WOOD DENSITY VARIATIONS IN THIRTEEN CANADIAN TREE SPECIES

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ABSTRACT

Wood density variations were determined for four softwoods and nine hardwoods of western Canada. Multiple-range test indicated significant ($P < 0.05$) differences for the majority of the multiple comparisons made among species. The mean wood densities varied slightly to significantly from the density means of adjoining regions and were highest for black spruce (18.2%). Correlations were also obtained between wood density and other variables.

Keywords: Wood density, boreal forest, prairie provinces, Northwest Territories, western Canada.

INTRODUCTION

Boreal forest is one of the largest tracts of forest remaining in the world. Extending from Newfoundland to Alaska in North America, the boreal forest region is a major source of timber and wood supply (Rowe 1972). It comprises approximately 3.58 million square kilometers of forest land in Canada and accounts for 82% of the country's total forest area. It has three main subregions in western Canada covering the prairie provinces and the Northwest Territories: predominantly forest occupies 48%, forest-tundra transition 44%, and aspen-grassland transition 8% (Maini 1968) (Fig. 1).

Wood density is known to vary with geographical location, climate, and ecoregions for many species (Hakkila 1979; Singh 1984b; Wang and Micko 1983). Density values are therefore needed for the noninventoried areas of western Canada for site-specific situations, such as converting tree volumes to weight and for providing biomass energy estimates in the northern areas (Singh 1984a; Singh and Micko 1984). Although Jessome (1977) included coefficient of variation information for the wood densities reported by him, the data were summarized on a national basis and the regional variations were not provided. Singh (1984b, 1986) investigated wood densities of tree species for the predominantly forest subregion of the boreal forest, but the characteristics of wood grown in the major transition ecotones, where climatic stresses may alter the structure of wood, were not included.

The present study was undertaken to obtain information on wood density variations in the vast forest-tundra and forest-grassland transitions, which together cover about 52% of the boreal zone in the prairie provinces and adjoining Northwest Territories. The objectives of the study were to determine the following: (1) the basic and oven-dry wood densities of important tree species of the boreal forest transition of western Canada, (2) the variation of tree wood density between the tree stems of the same species, (3) the difference in wood density between adjoining subregions and national means, and (4) the relationship of tree stem wood density with other commonly measured tree variables.

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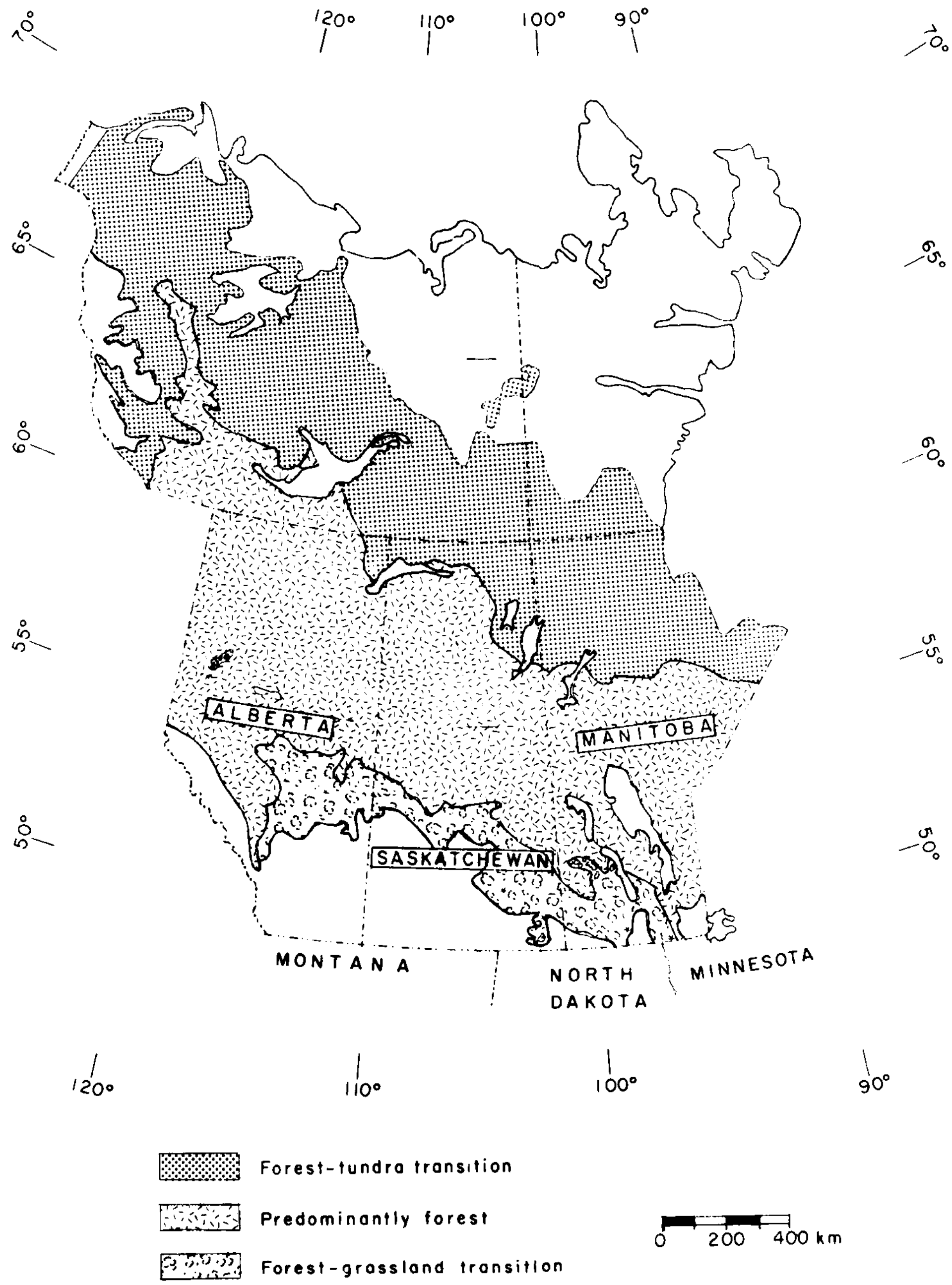

FIG. 1. Boreal forest subregions of the prairie provinces and Northwest Territories.

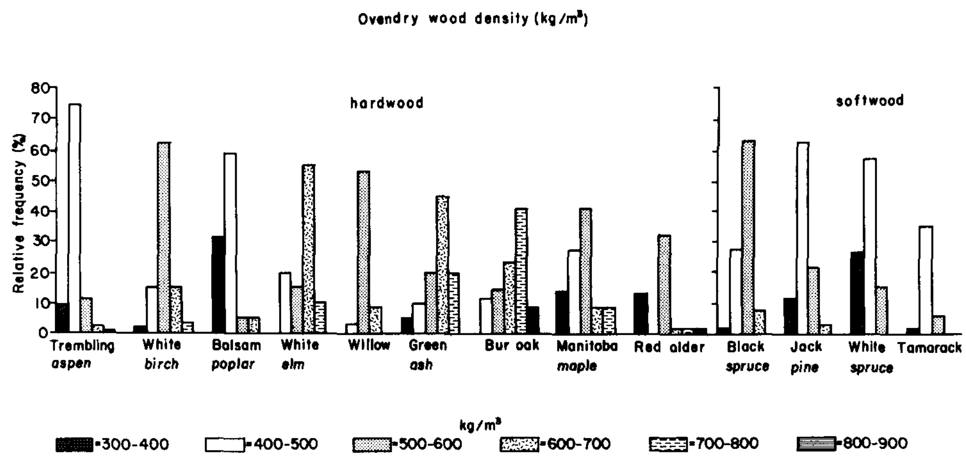

FIG. 2. Relative frequency distribution of oven-dry wood density (kg/m³) size classes.

PROCEDURES

Field sampling

A total of 13 tree species were sampled. These were four softwoods: white spruce (*Picea glauca* (Moench) Voss), black spruce (*P. mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.), tamarack (*Larix laricina* (Du Roi) K. Koch); and nine hardwoods: trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*P. balsamifera* L.), white birch (*Betula papyrifera* Marsh.), Manitoba maple (*Acer negundo* L.), bur oak (*Quercus macrocarpa* Michx.), green ash (*Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl.) Fern.), white elm (*Ulmus americana* L.), alder (*Alnus* sp.), and willow (*Salix* sp.).

Field samples were taken as 2.5-cm-thick disks or 4-mm-increment cores at breast height, wrapped in aluminum foil and kept frozen in plastic bags until analyzed in the laboratory. Diameters at breast height (dbh) and tree height (h) were recorded. Sampling covered about 182,000 km^2 of noninventoried and nonsampled forest land in Alberta, Saskatchewan, and Manitoba. A total of 50 circular plots of radius 2.825 m were located in each of the predetermined strata. Any of the 13 above-mentioned tree species in a plot were sampled according to three diameter size classes for trees over 9 cm dbh, and two diameter size classes for trees less than 9 cm dbh.

Laboratory procedure

Laboratory samples were debarked, trimmed of loose fiber, and water logged in an aspirator to attain natural green volume. The basic (and oven-dry) wood densities were obtained as oven-dry weight to green (and oven-dry) volume ratios according to standard procedures (Micko et al. 1984a). Green (and oven-dry) volumes were measured by the water displacement method. Oven-dry weights were determined after the sample green (and oven-dry) volumes were dried in a forced-draft oven at 103 ± 2 C for 24 hours or to a constant weight. The oven-dried samples were dipped in a 30% solution of paraffin wax in xylene to seal them against moisture penetration while determining oven-dry volumes.

TABLE 1. *Basic and oven-dry wood densities (kg/m³) and their variation in the sampled tree species.*

Tree species	Mean	N	Range	C.V.[1] %	Standard error
I. Basic					
1. Softwoods					
White spruce	386	26	288–499	13.5	10
Jack pine	415	209	268–645	12.5	4
Tamarack	458	65	348–540	8.5	5
Black spruce	462	698	289–711	10.5	2
2. Hardwoods					
Balsam poplar	386	39	308–551	13.3	8
Trembling aspen	401	216	319–605	11.1	3
Red alder	418	68	337–713	15.8	8
Manitoba maple	462	22	352–603	13.9	14
Willow	462	158	318–588	10.3	4
White birch	481	78	309–663	12.3	7
White elm	503	20	400–607	13.2	15
Green ash	527	20	361–649	15.9	19
Bur oak	584	34	368–693	15.0	15
II. Ovendry					
1. Softwoods					
White spruce	432	26	352–573	13.5	12
Jack pine	466	209	348–741	13.1	4
Tamarack	519	65	382–597	9.3	6
Black spruce	526	698	323–776	10.8	2
2. Hardwoods					
Balsam poplar	436	39	332–633	15.6	11
Trembling aspen	458	216	352–790	13.2	4
Red alder	480	68	387–811	16.3	9
Manitoba maple	520	22	356–718	18.2	20
Willow	522	158	356–694	10.9	4
White birch	556	78	362–769	13.6	9
White elm	600	20	482–730	12.5	17
Green ash	609	20	399–790	17.5	24
Bur oak	678	34	409–831	16.9	20

[1] Coefficient of variation.

Statistical analysis

Relative frequency of wood density size classes was obtained to show their distribution. Analysis of variance was done to determine significance of difference in mean densities of species. Duncan's multiple-range test was used on species in all possible combinations to isolate and locate differences among species. Cor-

TABLE 2. *Analysis of variance for 13 tree species for oven-dry wood densities (kg/m³).*

Source	df	SS	MS	*F*
Among species	12	3,116,352.000	259,696.000	65.540**
Within species	1,640	6,498,368.000	3,962.419	
Total	1,652	9,614,720.000		

** Significant at the 1% level.

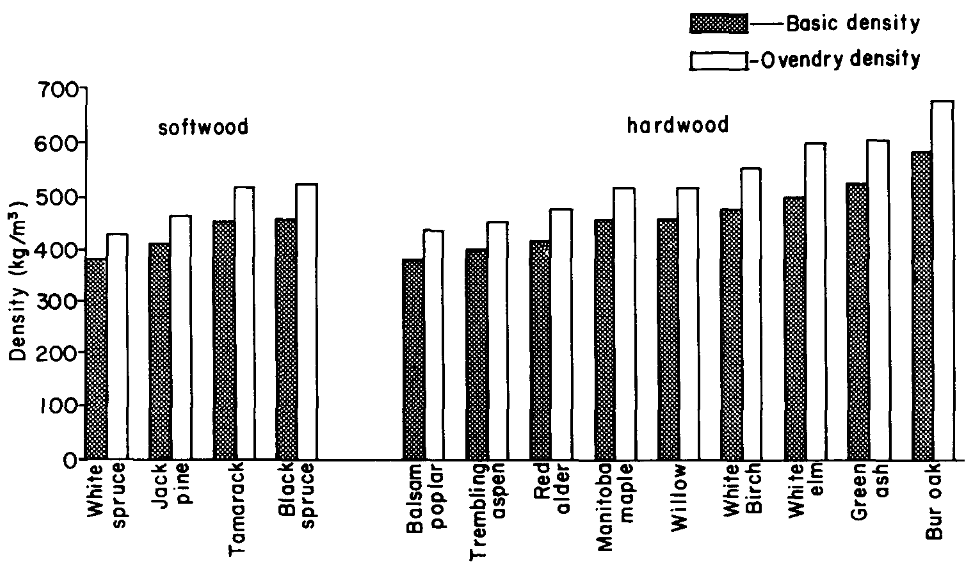

FIG. 3. Basic and oven-dry mean wood densities (kg/m^3) of 13 tree species.

relations between wood density and diameter outside bark (dbh), and tree height (h) were determined.

RESULTS AND DISCUSSION

The extensive sampling done in the boreal forest transition resulted in approximately normal distribution of wood density frequencies in most species (Fig. 2).

Wood density correlations with diameter and height

All species showed a highly significant ($P < 0.01$) relationship between dbh and h. Black spruce, white spruce, balsam poplar, red alder, and white elm had highly significant ($P < 0.01$) correlations between dbh and oven-dry wood density; the remaining eight species had no significant relationship (Micko et al. 1984b).

Yanchuk et al. (1984) reported an overall trend of a negative relationship between rate of growth and wood density in trembling aspen in Alberta. In the present study, tree height and oven-dry wood density showed a highly significant ($P < 0.01$) negative correlation for black spruce, white elm, and red alder. The bulk of the data presented here was from the northern transition region of the boreal forest, where the mean annual temperatures and consequently the growth rate are generally lower than those in the adjoining predominantly forest region to the south. The highly significant negative correlation between tree height and wood density for black spruce showed considerably higher (18.2%) wood densities for this species, which is one of the most commonly occurring tree species of the northern transitional belt of the boreal forest. White spruce and balsam poplar had only a significant ($P < 0.05$) negative correlation between tree height and wood density, and the correlations in remaining tree species were not significant at this level.

TABLE 3. *Multiple comparison of wood densities using Duncan's multiple-range test.*

Oven-dry wood density means[1] (kg/m³)												
White spruce	Balsam poplar	Trembling aspen	Jack pine	Red alder	Tamarack larch	Manitoba maple	Willow	Black spruce	White birch	White elm	Green ash	Bur oak
432	436	458	466	480	519	520	522	526	556	600	609	678
A	A	A	C	C					E			G
		B	B	D	D	D	D	D		F	F	

[1] Means not connected by a line are significantly different ($P < 0.05$); similar groups are identiifed by the same letter.

TABLE 4. *Comparison of the oven-dry wood densities of the present study with those reported by Jessome (1977) for Canada and by Singh (1984b, 1986) for the predominantly forest boreal subregion of the prairie provinces.*

	Canada			Predominantly forest boreal subregion						Boreal transition (present study)		
				Prairie provinces			NWT			Percent difference from		
	Jessome (1977)			Singh[1] (1984b)			Singh[1] (1986)					
Species	kg/m^3	n	C.V. %	kg/m^3	n	C.V. %	kg/m^3	n	C.V. %	Jessome[2] (1977)	Singh[3] (1984b)	Singh[4] (1986)
White spruce	393	125	11.8	398	59	8.9	439	57	14.5	9.9	8.5	−1.6
Jack pine	454	84	9.6	467	60	9.3	462	51	11.0	2.6	−0.2	0.9
Tamarack	544	39	8.0	533	45	8.6	506	49	8.6	−4.6	−2.6	2.6
Black spruce	445	66	9.3	447	58	8.4	499	45	9.1	18.2	17.7	5.4
Balsam poplar	416	36	6.4	392	57	12.2	395	54	10.3	4.8	11.2	10.4
Trembling aspen	424	34	6.8	430	57	10.1	432	54	6.9	8.0	6.5	6.0
Manitoba maple	501	28	8.8	—	—	—	—	—	—	3.8	—	—
White birch	588	35	7.1	618	52	6.8	—	—	—	−5.4	−10.0	—
White elm	617	83	9.2	—	—	—	—	—	—	−2.8	—	—
Green ash	556	19	10.5	—	—	—	—	—	—	9.5	—	—
Bur oak	694	21	8.1	—	—	—	—	—	—	−2.3	—	—

[1] Values relate to samples taken at breast height.
[2] % difference is 100 (present study − Jessome)/Jessome.
[3] % difference is 100 (present study − Singh prairies)/Singh prairies.
[4] % difference is 100 (present study − Singh NWT)/Singh NWT.

Density variations in species

Among the nine studied hardwoods, balsam poplar showed the lowest and bur oak the highest wood density. Of the four studied conifers, white spruce had the lowest density and black spruce had the highest (Table 1). The wood density of black spruce was exceeded by four hardwoods: white birch, white elm, green ash, and bur oak (Fig. 3).

Analysis of variance showed a highly significant ($P < 0.01$) difference among the species (Table 2). According to Duncan's multiple-range test, the wood densities for the majority of 78 possible comparisons were significantly ($P < 0.05$) different (Table 3).

The oven-dry wood density means reported in this study varied from −5.4 to 18.2% from those reported by Jessome (1977) for Canada, and from −10.0 to 17.7% and −1.6 to 10.4% from the wood densities in the predominantly forest boreal region of the prairie provinces (Singh 1984b) and the Northwest Territories (Singh 1986) (Table 4). Most of the tree species in this study had highly significant ($P < 0.01$) greater mean densities. Only four species (tamarack, white birch, white elm, and bur oak) showed lower values. Different tree species in other studies have been known to show opposite trends (Pronin 1971).

Disagreements with the mean densities of Canadian woods (Jessome 1977) were reported by Alemdag (1984) in Ontario for many of the 28 tree species studied by him. He suggested that the differences may be due to slightly different processing and calculation methods, and due to regional variation as a result of different vegetation and climatic zones. These are also the likely reasons for the differences reported here from the Canadian mean wood densities of Jessome (1977). However, the climatic stresses in the vast northern transitional belt may be the main reasons for the statistically significant variations for species such as black spruce from those reported for the predominantly forest subregion (Singh 1984b), because similar processing and calculation methods were used in both studies.

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