close-canopy stands, with no evidence of human influence, insect damage, or pathogens.

Method of Sampling: Six dominant or codominant trees were felled in each of four sites. The trees were at least one tree-height apart and were selected from an area of about I ha. Seven cross-sectional disks were cut from each tree: one at the base (about 15 cm above ground), one at breast height, and five others at equal intervals along the stem from the base to the top. A bark-to-bark strip was sawn from each disk along the average diameter of the disk.

Method of Density Calculation: The strips were sawn to uniform thickness and x-rayed. Radiographs were scanned on a densitomer (with a resolution of 0.01 mm) to measure ring width and density. Density of the whole stem was calculated based on ovendry weight and ovendry volume using a formula that estimated cumulative volume and weight of the whole stem from ring width, average ring density, and yearly height growth of the stem.

Jozsa, L.; Richards, J.; Johnson, S.G. 1989. Characterizing the resource. Pages 5-22 *in* Second growth Douglas-fir: its management and conversion for value. A report of the Douglas-fir task force. Forintek Can. Corp., Vancouver, B.C. Spec. Publ. SP-3.

Sampling Location: Six coastal Douglas-fir stands on Vancouver Island, British Columbia: Ladysmith, Cassidy, Jordan River, Lizard Lake, Campbell River, and Cowichan Lake.

Method of Sampling: Ten trees were cut per stand. Trees were fast growth, dominant or codominant. Disks, 2.5-cm thick, were cut at breast height and at intervals of 20% of the total tree height. Two opposite strips were sawn along the average diameter of the disk. The finished dimensions were about 4-5 mm wide on the transverse surface and about 2.5 mm along the grain.

Method of Density Calculation: The samples were pre-extracted with alcohol-benzene in an ultrasonic vibrator. Density was determined by x-ray method[19] based on green volume. Stem-wood density was calculated as in Jozsa and Powell (1987).

K

Keith, C.T.; Chauret, G. 1989. Wood quality and heritability studies in a jack pine progeny test. Report prepared for the Canadian Forestry Service, Ottawa, Ontario.

Sampling Location: Three progeny test plantations located in Adelard, Mackey, and Chalk River in the Upper Ottawa Valley, Ontario. The Chalk River and Adelard plantations had deep sandy soils of medium to fine textures. The Mackey plantation had

[19] Parker, M.L.; Bruce, R.D.; Jozsa, L.A. 1980. X-ray densitometry of wood at the WFPL. Forintek Can. Corp., West. For. Prod. Lab., Vancouver, B.C. Tech. Rep. 10.

sandy to gravelly soil with high water table. Trees were planted at 1.3 × 1.3 m spacing.

Method of Sampling: Trees were obtained through thinning operations when the trees were 20 years old. An average of 10 trees from about 55 families (out of the 100 families in each plantation) were sampled. Cross-sectional disks about 2-cm thick were taken at breast height for density determination.

Method of Density Calculation: Basic densities were determined on whole disks using the water displacement method for measuring green volume.

Keller, R.; Thoby, M. 1977. Liaisons entre l'état juvenile et l'état adulte pour quelques caractères technologiques et auxométriques chez le Douglas (*Pseudotsuga menziesii*). Ann. Sci. For. 34(3):175-203.

Sampling Location: France. Three plantations of Douglas-fir located at: 1) Saint-Just-D'Avray, experimental plots of the Silviculture and Production Station of the Centre National de Recherches Forestieres. Plantation age 62 years. 2) Guebwiller State Forest. Plantation age 60 years. 3) Verreries de Moussans State Forest, Stand 10 at the experimental station of the Amelioration des Arbres Forestiers du C.N.R.F. Plantation age 30 years.

Method of Sampling: Selected were 20, 31, and 30 trees from locations 1, 2, and 3, respectively. The locations were selected to represent different environment conditions. Increment cores were obtained at breast height. The cores were cut to obtain 10 growth rings closest to the pith (juvenile wood) and 10 growth rings closest to the bark (mature wood).

Method of Density Calculation: The samples were analyzed by x-ray densitometry.

Kellogg, R.M.; Swan, E.P. 1986. Physical properties of black cottonwood and balsam poplar. Can. J. For. Res. 16:491-496.

Sampling Location: Western Canada: Black cottonwood trees were obtained from Fraser Valley, Squamish Valley, and Kingcome Inlet in British Columbia. Balsam poplar trees were obtained from Lodgepole, Great Slave Lake, and Lac La Biche in Alberta.

Method of Sampling: Ten trees were randomly selected from each site. From each tree, a single bolt, 130 cm long, was cut right above the breast height (1.36 m from ground). Additional bolts of the same length were obtained at 25%, 50% and 75% of the total height of the tree from two trees for each site. A 5-cm thick disk was cut 25 cm from the lower end of the bolts. Two pith-to-bark wedges, at 180° intervals, were cut from the disks and analyzed for density.

Method of Density Calculation: Basic densities of the wedges were determined by the water displacement method. Whole-stem density was calculated by weighting the density of the wedges at each height level by the volume proportion represented by the wedges (disks) in the stem.

Kennedy, E.I. 1965. Strength and related properties of woods grown in Canada. Can. Dep. For., For. Prod. Res. Branch, Ottawa, Ontario. Publ. 1104.

See Jessome (1977).

Kennedy, E.I.; Jessome, A.P.; Petro, F.J. 1968. Specific gravity survey of eastern Canadian woods. Can. Dep. For. Rural Dev., For. Branch, Ottawa, Ontario. Dep. Publ. 1221.

Sampling Location: A total of 102 sawmills and logging sites were sampled in New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland in eastern Canada.

Method of Sampling: A minimum of 5 and a maximum of 10 specimens per species were taken at each sampling site. All specimens were free of defects such as knots and decay and were cut from green boards or planks if possible. If this was not possible, samples were taken from logs in skidways. Each specimen was the full cross section of the board and about 7.6 cm in length. To reduce the likelihood of taking two samples from any one tree, every fifth log of a particular species was selected. Specimens were cut 30 cm from the end of the board or plank. When logs were sampled, a 0.3-m-long section was removed from the ends of 10 freshly cut logs at the site or mill yard. A 7.6-cm thick disk was cut from each of these logs. A section 7.6 cm wide was cut from each disk from the pith to the bark, or, in the case of small disks, the section extended across the whole diameter of the disk.

Method of Density Calculation: Density was determined on each sample based on ovendry weight and green volume. The volumes of the samples were measured by the water immersion method. Ovendry weights were taken after drying of samples in an oven at 103°C.

Kennedy, R.W.; Swann, G.W. 1969. Comparative specific gravity of amabilis fir and western hemlock grown in British Columbia. Can. Dep. Fish. For., West. For. Prod. Lab., Vancouver, B.C. Inf. Rep. VP-X-50.

Sampling Location: Western Canada: Nine areas in British Columbia representing the wide distribution of western hemlock and amabilis fir. Fifteen locations for western hemlock (five in interior B.C. and ten on the coast, including one on Queen Charlotte Island). Nine of the ten coastal locations were sampled for amabilis fir.

Method of Sampling: Forty trees were sampled per area. One standard 4-mm increment core from pith-to-bark was taken at breast height. The cores were screened for knots, decay, and other visible defects. Maximum core length was 25.4 cm for dbh greater than 50.8 cm.

Method of Density Calculation: Basic densities were determined on the cores by the maximum-moisture-content method[20]. Total-stem density was estimated for each tree using the multiple regression equation relating core to whole-tree density

[20] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

developed by the U.S. density survey (U.S. Forest Service 1965). To obtain a single mean density value for the species, the mean densities for each sampling area were weighted by the number of trees sampled in the area.

Knigge, V.W. 1960. Die holzeigenschaften der kustentanne (*Abies grandis*). Allg. Forstz 7.

Sampling Location: Seven different sites in the coastal regions of Germany. Elevations ranged from 30 to 560 m; rainfall per year ranged from 306 to 430 mm. One site was considered very dense, one was open-grown, and one had been fertilized with calcium. One tree was considered very branchy.

Method of Sampling: Two trees were selected from a "very dense site", two from "open-grown", one from a fertilized site, one a "very branchy" tree, and one from each of three additional sites for a total of nine trees. Trees were selected to represent various conditions. Disks were taken at 2-m intervals up the stem. Samples were cut from each disk following a north-south and east-west cruciform pattern. The samples measured 2 $\times$ 2 cm on the cross section and 3 cm along the grain.

Method of Density Calculation: Density was measured on each of the samples using ovendry weight and volume.

Koch, P. 1987. Growth characteristics of lodgepole pine trees in North America. U.S. For. Serv., Intermt. Res. Stn., Ogden, Utah. Gen. Tech. Rep. INT-227.

Sampling Location: Nine stands, natural and unthinned, from 40° to 60° latitude, British Columbia.

Method of Sampling: Trees were represented by three diameter sizes: 76, 152, and 228 mm in dbh from three different elevations, of approximately the same age. They were free of insects and diseases. One 50-mm thick disk was cut at ground level and at intervals of one-tenth of the total height, including one from the apical tip.

Method of Density Calculation: Basic density was determined by the water displacement method. The total-stem density was the weighted average of the disk densities at each height level, the weighting factor being the volume proportion represented by the disks in the stem.

Krahmer, R.L. 1966. Variation of specific gravity in western hemlock trees. TAPPI 49(5):227-229.

Sampling Location: Clatsop County and Mount Hood National Forest in Oregon.

Method of Sampling: Twelve trees representing a wide range of diameters, ages, and rates of growth were selected from the two locations: seven trees from Clatsop County and five from Mount Hood National Forest. Cross-sectional disks were taken at 2.4-m intervals along the bole of each tree from stump height to a top diameter of 20 cm. Two types of samples were obtained from each disk: a wedge sample and a radial strip from pith to bark measuring 1 cm on the cross section and I cm along the grain. All samples were taken from the same cardinal direction.

Method of Density Calculation: The strips were subdivided into increments of 1 to 20 growth rings depending on the growth rate. Each increment was analyzed for basic density by the maximum-moisture-content method[21]. The density of the whole strip was calculated by weighting the density of each increment by its area.

The wedge samples were analyzed for basic density using the water immersion method to measure green volume.

The average tree density was derived from two values: one based on strip samples, the other on wedges. To estimate the average density of each tree, the values obtained at each height on the stem were weighted by the volume fraction represented by either the strip or wedge analyzed at that height.

Krahmer, R.L.; Snodgrass, J.D. 1967. Strength of western hemlock compared for two areas. For. Prod. J. 17(8):36-38.

Sampling Location: Clatsop County and part of Mount Hood National Forest west of the summit of the Cascade mountains, Oregon.

Method of Sampling: Forty trees were selected and cut according to a plan developed for random sampling of trees and wood. Sticks measuring 5 × 5 cm on the cross section by 15 cm long were obtained from bolts for preparing clear test specimens according to ASTM standards[22].

Method of Density Calculation: Densities were determined on the samples using their ovendry weights and unseasoned volumes, measured according to ASTM standards[23].

L

Lavers, G. 1983. The strength properties of timber. Dep. Environ., Princes Risborough Lab., Princes Risborough, Aylesbury, U.K. Build. Res. Establ. Rep.

Sampling Location: All values cited from this reference were based on materials grown outside of Canada. Refer to the tables for the geographic origin of the different species cited.

Method of Sampling: Generally, materials tested were collected in log form obtained from five or more trees of one species from one or more regions to cover the distribution range of the species.

The earlier work followed the cruciform pattern of sampling for small clear test specimens as described in ASTM standards[24]. Later sampling procedures abandoned the cruciform pattern and used a procedure in which the bolts were sawn into

[21] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

[22, 23, 24] American Society for Testing and Materials. 1989. Standard methods of testing small clear specimens of timber. D-143-83. Am. Soc. Test. Mater. 4:35-76.

sticks and "the probability of obtaining a stick at any distance from the centre of a cross section of a bolt was proportional to the area of timber at that distance".

Method of Density Calculation: The tests for wood density were carried out in conjunction with strength tests and were based on British standards. Density values were calculated based on ovendry weight and the volume during testing. Volume measurements were carried out on both green and air-dry samples. The moisture content of the air-dry samples are specified.

Littleford, T.W. 1961. Variation of strength properties within trees and between trees in a stand of rapid growth Douglas-fir. Can. Dep. For., For. Prod. Lab., Vancouver, B.C. Rep. V-1028.

Sampling Location: The University of British Columbia Research Forest at Haney, British Columbia. Two trees were obtained from the crest of a small hill and one at the base, a fourth from a southeast slope, and a fifth from a shelf forming the bank of a stream. The site was highly productive.

Method of Sampling: Five trees were selected to provide an even and fast growth rate up to a rotation age expected for Douglas-fir and to reflect the variation of growing conditions in the sites. Each was cut into three 1.2-m bolts. Midpoints of these bolts were at the 2.4-, 12.8-, and 23.2-m heights in the tree. The bolts were trimmed and reduced to 30.5 cm wide on the cross section, with the pith at the center, and discarding materials with large knots and eccentric growth rings. Using a grid pattern drawn on top of the cross-sectional surface of the bole, rough pieces measuring 5.7 ×5.7 cm on the cross section by 1.2 m long were sawn from all bolts. The rough pieces were machined further to produce a cross-sectional size of 5.1 × 5.1 cm. Specimens tested for bending and compression parallel were used for density determination.

Method of Density Calculation: Basic densities were determined on the samples. The green volumes were measured on samples at a moisture content above 25%. One percent of the total samples had 25-30% moisture content; the rest ranged from 30% to 170%. Volumes were determined by the water displacement method.

M

MacGregor, W.D. 1952. Sitka spruce-density survey project. Dep. Sci. Ind. Res., For. Prod. Res. Lab., Princes Risborough, Aylesbury, U.K. Prog. Rep. 1.

Sampling Location: Three Forest Commission plots in Wales. Stand ages were 21, 25, and 31 years.

Method of Sampling: Disks 30 cm thick were obtained at 0.3 m and 6.4 m above the ground from each tree.

Method of Density Calculation: Each disk was reduced in thickness to 2.54 cm and cut in half through the pith. After removing the bark, the area of each half disk was traced on paper and measured with a planimeter. The volume of the piece was then calculated from the area and its thickness. The half disks were dried in the oven and the weight taken. The density was calculated from the ovendry weight and green volume of the half disks. The average of the two half disks at the given height was the density of the tree at that height.

Maeglin, R.R. 1966. Predicting specific gravity of plantation-grown red pine. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Note 0149.

Sampling Location: Eleven plantations throughout Wisconsin, representing variation in fertility level, ground water presence, proximity to Lake Superior, and stand thinning.

Method of Sampling: Six trees were randomly selected regardless of height or diameter from each 1/25-ha plot established in each of the 11 plantations. A single core was taken bark-to-bark at breast height. The trees were felled and disks 5.1 cm thick were cut at ground level and at intervals of 1.2 m up the stem to a top diameter of 7.6 cm. This was done at all sites except one, where cores instead of disks were sampled up the stem.

Method of Density Calculation: Basic densities were determined on both cores and disks. The bark-to-bark cores were cut at the pith to give two pith-to-bark segments. These were trimmed to exclude the pith and bark, and their lengths immediately measured to the nearest 0.025 cm. Their volumes were calculated from their lengths and from the inside diameter of the core borer. Ovendry weight was taken to the nearest 0.001 g after drying at 105°C.

The disks were soaked and their green volumes determined by the water immersion method. Their ovendry weights were taken to the nearest 0.1 g after drying to constant weight at 105°C. The density of the tree was calculated as the average of the disk densities, weighted by the volume proportion represented by the disks in the stem.

Maeglin, R.R. 1973. Wisconsin wood density survey. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 202.

Pronin, D. 1971. Estimating tree specific gravity of major pulpwood species of Wisconsin. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. Pap. 161.

Sampling Location: The geographic range of the species in Wisconsin, established by the U.S. Forest Service.

Method of Sampling: Increment cores were obtained at breast height. Sampling of the felled trees for estimating the merchantable stem density was similar to that described under Maeglin (1966).

Method of Density Calculation: Basic densities were determined on both increment cores and disks from the felled trees. The procedure followed was as described under Maeglin (1966).

Density of the whole tree was calculated in two ways: from the weighted densities of the disks, weighting factor being the proportion of volume represented by the disks in the merchantable stem (Wahlgren et al. 1966); and from using a previously established regression equation relating breast-height core to whole tree density.

Maeglin, R.R.; Wahlgren, H. 1972. Western wood density survey. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2.

This study was a continuation of an earlier wood density survey on nine additional species in the western U.S. (U.S. Forest Service 1965). The sampling locations, sample selections, and analysis were similar to those described in that publication.

Magnussen, S.; Smith, V.G.; Yeatman, C.W. 1985. Tree size, biomass, and volume growth of twelve 34-year-old Ontario jack pine provenances. Can. J. For. Res. 15:1129-1136.

Sampling Location: The jack pine provenance test at the Petawawa National Forestry Institute, Ontario. Sampling area consisted of four blocks of twelve 100-tree plots. Low thinning of the plantation took place in 1969 (removing 32% of all stems), and in 1979 stem number was reduced to 30 per plot. Six trees were cut from seven randomly chosen provenances. Two trees were dominant, two were codominant, and two were intermediate. Disks were obtained at tree heights of 0, 0.5, 1.3, and 2.0 m above ground level and 2.0 m thereafter. A single sector was obtained from each disk.

Method of Density Calculation: Basic density was determined using the water displacement method. The total-stem density of the tree was calculated by taking the weighted average of the disk (sector) densities at each height level. The weighting factor was the inside-bark volume (calculated by Smalian formula) represented by the disks.

Markwardt, L.J.; Wilson, T.R.C. 1935. Strength and related properties of woods grown in the United States. U.S. For. Serv., For. Prod. Lab., Div. Res., Madison, Wisconsin. Tech. Bull. 479.

Sampling Location: As given in the tables for each species. All samples were grown in the U.S.

Method of Sampling: Logs generally 1.2-2.4 m were taken from each of five or more representative trees of each species. The upper end of the log selected was in most instances 4.9 m above the stump. Each 1.2-m log was divided into sticks following a cruciform pattern on the cross section of the log. Four to six sticks from each tree were tested for density. The sticks measured 5.1 × 5.1 cm on the cross section and 15.2 cm along the grain.

Method of Density Calculation: Density was expressed using volumes under three different moisture conditions: green, ovendry, and air-dry adjusted to 12% moisture content. Volumes were determined on the green pieces by measuring actual dimensions of the samples with a micrometer reading accurately to 0.0025 cm. The ovendry volumes were determined by dipping the samples in hot paraffin and using the water displacement method. The ovendry weights of the samples were taken before dipping them in paraffin.

McGowan, W.M. 1963. Strength and related properties of small clear specimens of Douglas-fir cut from stress-graded lumber. Can. Dep. For., For. Prod. Res. Branch, Vancouver, B.C. Publ. 1025.

Sampling Location: Eight mills located in the lower coastal area of British Columbia.

Method of Sampling: Three grades of unseasoned Douglas-fir lumber were selected in the mills: select structural, construction, and standard grades as described in the British Columbia Lumber Manufacturer's Association rules. Lumber 7.6 cm in thickness were selected. Each piece of lumber was cut at midlength: half was air-dried, the other half was kept green. Samples for strength tests were prepared from the two halves of the lumber in accordance with ASTM standard methods[25].

Method of Density Calculation: Densities were calculated on the ovendry weights and volumes at test of the samples. Samples tested for strength were used for density determination. Tests were carried out in both green and air-dry conditions. For the purpose of the present report, a species average was calculated for both green and air-dry volumes, using the combined data from the three grades of lumber tested.

McKimmy, M.D. 1959. Factors related to variation of specific gravity in young growth Douglas-fir. For. Prod. Res. Cent., Corvallis, Oregon. Bull. 8.

Sampling Location: U.S. experimental forests at Cascade Head in Oregon and at McLeary and Hood Canal in Washington; Williamette National Forest in Oregon, and Gifford National Forest in Washington. Average annual rainfall ranged from 94 to 226 cm. Soil drainage was good at each location.

Method of Sampling: Young growth (160 years old and under) Douglas-fir trees were selected at logging operations to represent four crown classes: dominant, codominant, high, and low intermediate.

Disks 30.5 cm thick were cut at intervals of 5 m throughout the length of each merchantable stem, starting from 0.9 to 1.2 m above the stump. The disks were split into rectangular blocks from pith to bark and further divided into smaller blocks of 10 growth rings for the first 40 growth rings from the pith.

Method of Density Calculation: Density was determined on each block using ovendry weight and green volume. Green volume was measured by the water immersion method. Mean density for each tree was the weighted average of densities at each height level. A species average and the coefficient of variation were calculated for the present report based on individual trees.

Meilleur, D.V. 1987. Evaluation of wood specific gravity in plus tree baseline selection methods for black spruce (*Picea mariana* (Mill.) B.S.P.). Undergraduate thesis. Fac. For., Lakehead Univ., Thunder Bay, Ontario.

[25] American Society for Testing and Materials. 1989. Standard methods of testing small clear specimens of timber. D-143-83. Am. Soc. Test. Mater. 4:35-76.

Sampling Location: Upland stand 60 km west of Thunder Bay, Ontario. Low stand density by Ontario standards (60% stocked).

Method of Sampling: Trees with superior and average growth in the stand were sampled. Trees were from a systematic grid of parallel compass lines laid out throughout the stand. Breast-height increment cores were divided into juvenile wood (pith to ring 20) and mature wood (ring 21 to bark).

Method of Density Calculation: Basic densities were determined on the cores by the maximum-moisture-content method[26].

Mullin, T. 1987. Relative density of plus trees selected in Nova Scotia. Personal communication.

See Sebastian (1984).

O

Okstad, T. 1987. The mechanical properties of small clear specimens of Sitka spruce (*Picea sitchensis* (Bong.) Carr). Medd. Nor. Inst. Skogforsk. 40.5.

Sampling Location: West coast of Norway (same as for Ishengoma and Nagoda (1987)).

Method of Sampling: Forty-one trees were selected from 29 sites in four different forest areas. The trees were bucked at intervals of 10% of the total height. The sections were split lengthwise or into quarters, depending on their size, and conditioned to 15-20% moisture content. The test blocks were obtained from these sections according to the Norwegian method[27].

Method of Density Calculation: Densities were calculated on the ovendry weights and volumes of the conditioned samples. Later, the densities were adjusted to 12% moisture content. The volumes of the conditioned samples were calculated from the width, length, and thickness of the samples measured by a caliper. Density was also determined on ovendry weight and green volume, using the same test samples used for measuring volumetric shrinkage.

Mean density based on ovendry weight and green volume was given for each stand. For the purpose of this report, the overall mean and the coefficient of variation based on the individual stand means were calculated.

Ouellet, D. 1983. Biomass prediction equations for twelve commercial species in Quebec. Environ. Can., Can. For. Serv., Laurentian For. Res. Cent., Ste. Foy, Quebec. Inf. Rep. LAU-X-62E.

[26] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. Serv., For. Prod. Lab., Madison. Wisconsion. Rep. 2014.

[27] International Organization for Standardization. 1975. Wood-test methods. Geneva, Switzerland. ISO 3129-1975.

Sampling Location: The most representative management unit in Quebec for each species was identified and sampled.

Method of Sampling: Merchantable trees (with dbh = or > 9.1 cm) were felled at 15 cm above ground. Unmerchantable trees (with dbh < 9.1 cm) were cut as close to the ground as possible. Merchantable stems were divided into three equal lengths. Unmerchantable stems were divided into two equal lengths. A disk, 3 to 4 cm thick, was taken at the lower end of each of the sections.

Method of Density Calculation: Each of the sections was weighed green. For the purpose of the present report, the following calculation of basic density was done from the raw data provided: total merchantable green volume (including bark) was calculated using Smalian formula. Bark volume was subtracted from total volume to obtain wood volume. Bark volume was estimated from bark weight and bark relative density obtained from published sources[28,29]. Total-stem density was the ratio of the total ovendry weight to total green volume of wood of the merchantable stem.

P

Peck, E.C. 1933. Specific gravity and related properties of softwood lumber. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Tech. Bull. 343.

Sampling Location: Lumber materials were collected from sawmills in Washington, Oregon, California, and Idaho for Douglas-fir; Washington and Oregon for western hemlock, Sitka spruce, and western larch; Idaho for western white pine; California, Idaho, and Montana for ponderosa pine; and Minnesota for northern (eastern) white pine.

Method of Sampling: High- and low-grade lumber with thicknesses up to and including 5.1 cm were studied. Test specimen was cut about 60 cm from one end of a lumber or board. Two cross-cuts were made at this point, producing a section of the board about 2.5 cm thick along the grain. Knots, decay, and other serious defects were avoided. For each grade or kind of lumber, 40 or more sections were procured. About 300 sections for each species were obtained from each mill, representing the clear wood of all products of the log except large timbers.

Method of Density Calculation: The densities of the samples were calculated from their ovendry weights and green volumes. The samples were soaked in cold water for 4-5 weeks to restore them to green condition. Green volume was determined by water displacement method. The samples were dried in an oven at 100°C to constant weight.

Pillow, M.Y. 1952. Some characteristics of young plantation-grown red pine in relation to properties of the wood. J. For. Prod., Res. Soc. 1/2:25-32.

[28] Isenberg, H.I. 1980. Pulpwoods of the United States and Canada. Vol. 1: Conifers. Third ed., revised by M.L. Harder and L. Louden. Inst. Pap. Chem., Appleton, Wisconsin.

[29] Millikin, D.E. 1955. Determination of bark volumes and fuel properties. Pulp. Pap. Mag. Can. 56(13):106-108.

Sampling Location: Eleven plantations in Wisconsin. Site indexes of the plantations were estimated as 12–18 m at a projected age of 50 years based on the ages and heights of dominant and codominant sampled trees.

Method of Sampling: Trees were sampled at different heights and sampling within trees included successive periods of growth, 5–15 years each.

Method of Density Calculation: Densities were determined on the ovendry weights and green volumes of the samples that had been used for total shrinkage test. The samples were resoaked in distilled water and cut into sections measuring 1.6 cm square in cross sections and 6.4 cm along the grain.

Polge, H. 1984. Influence des espacements de plantation sur la qualite du bois de Douglas. For. Entrep. 17:16-20.

Sampling Location: France; specific site not given. Stocking density in the plantation was 400 stems/hectare at 5 × 5 m spacing.

Method of Sampling: Five-mm diameter increment cores were taken at breast height of 17 selected trees.

Method of Density Calculation: Density was determined on each core by x-ray densitometry method. The cumulative density of the last 10 rings closest to the bark was determined for each core. The arithmetic mean of all the observations was reported.

Princes Risborough Laboratory. 1958. Report on the properties of four different provenance consignments of Sitka spruce. Princes Risborough, Aylesbury, U.K. Unpubished report.

Sampling Location: Radnor Forest, Radnorshire, Wales. Seeds were from Queen Charlotte Islands, B.C., Canada; and California, Oregon, and Washington, U.S.

Method of Sampling: Five trees representing each of the four provenances and size ranges were obtained from thinnings. Heights of the trees were measured at top diameter of 7.6 cm. Diameters given were measured at one-half the height of the trees. Disks 2.5-cm thick were cut at the butt, clear of the butt swelling, and at intervals of 3 m up the tree to 9–12 m height. Samples were cut at every fifth annual ring from the bark.

Method of Density Calculation: Green volumes of the test samples were estimated from their surface area and thickness. The average density values for a whole disk and a whole tree were obtained successively as weighted averages of the individual sections.

Princes Risborough Laboratory. 1959. Combined report on the properties of thinnings of homegrown Douglas-fir (*Pseudotsuga taxifolia*). Princes Risborough, Aylesbury, U.K. Unpublished report.

Sampling Location: Eight different locations in Great Britain.

Method of Sampling: Test samples were obtained from thinnings from plantations.

Method of Density Calculation: Not given, but probably similar to that given for Sitka spruce in Princes Risborough Laboratories (1958).

Pronin, D. 1971. Estimating tree specific gravity of major pulpwood species of Wisconsin. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. Pap. 161.

See Maeglin (1973).

R

Risi, J.; Zeller, E. 1960. Specific gravity of the wood of black spruce (*Picea mariana* Mill. (B.S.P.)) grown on a hylocomium-cornus site type. Laval Univ. For. Res. Found., Quebec City, Quebec. Contrib. 6.

Sampling Location: Laurentide Park in Quebec; elevation about 853 m; flat valley; hyloconium–cornus site as ecologically defined by Lafond[30].

Method of Sampling: Five dominant and codominant black spruce trees were selected within an area of 0.4 ha. From all stems, disks 5–8 cm thick were cut at intervals of 1.2 m starting from the ground level. Each disk was recut to a final thickness of 3 cm and sanded on both faces. On one of the faces, a grid with 5.1 $\times$ 5.1 cm squares was drawn. Following the grid, blocks were cut from the disks, discarding any material with knots or compression wood, or pith material. Three blocks with growth ring widths between 0.7 and 1.8 mm were randomly chosen from each disk, giving a total of 316 samples from five trees for density measurement.

Method of Density Calculation: Densities were determined from the ovendry weights and green volumes of the blocks. The samples were soaked in distilled water for 18 days and their volumes determined by the water immersion method. Ovendry weights of the blocks were taken after drying them for 48 hours at 103°C + 2°C.

Robertson, E.O.; Jozsa, L.A.; Spittlehouse, D.L. 1990. Estimating Douglas-fir wood production from soil and climate data. Can. J. For. Res. 20:357-364.

Sampling Location: Three established plots on the forested northwest slope of Mesachie Mountain, Vancouver Island, British Columbia. The plots are in an even-aged, approximately 70-year-old stand of Douglas-fir in a naturally regenerated site.

Method of Sampling: The 10 largest trees from each site were sampled. Where major defects such as scars, forks, or damaged crowns were discovered, the tree was eliminated from the sample and a dominant or codominant tree in close proximity to the 20 $\times$ 20 m plot was selected as a replacement. Pith-to-bark increment cores were taken at breast height from each tree from three or four directions at 90° intervals. The two best cores were selected for testing.

[30] Lalond, A. 1956. Notes sur l'identification des types forestières. North Shore Paper Company, Baie-Comeau, Quebec.

Method of Density Calculation: The cores were extracted in a Soxhlet apparatus for 3 days in a 2:1 solution of ethanol-benzene, 3 days in ethanol, and 5 days in distilled water. The cores were air-dried and sawn on a twin blade saw to produce strips of uniform thickness. The strips were scanned on a computerized direct reading densitometer. Direct data acquisition and a subsequent processing program were used to calculate mean core densities. For this report, mean core density was calculated as the arithmetic mean of all the individual values.

Roddy, D.M. 1983. Jack pine wood density. Woodlands Enterprises Ltd., Prince Albert, Saskatchewan. Intern. Rep.

Roddy, D.M. 1986. Report on white spruce wood density data. Woodlands Enterprises Ltd., Prince Albert, Saskatchewan. Intern. Rep.

Sampling Location: Saskatchewan.

Method of Sampling: Plus trees were selected according to the selection criteria of Prince Albert Pulpwood's tree improvement program. Disks were taken at breast height (1.3 m), at 4.5 m, and at 5-cm diameter top. A sector was cut from the large disks for density determination. Smaller disks were analyzed as such. Increment cores, 11 mm in diameter, were also taken at breast height.

Method of Density Calculation: Basic densities were determined on the test samples by the water displacement method. Increment cores were divided into juvenile wood (pith to ring 10) and mature wood (ring 11 to bark) and analyzed separately. To calculate for whole-core densities, the juvenile and mature wood densities were weighted by their respective widths in the core. Total-stem density was calculated as the weighted average of the disk densities, the weighting factor being the volume of the stem segment represented by the disk.

S

Sachsse, V.H.; Brandes, H.F.; Menge, A. 1982. Das holz der *Tsuga heterophylla* Sarg. (Hemlock) aus einem niedersachsischen Versuchsanbau. Forstarchiv. 53(5):163-172.

Sampling Location: Oldest hemlock experimental plantation, 0.1 ha in size, at Division 51A of lower Saxony District, 30 km south of Hanover, within a larger forest of mixed hardwoods (oak and beech). Elevation was 135 m above sea level; average yearly temperatures of 8°C and 15°C during growing season.

Method of Sampling: Four logs were obtained from the forest; two showed eccentric growth and one showed slow initial growth and wider rings near the bark. Twenty-five samples were obtained from each log. A 5-cm thick disk was obtained from each log at 2-m intervals from the butt end. The logs measured from 22 to 26 m in length. Clear test blocks were cut from each disk.

Method of Density Calculation: Wood density of each block was estimated from its ovendry weight and ovendry volume. The volumes of the test blocks were calculated from their dimensions.

Saucier, J.R.; Taras, M.A. 1969. Regional variation in specific gravity of seven pines in the southern United States. U.S. For. Serv., Southeast For. Exp. Stn., Asheville, North Carolina. Res. Pap. SE-45.

Sampling Location: White pine was sampled in four locations in the southern Appalachian region of the U.S.

Method of Sampling: Two increment cores, 4.5 mm in diameter, were obtained at 180° to each other at breast-height from 559 superior trees in the site. The better of the two cores was used for density determination.

Method of Density Calculation: Densities were determined on the ovendry weights and green volumes of the cores using the maximum-moisture-content method[31].

Savill, P.S.; Sandels, A.J. 1983. The influence of early respacing on the wood density of Sitka spruce. Forestry (Oxford). 56(2):109-120.

Sampling Location: A 4-ha respacing experimental stand at Baronscourt, in Co. Tyrone, Northern Ireland. There were five respacing treatments allocated to plots of 0.15 ha designed to give crop densities of about 2900, 1450, 725, 475, and 320 stems per hectare.

Method of Sampling: Trees were selected randomly from the upper two-thirds of the range of breast-height diameters. Two pith-to-bark increment cores were taken at right angles to each other from the breast height of 10 trees in each plot. Samples with knots were rejected.

Method of Density Calculation: Densities of the samples were measured by x-ray densitometry at Oxford University. The samples were dried to 12% moisture content before x-ray. An optical microdensitometer was used to scan the films in 200 micron steps across each radius from pith to bark. The mean density of each radius was calculated.

Sebastian, L.P. 1984. Relative density variation of the xylem in plus trees. Fac. For., Univ. New Brunswick, Fredericton, New Brunswick. Prog. Rep. 3.

Mullin, T. 1987. Relative density of plus trees selected in Nova Scotia. Personal communication.

Simpson, D. 1988. Relative density of plus trees selected in New Brunswick. Fredericton, New Brunswick. Personal communication.

Sampling Location: New Brunswick and Nova Scotia.

Method of Sampling: Plus trees and comparison trees were selected according to height growth and stem and crown quality. For jack pine and black spruce, 2.5-cm thick discs were cut at breast height and at half-height. A defect-free portion of the disk was used to obtain two opposite sectors. For the other species, white spruce and

[31] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. Serv., For. Prod. Lab., Madison. Wisconsion. Rep. 2014.

tamarack, two pith-to-bark cores were taken at right angles to each other at breast height from the plus tree, and one core at breast height from up to five comparison trees.

Method of Density Calculation: Sectors from discs were soaked in water under vacuum for 4-7 days to achieve green volume. Green volume was measured by water immersion method. Samples were ovendried at 105°C for 3 days and weighed.

Core samples were soaked in water under vacuum for one week to obtain maximum-moisture-content condition. Relative density was determined by the maximum-moisture- content method.

Total-stem density was calculated as the arithmetic average of the disc (sector) density at breast-height and at half-height.

Simpson, D. 1988. Relative density of plus trees selected in New Brunswick. Fredericton, New Brunswick. Personal communication.

See Sebastian (1984).

Singh, T. 1984. Variation in the ovendry wood density of ten prairie tree species. For. Chron. 60(4):217-221.

Singh, T. 1986. Wood density variation of six major tree species of the Northwest Territories. Can. J. For. Res. 16(1):127-129.

Sampling Location: A) 1984: boreal forest region in Alberta, Manitoba, and Saskatchewan. B) 1986: Hay River, Fort Simpson, and Fort Smith in southwestern Northwest Territories.

Method of Sampling: All trees were selected to represent equally four diameter size classes: less than or equal to 10 cm; 11-20 cm; 20-30 cm; and greater than 30 cm. Trees were felled 15 cm above ground (stump height). Merchantable stems were divided into four equal lengths from stump height to top diameter (10 cm dob); nonmerchantable stems (from 10 to 2 cm dob) were divided into three. A total of 10 disks were obtained from each tree at stump height, one at breast height, one from the top end of each of the equally divided sections, and one at midpoint from 2 cm dob to the tip. For nonmerchantable-size trees, only six disks were obtained. A sector was cut from each disk for density determination.

Method of Density Calculation: Densities were calculated on both ovendry and green volume bases. Green and ovendry volumes were measured by water displacement. Samples were dried in an oven at 103°C to constant weight. Ovendry samples were dipped in paraffin wax (30% solution in n-hexane) before measuring for volume. Total-stem density was calculated as the weighted average of the disk (sector) densities at each height level. The weighting factor was the volume of the stem section represented by the disks.

Singh, T. 1987. Wood density variations in thirteen Canadian tree species. Wood Fiber Sci. 19(4):363-369.

Sampling Location: Forest-tundra and forest grassland transitions in Alberta, Saskatchewan, Manitoba, and adjoining parts of the Northwest Territories.

Method of Sampling: A total of 50 circular plots of radius 2.8 m were located in predetermined strata. Any of the 13 species analyzed, present in a plot, were sampled at breast height. Three diameter size classes were sampled: 9 cm dbh, and two size classes for trees less than 9 cm dbh. Samples were either 4-mm increment cores or 2.5-cm-thick disks.

Method of Density Calculation: Density was determined on both green and ovendry volume bases. Samples were water-logged in an aspirator to achieve green volume. Green and ovendry volumes were measured by water displacements. Ovendried samples were coated with 30% solution of paraffin in xylene before measuring ovendry volume by water displacement. Green samples were dried to constant weight in an oven at 103°C.

Skolmen, R.G. 1963. Wood density and growth of some conifers introduced to Hawaii. U.S. For. Serv., Pac. Southwest For. Range Exp. Stn., Berkeley, California. Res. Pap. PSW-12.

Sampling Location: Puu Kihe and Kaluakauka, Hawaii.

Method of Sampling: Increment cores were taken at breast height using a borer of approximately 4.5-mm diameter.

Method of Density Calculation: Densities were determined from the ovendry weights and green volumes of the cores. The cores were trimmed immediately after extraction from the tree and their lengths measured. The length and diameter of each core were used to calculate volume. The cores were ovendried to constant weight.

Smith, W.J. 1970. Wood density survey in western Canada. Can. Dep. Fish. For., West. For. Prod. Lab., Vancouver, B.C. Inf. Rep. VP-X-66.

Sampling Location: Productive log operational sites in Alberta and British Columbia, except the coast and Atlin areas. Only lodgepole pine and white spruce were sampled in Alberta.

Method of Sampling: Disks about 8 cm thick were cut about 60 cm away from ends of logs randomly selected at log sites. Pith-to-bark portions were split along average diameters to provide roughly 8-cm squares along the radius. Finally, the specimens were machine finished into 3.8 × 3.8 cm cross sections in various lengths, depending on the diameter of the trees. Samples were taken from the most convenient or exposed ends of logs without regard to "where logs originated in commercial boles of trees". Sampling intervals were widely spaced to prevent the possibility of taking more than one sample per tree. "Selection in this manner rules out the possibility of direct comparisons between specific trees but automatically provides an 'average value' of relative density for a unit area."

Method of Density Calculation: Basic density was determined by the water displacement method[32].

[32] American Society for Testing and Materials. 1989. Standard methods of testing small clear specimens of timber. D-143-83. Am. Soc. Test. Mater. 4:35-76.

To estimate species average, the arithmetic mean density for each unit area was computed and weighted by the best available estimate of standing timber volume for that species in that unit area.

Snodgrass, J.D.; Noskowiak, A.F. 1968. Strength and related properties of Douglas-fir from mill samples. Oregon State Univ., Sch. For., Res. Lab., Corvallis, Oregon. Bull. 10.

Sampling Location: Coastal and interior regions of Oregon, Washington, Arizona, Colorado, Idaho, Montana, New Mexico, Wyoming, and Utah.

Method of Sampling: The commercial range of Douglas-fir was stratified for sampling. Strata were determined "by segregating the mills within each area into six classes according to their capacity for producing lumber during an 8-hr shift". Sample allocation to a stratum within a region was proportional to the volume production in the stratum. Samples were collected from rough, unseasoned lumber of random length, width, and grade, avoiding the possibility of sampling two pieces from the same tree. Seven pieces constituted a sample. Only clear specimens were tested. Where boards or timbers were available, a sample of five pieces was collected for density determination.

Method of Density Calculation: Densities were determined on ovendry weights and unseasoned volumes of samples, which were used for static bending test. Samples were 15.2 cm long along the grain and about 3.8 $\times$ 3.8 cm on the cross section. Mean density for the species was the weighted average of strata and region values, the weighting factor being estimates of lumber production within strata and regions.

Standish, J.T. 1983. Development of a system to estimate quantity of biomass following logging in British Columbia forests to specified recovery criteria. Report prepared for the Canadian Forestry Service, Ottawa, Ontario.

Sampling Location: British Columbia (except the Queen Charlotte Islands, the north coastal region, the Peace River region, or the northwestern part of the province north of Highway 16), and Yukon.

Method of Sampling: Seventeen softwood and four hardwood species and their varieties were included in this study. A predetermined number of trees were assigned to each dbh and height class for each species and allocated to various geographic areas defined by administrative boundaries and access. Selected trees were codominant crown class, and free of forking, dead or broken tops, decay, and any signs of disease or infestation. Except in some cases, trees selected were 120 years old. The trees were felled 30 cm above the ground, delimbed, and sawed into sections at approximately 2-m intervals. Sample disks were cut from the top end of each section. Top portions less than 2.5 cm in diameter were not included. A sector was cut from the larger disks for easier handling.

Method of Density Calculation: Basic density of the whole stem was determined as follows: each stem section was weighed fresh to the nearest 0.1 kg in the field laboratory; the section volume was determined by the Smalian formula. For large stem sections (diameter greater than 30 cm), fresh weight was calculated from mass-to-volume ratios determined on the sample disks. Green volumes of the disks was measured by water displacement according to TAPPI standard methods[33].

For the present report, the sum of the ovendry weights of the stem sections was divided by the sum of their green volumes. Disk at stump height was excluded from calculation of stem density.

Stevens, W.C.; Johnston, D.D. 1966. Specific gravity and moisture content of freshly-felled conifers. J.R. Scott. For. Soc. 20(4):255-260.

Sampling Location: Eleven geographical regions: north, east, and west Scotland; northeast, east, southeast, southwest, and northwest England; north and south Wales; and the Midland Counties. These geographical regions corresponded to the districts of the Meteorological Offices.

Method of Sampling: The random selection plan included three forests in each region, a compartment in each forest, and 10 trees in each compartment within a circular plot of approximately one-fifth of an acre. Starting from 46 cm from the base, a disk about 10.2 cm thick was obtained at intervals of 91 cm up to a top diameter of about 5.1 cm. A 45° sector was cut from each disk for density determination.

Method of Density Calculation: Densities were determined from the ovendry weights and green volumes of the sectors. Volume was measured by water displacement. Ovendry weights were obtained after drying the samples for 3 days at 100-105°C. The mean values given for each forest (site) have been calculated from the aggregate weights and volumes for that forest. For the present report, species average for each country was calculated from the arithmetic mean of the site means.

Sunley, J.G.; Lavers, G.M. 1961. Variations in the strength and specific gravity of Sitka spruce grown in Great Britain. J. Inst. Wood Sci. 7:15-27.

Sampling Location: Six regions in the British Isles: southwest and northwest England; south and north Wales; and west and north Scotland. Each region corresponded to a district of the Meteorological Offices as divided by the Forestry Commission.

Method of Sampling: The Forestry Commission had classified the stands in the regions into one of five quality classes according to the height to which trees of a given species grow in a certain time. Three stands of different quality classes were selected in each of the six regions. Each stand was randomly sampled for 10 trees, providing a total of 180 trees.

Two 0.9-m long bolts were randomly taken from each tree. These bolts were taken from that part of the stem between 60 cm above the ground and the top, at which the diameter was 15 cm. From the bottom of each bolt, a 2.5-cm thick disk was cut for density measurement of the whole cross section. Although small clear blocks were also tested for density in conjunction with strength tests, only density values based on disks are reported in the present publication.

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[33] Technical Association of the Pulp and Paper Industry. 1953. TAPPI standard method T18M-53. Norcross, Georgia.

Method of Density Calculation: Density was determined on the ovendry weight and green volume of the whole disk. The volume of each disk was estimated from its thickness and area. The disks were machined to exact thickness and their cross-section surfaces were traced on paper and measured by a planimeter to obtain the area. Weights were taken after drying the disks at 102°C. There was no weighting described in calculating the mean density of the species for each region. For the present report, species density average for Wales, Scotland, and England were calculated as the arithmetic mean of the two regions sampled in each.

T

Tackle, D. 1962. Specific gravity of lodgepole pine in the Intermountain Region. U.S. For. Serv., Intermt. For. Range Exp. Stn., Ogden, Utah. For. Res. Note.

Sampling Location: Targhee and Sawtooth national forests in Idaho; Ashley National Forest in Utah, and Bridger National Forest in Wyoming. Elevation ranged from 1981 to 2560 m.

Method of Sampling: Forty-four dominant lodgepole pine trees were felled and sampled in two ways: 1) increment cores to the pith of each tree were taken at breast height; 2) disks were cut at stump height, breast height, and 2.4-m intervals up the stem.

Method of Density Calculation: Densities were determined on both cores and disks from their ovendry weights and green volumes. The volumes of the cores were estimated from their length and diameter as described (see Maeglin 1966). The volumes of the disks were determined by a water displacement method. The ovendry weights of the cores and the disks were taken after drying in an oven at 105°C. Density at breast height was calculated both from the cores and the disks. To estimate whole-stem density, the density of each disk was weighted by the volume represented by the disk in the stem.

Taylor, F.W. 1977. Variation in specific gravity and fiber length of selected hardwoods throughout the mid-south. For. Sci. 23(2):190-194.

Sampling Location: National forests in Quachita, Holly Springs, and Bankhead, in the midsouthern U.S.

Method of Sampling: Ten trees with no visible sign of damage, disease, or lean at the breast-height level were selected from each site. A large (11-mm diameter) increment core from pith to bark was removed from the southern radius at breast height of each tree. The cores were divided into two segments: the first consisted of the first ten growth rings from the pith; the second consisted of growth rings from the 21st to the bark.

Method of Density Calculation: Density was determined on all core segments on ovendry weight and green volume bases. Green volume of the cores was measured by the water immersion technique. Values are reported only for the mature wood (from the 21st ring to the bark).

Taylor, F.W.; Wang, E.I.C.; Yanchuk, A.; Micko, M.M. 1982. Specific gravity and tracheid length variation of white spruce in Alberta. Can. J. For. Res. 12:561-566.

Wang, I.C.; Micko, M.M. 1984. Wood quality of white spruce from central Alberta. Can. J. For. Res. 14:181-185.

Sampling Location: Two stands (one high and one low elevation) from the Bow-Crow, Edson, and Footner Lake provincial forests within the natural range of lodgepole pine in Alberta.

Method of Sampling: Ten trees were selected from each stand. Trees were codominant or dominant with straight stems and normal crowns and no visible signs of disease or damage. Six trees were felled and disks were removed from each at 1.5, 4, 7, 10, 13, and 16 m from the ground. Wedges of 10° from pith-to-bark were taken from each disk in each cardinal direction. One pith-to-bark increment core, 11 mm in diameter, was also taken at breast height from the southern radius of each sample tree. This was used to evaluate breast-height density.

Method of Density Calculation: Basic densities were determined on both cores and wedges. The increment cores were divided into four segments containing consecutive growth rings from the pith to the bark. Green volumes of the samples were determined by water displacement. After volume measurements, the samples were dried, extracted, redried, and reweighed. Extraction was done by elution with alcohol-benzene in a Soxhlet apparatus according to the method described by Taylor[34].

The density of the whole core (pith-to-bark) was obtained by weighting the densities of the different core segments by each segment's proportion in the entire core. Total-stem density was calculated by taking the weighted average of the disk densities (average of four sectors), the weighting factor being the volume of the stem represented by the disks.

U

U.S. Forest Service. 1965. Western wood density survey, Report No. 1. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 17.

Sampling Location: A total of 4225 plots located in the commercial forest areas of 12 states in the western U.S., representing the natural range of the nine subject species, extending from the Great Plains to the Pacific Ocean. All plots were in areas of active logging to allow destructive sampling. The states are specified in the tables for the individual species.

Method of Sampling: Sampling design and plot procedures varied among the Pacific northwest, Pacific southwest, and intermountain states sites. The set of sampling procedures followed for each principal area was lengthy and is described only briefly here.

Trees were selected to ensure a representative sample of the natural distribution and volume of the nine species. All selected trees had a minimum dbh of 12.7 cm. An

[34] Taylor, F.W. 1974. Effect of extraction on the volume dimensions and specific gravity of solid wood flocks. Wood Sci. 6(4):396-404.

increment core was extracted to the center of the tree at breast height (1.4 m) up to a maximum of 25.4 cm in length. Cores were screened for rot, pitch pockets, and knots. No core with less than 12.7 cm of sound wood was accepted, provided the diameter of each tree was large enough for this standard. Twenty to forty of the trees cored for each area were selected by two-way stratification using 12.7-cm dbh classes (e.g., 12.7 to 22.9 cm) and 0.05 relative density classes (e.g., 0.250 to 0.299). No more than three trees per class were selected. These trees were felled and cut into boles 4.9 m long, starting from breast height to a merchantable top diameter. Top diameters ranged from 7.6 to 25.4 cm depending on location, species, and tree diameter. Clear disks 3.8-cm thick were taken from the butt end of each bole and from the top of the last bole.

Method of Density Calculation: Whole-tree density was estimated from a single increment core taken at breast height, through regression equations relating breast-height core to whole-tree density. The following steps were carried out in developing these equations:

i) Basic densities of the breast-height cores were determined from their ovendry weights and green volumes. Green volumes of the cores were calculated from core length (measured to the nearest 0.025 cm) and diameter (based on the diameter of the increment borer).

ii) Densities of the whole trees were calculated from the disk densities weighted by the volume proportion of the bole represented by the disks in the whole stem. The density of each disk was determined from its ovendried weight and green volume, which was estimated by the water immersion method. The volume of the individual boles was calculated by the Smalian formula.

iii) Regression equations were set up for each species. In these equations, the whole tree density was the dependent variable; breast-height core density and dbh were the independent variables.

For the present report, species averages at breast height and for whole trees were calculated using the given average density values and volume weighting factors for each forest survey unit.

Uusvaara, O.; Pekkala, O. 1979. Technical properties of the wood and pulp of certain foreign and uncommon native species. Commun. Inst. For. Fenn. 96(2):1-59.

Sampling Location: Southern and eastern Finland.

Method of Sampling: Ten trees were selected per stand to represent different diameter classes in the stand. The disks, 4 to 5 cm thick, were taken at 1-m intervals from stump to the top.

Method of Density Calculation: The densities of the disks were determined from their ovendry weights and green volumes measured by water displacement. The whole-stem density was calculated by weighting the disk densities at different heights by the "corresponding basal area of the cutting surface".

V

Van der Zwan, R.P.; Polman, J.E. 1988. Wageningen, The Netherlands. Personal communication.

Sampling Location: Plantations in Veluwe, The Netherlands.

Method of Sampling: For western red cedar and western hemlock, sampling was from the whole tree. Douglas-fir trees were sampled from the first 2 m from the ground. In all cases, a random method of sampling was used. No detailed description on method of sampling was available.

Method of Density Calculation: Densities were determined on the samples based on weight and volume at 15% moisture content.

Veveris, A.; Pirags, D.; Kiploks, E. 1982. Investigations of the wood properties of Douglas-fir. Lesovedenie 5:72-75.

Sampling Location: Douglas-fir stands in the Baltic regions of Estonia, Latvia, Lithuania, and the Kaliningrad oblast.

Method of Sampling: No specifics were given. The values given in the cited reference have been assumed as being breast-height values in the absence of specific information.

Method of Density Calculation: No description was given as to method. For the purpose of the present report, the density values are assumed to have been based on ovendry weight and volume.

Villeneuve, M.; Morgenstern, E.K.; Sebastian, L.P. 1987. Variation patterns and age relationship of wood density in families of jack pine and black spruce. Can. J. For. Res. 17:1219-1222.

Sampling Location: Two progeny tests of open-pollinated families planted at the Petawawa National Forestry Institute, Chalk River, Ontario.

Method of Sampling: Twelve families of black spruce were sampled in five replications and 10 families of jack pine in six replications. From a constant compass direction, 12-mm diameter increment cores were obtained at breast height. Starting from the bark, the cores were divided into sections of five growth rings each for density determination.

Method of Density Calculation: The basic density of each five-growth-ring section was determined by the maximum-moisture-content method[35]. For the purpose of the present report, the density of the whole core was calculated by taking the density of each five-growth-ring section and weighting it by its width. The species average was calculated as the arithmetic mean of the whole-core values.

W

Wahlgren, H.E.; Hart, A.C.; Maeglin, R.R. 1966. Estimating tree specific gravity of Maine conifers. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 27.

[35] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

Sampling Location: For detailed descriptions of sample locations for each of the species, and procedure for selecting sample plots trees, please refer to the publication.

Method of Sampling: From each selected tree, disks 3-cm thick were obtained at breast height and from the top of each consecutive 1.2-m bole, up to a top diameter of 10.2 cm, or for the entire merchantable length of the tree.

Method of Density Calculation: The basic density of each disk was determined by the water immersion method. Disks were dried in a forced-air oven at 105°C. The density of each bole was estimated as the average of its two terminal disks, and the density of the whole stem was the weighted average of the bole densities, the weighting factor being the proportion of the bole volume in the stem.

Wahlgren, H.E.; Baker, G.; Maeglin, R.R.; Hart, A.C. 1968. Survey of specific gravity of eight Maine conifers. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Res. Pap. 95.

Sampling Location: Maine. Sample plots were chosen for "combinations of three stand factors: type, density (crown closure) and height".

Method of Sampling: Two increment cores were obtained from each tree at breast height. All trees were no less than 11.7 cm in dbh. On growth plots with less than five trees, all trees were sampled.

Method of Density Calculation: Densities of the breast-height cores were calculated from their ovendry weight and green volume (Maeglin 1966). From a previously established equation (Wahlgren, et al. 1966), tree density was estimated from the density of the breast-height core.

Walford, G.B. 1985. The mechanical properties of New Zealand-grown Douglas fir. N.Z. For. Serv., For. Res. Inst., Rotorua, N.Z. Bull. 94.

Sampling Location: Kaingaroa Forest (contains half of New Zealand's production of Douglas-fir), Waimihia, and Golden Downs (New Zealand). Sixteen compartments were sampled in Kaingaroa, four in Waimihia, and four in Golden Downs.

Method of Sampling: Compartments scheduled for clear-felling from 1984 to 1986 were sampled. Twenty-five trees per compartment were sampled for increment cores at breast height.

Method of Density Calculation: The cores were trimmed to contain only the last 50 mm of wood and their densities measured by the maximum-moisture-content method[36]. Using a previously established equation, whole-tree densities were predicted from the breast-height cores. The mean density of the species for each forest was weighted according to the percentage volume production contributed by the forest.

Wang, I.C.; Micko, M.M. 1984. Wood quality of white spruce from north central Alberta. Can. J. For. Res. 14:181-185.

[36] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.

See Taylor et al. (1982).

Wilde, S.A.; Paul, B.H. 1959. Growth, specific gravity, and chemical composition of quaking aspen on different soil types. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2144.

Sampling Location: Nine sample plots about 0.8 ha located on representative soil types in six counties in central and northern Wisconsin. The soil types included droughty outwash sands, fertile morainic silt loams, and poorly drained soils.

Method of Sampling: Five codominant trees were selected in each plot and 30-cm thick disks were obtained from each tree at a height level of 1.5-1.8 m above the ground.

Method of Density Calculation: Basic density was determined on each disk. Green volume was measured by the water immersion method.

Wilde, S.A.; Paul, B.H.; Mikola, P. 1951. Yield and quality of jack pine pulpwood produced on different types of sandy soils in Wisconsin. J. For. 49(12):878-881.

Sampling Location: A wide range of soil productive capacity for jack pine stands, including five soil types, in 24 one-fifth-acre plots located in eight counties in Wisconsin. The soil types were Aeolian sand (8 plots), melanized sand (14 plots), podzolic sand (15 plots), and clay-podzolic sand (6 plots).

Method of Sampling: Five codominant trees of approximately average diameter were felled in each sample plot. A 20-cm thick disk was removed at a height of 1.5 m and 7.6 m.

Method of Density Calculation: Basic density was determined on each disk by the water immersion method. The density obtained at the 1.5-m height level is presented in the present report as breast-height density.

Wisse, J.H. 1968. Enige technische eigenschappen van in Nederland gegroeid Douglas Hout. Meded. Landbouwhogesch. Wageningen 68-4.

Sampling Location: The Netherlands.

Method of Sampling: Twenty-five trees from different parts of the country. The trees were sampled and cut for strength tests, and these samples were used to determine wood relative density. The samples were cut into 80 × 5 × 5 cm for static bending, 15 × 5 × 5 cm for crushing, and 30 × 2 × 2 cm for impact bending.

Method of Density Calculation: Density was determined from the weight and volume of each sample at 15% moisture content. The mean density for the species is the arithmetic mean of all the individual observations.

Y

Yanchuk, A. 1987. Alberta For. Lands Wildl., Alberta For. Serv., Edmonton, Alberta. Personal communication.

Sampling Location: Alberta.

Method of Sampling: Parent trees were selected and sampled for two opposite increment cores, 11 mm in diameter, at breast height. In the case of lodgepole pine, a disk about 5.0 cm thick was taken from the stem at breast height. When disks were too large to process, two opposite sectors were cut from the disks for density determination. Samples were divided into juvenile and mature wood as follows: juvenile (rings 1–20), intermediate (rings 21–50), and mature wood (rings 51 and up). Test samples were free of knots and other defects.

Method of Density Calculation: Basic density was determined on each sample by the water displacement method. Ovendrying of samples was done in a convection oven at 103°C for 24 hours. To obtain whole-core densities, the densities of the core segments were weighted by the proportion (length) of the segments. Densities of the disk sections required no weighting.

Yang, K.C.; Hazenberg, G. 1987. Geographical variation in wood properties of *Larix laricina* juvenile wood in northern Ontario. Can. J. For. Res. 17:648-653.

Sampling Location: Two stands in 12 locations in northern Ontario from latitudes 46° to 56° north.

Method of Sampling: Ten trees were selected in each of the stands. Two 12-mm increment cores were obtained at breast height from the north-south and east-west directions of each of the standing trees.

Method of Density Calculation: The cores were extracted with 50% acetone and divided into individual rings. Relative density was determined on individual growth rings by the maximum-moisture-content method[37]. Juvenile and mature wood boundaries were determined by the variation in tracheid length. The width of juvenile wood varied from 16 to 40 growth rings.

The density of juvenile wood was calculated as the average of the density of growth rings in the juvenile wood. Mature wood density was not calculated.

[37] Smith, D.M. 1954. Maximum-moisture-content method for determining specific gravity of small wood samples. U.S. For. Serv., For. Prod. Lab., Madison, Wisconsin. Rep. 2014.