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Estimating downed-dead roundwood fuel volumes in central Alberta

T. Singh

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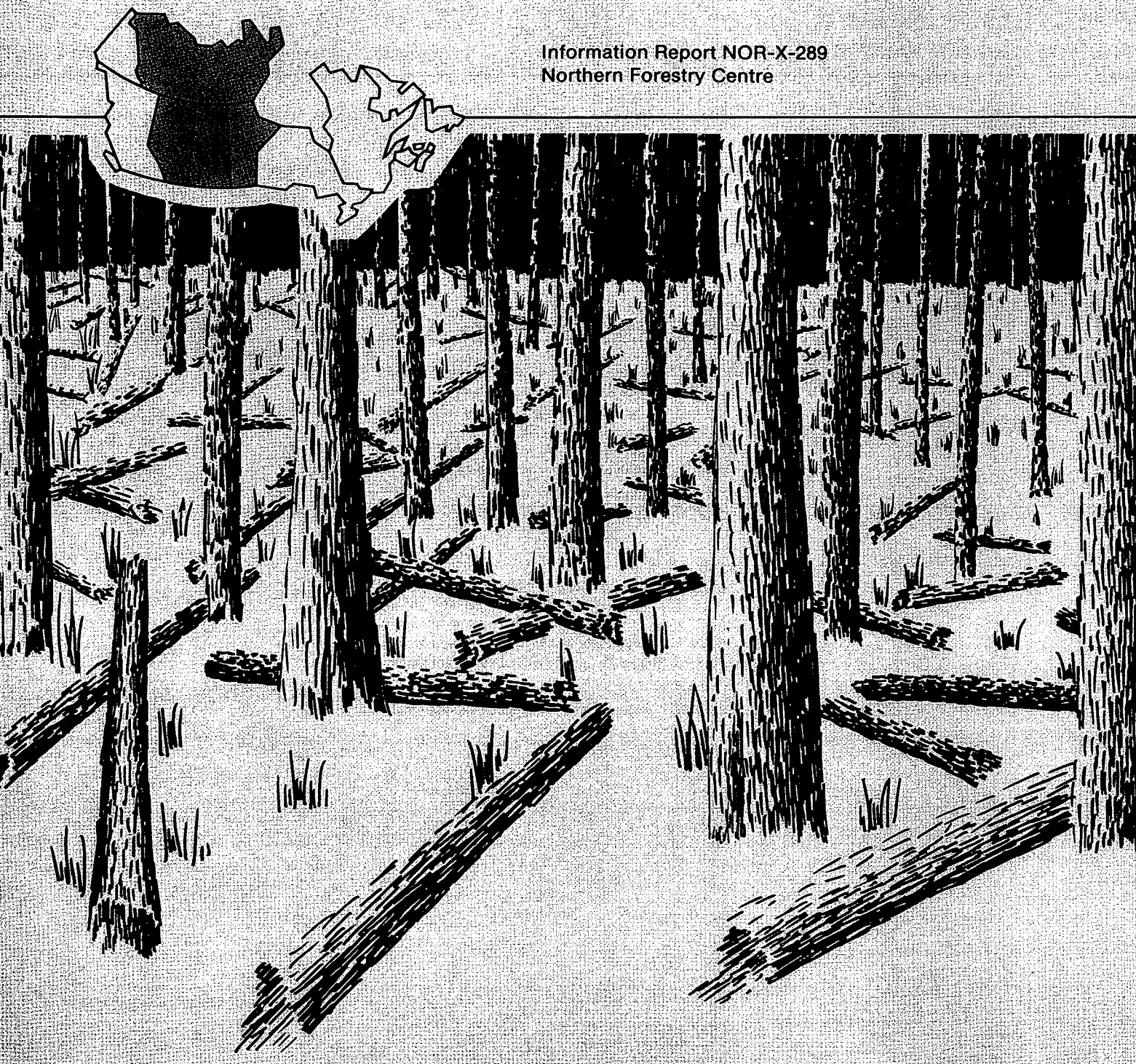
Northern Forestry Centre



Energy from the Forest

Canada

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ESTIMATING DOWNED-DEAD ROUNDWOOD FUEL VOLUMES IN CENTRAL ALBERTA

T. Singh

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ABSTRACT

A total of 46 pine- and spruce-dominated stands at five locations in central Alberta were sampled using the line intersect method to determine downed-dead fuel volumes. The stands were classified into five subgroups on the basis of species composition and basal area. The components of downed-dead materials were classified into three main fuel condition classes: (1) sound, (2) partly decomposed, and (3) punky. The total downed-dead fuels (m^3/ha) in the dominant subgroups were jack pine 4.7–64.5, black spruce 1.7–63.8, white spruce 33.7–52.1, balsam fir 56.5, and tamarack 7.7. Prediction equations were derived to estimate roundwood fuel volumes from the following stand measurements: basal area, stem density, crown density, height, and age.

RESUME

Dans 46 peuplements se trouvant à 5 endroits dans le centre de l'Alberta, un échantillonnage linéaire a été effectué pour déterminer les volumes de bois mort gisant au sol. Ces peuplements, où dominaient les pins et les épinettes, ont été classés en 5 sous-groupes suivant leur composition (espèces) et leur surface terrière. Le matériel mort, au sol, a été classé en trois catégories selon son état: (1) sain, (2) partiellement décomposé; et (3) pourri. Les quantités totales de combustibles morts gisant au sol dans les sous-groupes dominants variaient de 4,7 à 64,5 m^3/ha pour le pin gris, de 1,7 à 63,8 m^3/ha pour l'épinette noire, de 33,7 à 52,1 m^3/ha pour l'épinette blanche; il était de 56,5 m^3/ha pour le sapin baumier et de 7,7 m^3/ha pour le mélèze laricin. On a établi des équations pour l'estimation des volumes de combustibles (bois rond) à partir des données suivantes de mesure des peuplements: la surface terrière, la densité de peuplement, la densité du couvert, la hauteur et l'âge.

FOREWORD

ENFOR is the acronym for the ENergy from the FORest (ENergie de la FORêt) program of the Canadian Forestry Service. This program of research and development is aimed at securing the knowledge and technical competence to facilitate in the medium to long term a greatly increased contribution from forest biomass to our nation's primary energy production. It is part of the federal government's efforts to promote the development and use of renewable energy as a means of reducing dependence on petroleum and other nonrenewable energy sources.

The ENFOR program is concerned with the assessment and production of forest biomass with potential for energy conversion and deals with such forest-oriented subjects as inventory, harvesting technology, silviculture and environmental impacts. (Biomass Conversion, dealing with the technology of converting biomass to energy or fuels, is the responsibility of the Renewable Energy Division of the Department of Energy, Mines and Resources.) Most ENFOR projects, although developed by CFS scientists in the light of program objectives, are carried out under contract by forestry consultants and research specialists. Contractors are selected in accordance with science procurement tendering procedures of the Department of Supply and Services. For further information on the ENFOR Biomass Production program, contact

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Canadian Forestry Service
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Ottawa, Ontario
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 the Canadian Forestry Service.

INTRODUCTION

Most conventional forest stand inventories do not provide information on the volume of downed-dead woody materials. A knowledge of standing and dead woody components of forests is useful because it provides a more complete inventory of the total biomass in a stand and quantifies combustible materials to help predict fire intensity and behavior in specific forest cover types. Roundwood fuel volumes determine potential surface fire intensity, which influences crown fire potential.

The objectives of the study were 1) to determine roundwood volumes of downed-dead woody fuels in central Alberta forest cover types, and 2) to develop regression equations to estimate these fuels from commonly measured forest stand variables.

METHODS

The available information relating to fire and fuels in Alberta and the prairie provinces was used to select field sampling, prediction, and comparison procedures adopted in the study (Bentz 1981; Byram 1959; Delisle 1986; Hawkes 1979; Kiil 1968; Murphy and Quintilio 1978; Quintilio et al. 1977; White 1985).

Field Sampling

Field sampling was done in 1978 in 46 stands near five different locations, namely, Drayton Valley and Caroline in the Rocky-Clearwater Forest, Heart Lake in the Lac la Biche Forest, and Martin Hills and Swan Hills in the Slave Lake Forest (Fig. 1). The sampled stands consisted of the following coniferous and deciduous tree species: white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* (L.) Mill.), tamarack (*Larix laricina* (Du Roi) K. Koch), trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.), and white birch (*Betula papyrifera* Marsh.).

The cover types were identified from Alberta Forest Service (AFS) Phase III Inventory maps to ensure a range of density, age, and height classes from geographically diverse areas, and the stands were located no more than 5 km from all-weather roads. The stands had four crown density classes: A, 6–30%; B, 31–50%; C, 51–70%; and D, 71–100%. There were five height classes used: 0, 0–6.0 m; 1, 6.1–12.0 m; 2, 12.1–18.0 m; 3, 18.1–24.0 m; and 4, 24.1–30.0+ m. The average age of the stands varied from 28 to 187 years, and half of the stands were in the 80–90 year group.

Field data were collected on living and dead woody materials for deriving roundwood volume estimates by the line intersect method (Van Wagner 1982a, b):

$$V = (k/L) \Sigma d^2$$

where V is the volume of woody material (m^3/ha), L is the length of the sampled line (m), d is the woody piece diameter at intersection (cm), and k is the equation constant equal to 1.234. The downed-dead woody pieces intersecting the transects were classified by diameter classes (0–1.0 cm, 1.1–2.0 cm, 2.1–5.0 cm, 5.1–10.0 cm, and pieces ≥10.1 cm in higher classes successively incremented by 2 cm each time) and according to their state of decomposition (sound, partially decomposed, and punky).

Data Analysis

Plotting the fuel volumes against various stand variables suggested linear components (Fig. 2) to be included in the predictor model:

$$F.VOL = a + b(BA.PN) + c(BA.SP) + d(BA.REM) + e(N.TR) + f(DEN) + g(HT) + h(AGE)$$

where F.VOL is downed-dead roundwood fuel volume (m^3/ha) estimated from basal areas (m^2/ha) of pine (BA.PN), spruce (BA.SP), and remaining tree species including standing dead trees (BA.REM), total number of trees per hectare (N.TR), crown density class (DEN), height class (HT), and age (AGE). The coefficients a, b, ... h are the regression estimates derived from the field data.

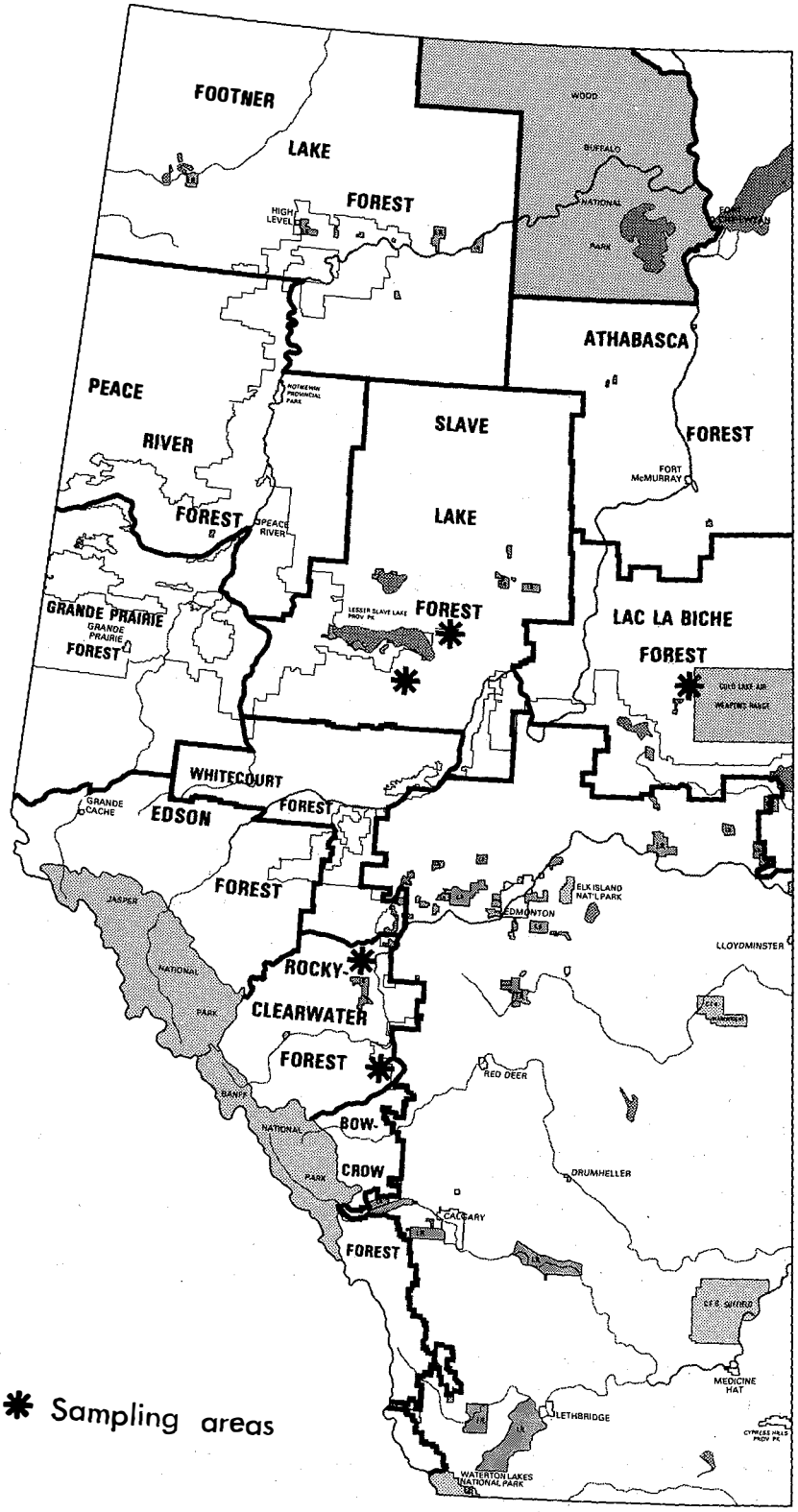

Figure 1. Locations of sampled stands. (Base map material provided by the Cartographic Services Section, Resource Evaluation and Planning Division, Alberta Forestry, Lands and Wildlife.)

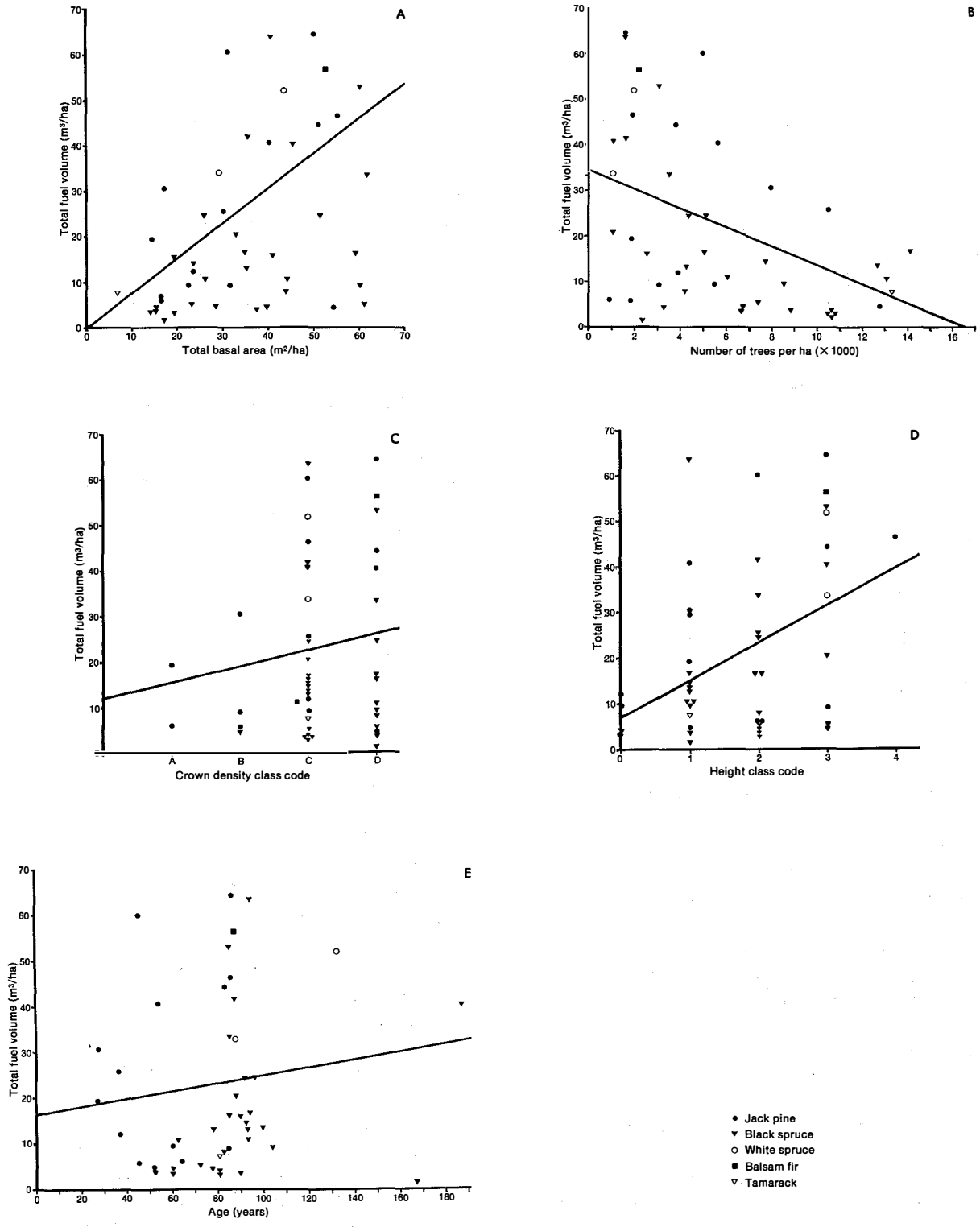

Figure 2. Relationship between stand variables (*A* total basal area, *B* number of trees/ha, *C* crown density, *D* stand height, and *E* age) and downed-dead fuel volumes.

RESULTS AND DISCUSSION

Length of line sampled from any one type varied from 200 to 2 400 m; all but four were in the 400–1 600 m range. Prism plots and line transects totaled 300 and 40 000 m, respectively[1].

The stand parameters of the forest cover types included in the study differed widely from each other (Table 1). The roundwood fuel volumes, based on AFS forest cover types, also differed greatly (Table 2). On the basis of relative basal area (Table 3) and relative density (Table 4), the 46 forest stands were from five main dominant subgroups, namely jack pine (14), black spruce (28), white spruce (2), balsam fir (1), and tamarack (1). Of all the main tree species, only jack pine and black spruce occurred occasionally as pure stands.

The total fuel volume estimates for the five subgroups are shown in Figure 2. The breakdown into sound, partially decomposed, and punky components is shown in Figures 3 and 4.

Jack Pine Dominated Stands

Jack pine formed a pure crop in four stands (1, 2, 6, and 7) but occurred as a mixture in the remaining 10 stands (3–5 and 8–14) with one or more companion tree species, mainly trembling aspen, black spruce, and white birch. Jack pine diameters ranged in size from 2 to 48 cm, basal area ranged from 14.5 to 39.1 m^2/ha, and stem density ranged from 620 to 8 031 stems/ha (Table 1). The species presence for jack pine varied from 33.1 to 100 percent, based on all standing trees.

The predominant fuel materials in this cover type were punky, followed by partly decomposed and sound. The sound fuels ranged from 0.4 to 22.2 m^3/ha, partly decomposed ranged from 0.5 to 22.3 m^3/ha, and punky ranged from 1.7 to 35.8 m^3/ha. The total fuel volumes varied from 4.7 to 64.5 m^3/ha (Table 2).

Black Spruce Dominated Stands

Black spruce was the most sampled forest cover type, making up a total of 28 stands (15–42) out of the 46 sampled for the study. This species ranged in diameter from 2 to 50 cm. Basal area ranged from 11.0 to 54.0 m^2/ha, and the number of stems per hectare ranged from 511 to 13 942 (Table 1). Companion species in the mixed stands were mainly jack pine, white spruce, trembling aspen, and balsam fir. The presence of black spruce varied from 52.1 to 100 percent, based on all standing trees.

Punky fuels were dominant in the black spruce cover type, followed by partly decomposed and sound materials. The punky materials varied from 0.1 to 29.6 m^3/ha, the partly decomposed fuels ranged from 0.9 to 26.8 m^3/ha, and the sound materials varied from 0.1 to 22.1 m^3/ha. Total fuel volumes ranged from 1.7 to 63.8 m^3/ha (Table 2).

White Spruce Dominated Stands

The presence of white spruce in the stands selected for this cover type (43 and 44) ranged from 33.9 to 84.1 percent, based on all standing trees. The companion tree species in the mixed stands were mainly balsam fir and jack pine.

The dominant fuel in the white spruce cover type was punky, followed by partly decomposed and sound materials. The fuel volumes for the three categories were 28.3 to 32.0 m^3/ha, 2.8 to 15.0 m^3/ha, and 2.5 to 5.2 m^3/ha. The total fuel volumes in the two sampled stands were 33.7 and 52.1 m^3/ha (Table 2).

Balsam Fir Dominated Stand

The stand characteristics of the only stand in which balsam fir was dominant (45) showed quite high fuel volumes compared to other forest cover types; partly decomposed fuels were the largest, followed by punky and sound materials. The balsam fir fuel volumes were as follows: partly decomposed, 30.6 m^3/ha; punky, 14.6 m^3/ha; and sound, 11.3 m^3/ha. Total fuel volume averaged 56.5 m^3/ha (Table 2).

Tamarack Dominated Stand

The stand characteristics of the only stand where tamarack was dominant (46) showed the lowest fuel volumes compared to the means for the other forest cover types sampled. The partly decomposed downed-dead materials were the most abundant: 3.8 m^3/ha, compared to 3.4 m^3/ha for punky and 0.6 m^3/ha for sound fuels. Total fuel volume for all tree species and fuel categories averaged 7.7 m^3/ha (Table 2).

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[1] Pollock, W.S. 1979. Development of a method to predict logging residues. Final report, ENFOR contract for project P-23. Timmerlinn Woodland Services Ltd., Ste. Agathe des Monts, Quebec.

Table 1. Stand variables for the forest cover types sampled in central Alberta

Forest subgroup, stand number, and main tree species	Stand age (yr)	Class code		Stand density (stems/ha)	Basal area (m^2/ha)	Diameter class[c]	
		Crown density[a]	Height[b]			Range (cm)	Predominant (cm)
Jack pine dominated stands							
1 Jack pine	28	A	1	1 881	14.5	4–28	4
2 Jack pine	45	A	2	1 812	16.5	2–28	2
3 Jack pine	28	B	1	7 731	17.4	2–18	2
Trembling aspen				318	0.4	4–4	4
Total				8 049	17.8		
4 Jack pine	64	B	2	812	15.5	4–34	4
Dead				92	1.0	8–24	8
Total				904	16.5		
5 Jack pine	85	B	3	1 885	28.0	4–28	14
Trembling aspen				942	1.0	2–20	2
Dead				260	2.5	8–18	10
Total				3 087	31.5		
6 Jack pine	60	C	0	5 452	22.5	2–28	2
7 Jack pine	37	C	0	3 899	23.0	4–18	8
8 Jack pine	36	C	1	8 031	26.7	2–24	4
Trembling aspen				251	0.5	4–6	4
Dead				2 290	3.2	2–12	2
Total				10 572	30.3		
9 Jack pine	46	C	2	3 189	28.9	4–40	6
Trembling aspen				140	0.7	4–20	4
Black spruce				13	0.1	10–10	10
Dead				1 743	2.1	2–18	2
Total				5 085	31.8		
10 Jack pine	86	C	4	620	29.1	12–48	26
Black spruce				777	16.5	10–50	10
White birch				45	1.0	10–26	10
Other				16	1.3	22–40	22
Dead				413	7.4	8–38	12
Total				1 871	55.2		
11 Jack pine	54	D	1	2 221	32.0	4–24	8
Black spruce				3 208	7.0	2–16	2
Dead				215	1.3	8–14	8
Total				5 644	40.3		

Continued on next page.

Table 1. Continued

Forest subgroup, stand number, and main tree species	Stand age (yr)	Class code		Stand density (stems/ha)	Basal area (m^2/ha)	Diameter class[c]	
		Crown density[a]	Height[b]			Range (cm)	Predominant (cm)
12 Jack pine	52	D	2	4 733	30.0	6–18	8
Black spruce				6 842	20.5	4–12	6
Dead				1 136	3.5	4–12	6
Total				12 711	54.0		
13 Jack pine	83	D	3	2 297	39.1	2–38	12
Black spruce				1 082	7.2	2–24	2
White birch				16	0.2	10–14	10
Other				11	0.7	20–44	20
Dead				477	4.1	6–40	6
Total				3 883	51.2		
14 Jack pine	86	D	3	904	36.0	10–38	20
Black spruce				155	4.8	16–30	18
Trembling aspen				52	2.5	16–38	16
Dead				404	6.8	8–34	12
Total				1 515	50.0		
Black spruce dominated stands							
15 Black spruce	N/A	B	1	6 132	24.0	2–30	4
Jack pine				133	1.0	6–22	6
Trembling aspen				118	1.3	10–14	10
Dead				330	1.8	4–14	4
Total				6 713	28.0		
16 Black spruce	60	C	0	8 575	11.5	2–14	2
Dead				2 304	8.0	4–16	4
Total				10 879	19.5		
17 Black spruce	62	C	1	12 439	39.5	2–16	2
Trembling aspen				672	4.0	6–16	8
Dead				64	0.5	10–10	10
Total				13 175	44.0		
18 Black spruce	52	C	2	6 630	37.3	2–28	2
Dead				141	0.6	4–16	4
Total				6 771	37.9		
19 Black spruce	167	D	1	2 197	15.5	6–16	6
Dead				160	1.5	10–14	10
Total				2 357	17.0		

Continued on next page.

Table 1. Continued

Forest subgroup, stand number, and main tree species	Stand age (yr)	Class code		Stand density (stems/ha)	Basal area (m^2/ha)	Diameter class[c]	
		Crown density[a]	Height[b]			Range (cm)	Predominant (cm)
20 Black spruce	82	D	2	2 825	33.5	4–32	12
Trembling aspen				986	1.3	2–34	2
Tamarack				166	3.3	12–32	12
Other				41	2.5	18–38	30
Dead				180	3.3	10–24	12
Total				4 198	43.8		
21 Black spruce	85	D	3	1 651	32.8	6–50	10
Jack pine				291	10.3	14–34	16
Balsam fir				198	4.5	10–30	10
Other				77	4.0	16–36	16
Dead				829	8.8	10–32	10
Total				3 046	60.3		
22 Black spruce	94	C	1	788	20.0	10–30	20
Jack pine				338	12.8	10–34	18
Dead				386	7.8	10–28	12
Total				1 512	40.5		
23 Black spruce	N/A	C	1	12 614	23.3	2–16	2
Balsam poplar				47	0.5	8–22	8
Dead				25	0.1	8–8	8
Total				12 686	23.9		
24 Black spruce	187	C	3	670	30.5	10–50	16
Jack pine				212	7.0	14–34	20
Balsam fir				98	3.0	14–50	14
Other				44	3.5	24–50	26
Dead				58	1.5	14–34	14
Total				1 082	45.5		
25 Black spruce	104	D	1	6 916	54.0	4–36	10
Jack pine				16	0.3	14–14	14
Balsam fir				6	0.8	36–42	36
Dead				1 628	5.0	4–18	4
Total				8 566	60.0		
26 Black spruce	N/A	D	2	4 227	27.5	4–20	8
Jack pine				2 044	25.5	8–26	10
Trembling aspen				11	0.5	24–24	24
Dead				1 149	7.5	6–14	6
Total				7 431	61.0		

Continued on next page.

Table 1. Continued

Forest subgroup, stand number, and main tree species	Stand age (yr)	Class code		Stand density (stems/ha)	Basal area (m^2/ha)	Diameter class[c]	
		Crown density[a]	Height[b]			Range (cm)	Predominant (cm)
27 Black spruce	85	D	2	3 967	45.0	4–30	10
Jack pine				543	9.3	8–30	12
Tamarack				17	0.4	14–26	14
Other				17	0.3	12–16	12
Dead				503	3.9	4–24	6
Total				5 047	58.7		
28 Black spruce	81	C	1	8 145	11.2	2–20	2
Tamarack				1 211	1.1	2–18	2
Dead				1 344	3.4	2–18	2
Total				10 700	15.6		
29 Black spruce	90	C	2	2 175	33.0	8–40	10
Jack pine				225	5.5	10–44	16
White birch				22	0.5	16–18	16
Other				8	0.3	20–20	20
Dead				99	1.5	10–20	16
Total				2 529	40.8		
30 Black spruce	N/A	C	2	10 574	14.0	2–14	2
Jack pine				64	0.5	10–10	10
Dead				199	1.0	8–8	8
Total				10 837	15.5		
31 Black spruce	88	C	3	790	22.5	12–44	20
Jack pine				42	2.5	20–50	20
Trembling aspen				33	2.0	18–46	18
Dead				164	5.5	16–26	20
Total				1 029	32.5		
32 Black spruce	72	C	3	511	11.0	12–26	12
Tamarack				422	12.0	14–26	14
Total				933	23.0		
33 Black spruce	81	D	0	8 766	12.3	2–18	2
Tamarack				64	0.6	8–22	8
Dead				166	1.1	8–10	10
Total				8 996	14.0		
34 Black spruce	93	D	1	5 919	25.5	4–16	6
Dead				138	0.5	6–8	6
Total				6 057	26.0		

Continued on next page.

Table 1. Continued

Forest subgroup, stand number, and main tree species	Stand age (yr)	Class code		Stand density (stems/ha)	Basal area (m^2/ha)	Diameter class[c]	
		Crown density[a]	Height[b]			Range (cm)	Predominant (cm)
35 Black spruce	96	D	2	2 794	29.1	4–32	10
Jack pine				388	12.0	12–34	14
White spruce				354	2.8	4–20	10
Other				17	0.5	16–28	16
Dead				887	6.8	4–30	4
Total				4 440	51.1		
36 Black spruce	93	C	1	4 369	34.8	6–20	6
Dead				8	0.3	20–20	20
Total				4 377	35.0		
37 Black spruce	92	C	1	7 745	19.0	2–24	2
38 Black spruce	88	C	2	1 273	26.5	10–34	14
Jack pine				163	5.5	8–50	8
Trembling aspen				25	1.0	20–26	20
Other				20	0.5	18–18	18
Dead				136	2.0	8–30	8
Total				1 617	35.5		
39 Black spruce	92	C	2	4 808	18.0	4–24	6
Jack pine				238	6.0	14–24	16
Dead				82	1.5	14–16	16
Total				5 128	25.5		
40 Black spruce	94	D	1	13 942	32.3	2–20	2
Trembling aspen				169	2.3	10–18	10
Total				14 111	34.5		
41 Black spruce	85	D	2	2 503	32.0	4–40	12
Jack pine				775	25.5	10–40	16
Dead				315	4.0	6–26	12
Total				3 593	61.5		
42 Black spruce	78	D	3	2 155	15.3	6–28	6
Jack pine				962	21.5	8–34	16
Trembling aspen				26	0.8	14–26	14
Dead				159	2.3	10–20	14
Total				3 302	39.8		

Continued on next page.

Table 1. Continued

Forest subgroup, stand number, and main tree species	Stand age (yr)	Class code		Stand density (stems/ha)	Basal area (m^2/ha)	Diameter class[c]	
		Crown density[a]	Height[b]			Range (cm)	Predominant (cm)
White spruce dominated stands							
43 White spruce	132	C	3	656	19.8	4–50	4
Balsam fir				424	5.5	6–38	6
Jack pine				372	13.3	12–50	12
Other				157	1.8	6–38	6
Dead				326	3.0	8–30	8
Total				1 935	43.3		
44 White spruce	88	C	3	876	22.5	6–50	10
Balsam fir				101	2.5	12–42	12
Jack pine				61	3.5	14–40	14
Other				4	0.5	40–40	40
Total				1 042	29.0		
Balsam fir dominated stand							
45 Balsam fir	87	D	3	899	13.3	6–36	6
Black spruce				670	23.0	10–46	12
Trembling aspen				101	6.3	16–50	28
Other				111	6.0	14–50	20
Dead				387	4.0	6–24	8
Total				2 168	52.5		
Tamarack dominated stand							
46 Tamarack	81	C	1	10 080	4.7	2–4	2
Dead				3 183	2.0	2–4	2
Total				13 263	6.7		

[a] Crown density classes percentages are as follows: A, 6–30%; B, 31–50%; C, 51–70%; D, 71–100%.
[b] Height classes are as follows: 0, 0–6.0 m; 1, 6.1–12.0 m; 2, 12.1–18.0 m; 3, 18.1–24.0 m; 4, 24.1–30.0+ m.
[c] Diameter at breast height of all standing trees.

Table 2. Roundwood fuel volumes

Forest subgroup and stand number	Roundwood fuel volume			Diameter class[a]	
	Condition	(m^3/ha)	%	Range (cm)	Predominant (cm)
Jack pine dominated stands					
1	Sound	0.622	3.1	0–7	0
	Partly decomposed	2.396	12.3	1–22	22
	Punky	16.446	84.6	1–26	14
	Total	19.464			
2	Sound	1.239	20.3	0–18	0
	Partly decomposed	1.897	31.0	1–24	24
	Punky	2.963	48.7	1–26	7
	Total	6.099			
3	Sound	1.211	3.9	0–14	0
	Partly decomposed	4.659	15.0	1–22	7
	Punky	25.067	81.1	1–28	16
	Total	30.937			
4	Sound	1.705	27.9	0–12	12
	Partly decomposed	2.682	43.8	1–16	7
	Punky	1.723	28.3	1–20	7
	Total	6.110			
5	Sound	1.768	19.1	0–12	0
	Partly decomposed	2.764	29.8	1–12	7
	Punky	4.722	51.1	1–20	20
	Total	9.254			
6	Sound	0.353	3.6	0–0	0
	Partly decomposed	0.534	5.5	1–7	7
	Punky	8.718	90.9	1–14	7
	Total	9.605			
7	Sound	0.441	3.5	0–3	0
	Partly decomposed	2.260	18.3	1–14	14
	Punky	9.633	78.2	1–28	14
	Total	12.334			
8	Sound	2.968	11.5	0–18	7
	Partly decomposed	13.854	53.7	1–20	7
	Punky	8.942	34.8	1–28	26
	Total	25.764			

Continued on next page.

Table 2. Continued

Forest subgroup and stand number	Roundwood fuel volume			Diameter class[a]	
	Condition	(m^3/ha)	%	Range (cm)	Predominant (cm)
9	Sound	12.379	20.5	0–26	7
	Partly decomposed	19.437	32.2	1–28	7
	Punky	28.400	47.3	1–36	18
	Total	60.216			
10	Sound	12.491	26.7	0–28	14
	Partly decomposed	19.117	40.9	1–32	7
	Punky	15.060	32.4	1–28	16
	Total	46.668			
11	Sound	0.879	2.1	0–7	0
	Partly decomposed	3.873	9.5	1–24	14
	Punky	35.844	88.4	1–36	24
	Total	40.596			
12	Sound	0.447	9.4	0–3	0
	Partly decomposed	2.023	42.9	1–10	3
	Punky	2.238	47.7	1–16	7
	Total	4.708			
13	Sound	7.627	17.1	0–28	12
	Partly decomposed	17.956	40.3	1–44	7
	Punky	18.892	42.6	1–44	38
	Total	44.475			
14	Sound	22.195	34.3	0–22	12
	Partly decomposed	22.306	34.5	1–36	7
	Punky	20.037	31.2	1–24	14
	Total	64.538			
Black spruce dominated stands					
15	Sound	0.601	12.3	0–7	0
	Partly decomposed	3.105	63.8	1–16	7
	Punky	1.160	23.9	1–14	7
	Total	4.866			
16	Sound	1.511	43.9	0–18	0
	Partly decomposed	1.528	44.4	1–12	7
	Punky	0.398	11.7	1–14	14
	Total	3.437			

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Table 2. Continued

Forest subgroup and stand number	Roundwood fuel volume			Diameter class[a]	
	Condition	(m^3/ha)	%	Range (cm)	Predominant (cm)
17	Sound	1.174	10.9	0–7	0
	Partly decomposed	3.506	32.7	1–20	20
	Punky	6.030	56.4	1–26	26
	Total	10.710			
18	Sound	1.157	27.1	0–12	0
	Partly decomposed	1.291	30.3	1–12	7
	Punky	1.808	42.6	1–14	7
	Total	4.256			
19	Sound	0.668	40.0	0–7	0
	Partly decomposed	0.937	56.2	1–7	7
	Punky	0.061	3.8	1–3	3
	Total	1.666			
20	Sound	0.778	9.3	0–12	0
	Partly decomposed	4.935	59.4	1–20	7
	Punky	2.588	31.3	1–16	14
	Total	8.301			
21	Sound	11.794	22.1	0–24	12
	Partly decomposed	26.834	50.3	1–32	7
	Punky	14.675	27.6	1–38	18
	Total	53.303			
22	Sound	22.096	34.6	0–20	7
	Partly decomposed	21.527	33.7	1–24	16
	Punky	20.216	31.7	1–26	12
	Total	63.839			
23	Sound	1.112	7.9	0–12	0
	Partly decomposed	2.605	18.6	1–20	3
	Punky	10.223	73.5	1–30	22
	Total	13.940			
24	Sound	2.179	5.4	0–14	14
	Partly decomposed	8.303	20.6	1–32	32
	Punky	29.646	74.0	1–50	50
	Total	40.128			
25	Sound	1.854	19.4	0–22	22
	Partly decomposed	4.568	47.8	1–26	7
	Punky	3.121	32.8	1–24	7
	Total	9.543			

Continued on next page.

Table 2. Continued

Forest subgroup and stand number	Roundwood fuel volume			Diameter class[a]	
	Condition	(m^3/ha)	%	Range (cm)	Predominant (cm)
26	Sound	1.335	24.0	0–14	14
	Partly decomposed	2.148	38.6	1–7	7
	Punky	2.069	37.4	1–14	7
	Total	5.552			
27	Sound	4.978	30.3	0–18	7
	Partly decomposed	7.585	46.2	1–16	7
	Punky	3.851	23.5	1–16	7
	Total	16.414			
28	Sound	0.662	17.7	0–18	7
	Partly decomposed	1.794	47.9	1–18	7
	Punky	1.281	34.4	1–14	12
	Total	3.737			
29	Sound	3.747	22.9	0–18	0
	Partly decomposed	4.494	27.5	1–22	16
	Punky	8.089	49.6	1–38	38
	Total	16.330			
30	Sound	0.722	20.1	0–3	0
	Partly decomposed	1.590	44.4	1–10	10
	Punky	1.268	35.5	1–12	12
	Total	3.580			
31	Sound	1.889	9.1	0–12	0
	Partly decomposed	11.512	55.9	1–20	20
	Punky	7.164	35.0	1–26	12
	Total	20.565			
32	Sound	0.111	2.0	0–0	0
	Partly decomposed	4.606	86.6	1–14	10
	Punky	0.596	11.4	1–7	7
	Total	5.313			
33	Sound	0.775	20.7	0–7	0
	Partly decomposed	2.049	54.9	1–16	7
	Punky	0.902	24.4	1–14	14
	Total	3.726			
34	Sound	1.650	14.9	0–12	7
	Partly decomposed	5.363	48.6	1–7	7
	Punky	4.010	36.5	1–14	
	Total	11.023			

Continued on next page.

Table 2. Continued

Forest subgroup and stand number	Roundwood fuel volume			Diameter class[a]	
	Condition	(m^3/ha)	%	Range (cm)	Predominant (cm)
35	Sound	9.095	36.7	0–18	7
	Partly decomposed	11.045	44.6	1–26	7
	Punky	4.613	18.7	1–18	7
	Total	24.753			
36	Sound	1.293	9.7	0–7	7
	Partly decomposed	6.540	49.0	1–12	7
	Punky	5.485	41.3	1–16	7
	Total	13.318			
37	Sound	0.864	5.7	0–7	0
	Partly decomposed	3.532	23.6	1–20	7
	Punky	10.521	70.7	1–24	16
	Total	14.917			
38	Sound	12.888	30.7	0–22	16
	Partly decomposed	9.509	22.6	1–18	16
	Punky	19.555	46.7	1–26	18
	Total	41.952			
39	Sound	1.040	4.2	0-10	0
	Partly decomposed	2.798	11.3	1–12	10
	Punky	20.758	84.5	1–24	7
	Total	24.596			
40	Sound	1.078	6.4	0–7	7
	Partly decomposed	5.195	30.8	1–30	7
	Punky	10.547	62.8	1–18	7
	Total	16.820			
41	Sound	9.921	29.3	0–18	16
	Partly decomposed	14.498	42.9	1–22	20
	Punky	9.353	27.8	1–22	20
	Total	33.772			
42	Sound	2.236	49.9	0–20	7
	Partly decomposed	1.764	39.4	1–14	7
	Punky	0.477	10.7	1–7	7
	Total	4.477			
White spruce dominated stands					
43	Sound	5.237	10.0	0–20	7
	Partly decomposed	14.954	28.6	1–32	7
	Punky	31.955	61.4	1–44	36
	Total	52.146			

Continued on next page.

Table 2. Continued

Forest subgroup and stand number	Roundwood fuel volume			Diameter class[a]	
	Condition	(m^3/ha)	%	Range (cm)	Predominant (cm)
44	Sound	2.525	7.4	0–18	18
	Partly decomposed	2.811	8.3	1–7	7
	Punky	28.336	84.3	1–50	36
	Total	33.672			
Balsam fir dominated stand					
45	Sound	11.319	20.0	0–20	16
	Partly decomposed	30.627	54.1	1–26	7
	Punky	14.569	25.9	1–28	14
	Total	56.515			
Tamarack dominated stand					
46	Sound	0.567	7.3	0–7	0
	Partly decomposed	3.767	48.9	1–16	16
	Punky	3.359	43.8	1–22	22
	Total	7.693			

[a] Diameter of woody materials.

Table 3. Relative basal area of tree species in the sampled stands based on live trees

Stand no.	Species composition (%)									Live (m^2/ha)	Dead (m^2/ha)
	Jack pine	Black spruce	White spruce	Balsam fir	Tamarack	Trembling aspen	Balsam poplar	White birch	Other		
1	100.0	0	0	0	0	0	0	0	0	14.5	0
2	100.0	0	0	0	0	0	0	0	0	16.5	0
3	97.8	0	0	0	0	2.2	0	0	0	17.8	0
4	100.0	0	0	0	0	0	0	0	0	15.5	1.0
5	96.6	0	0	0	0	3.4	0	0	0	29.0	2.5
6	100.0	0	0	0	0	0	0	0	0	22.5	0
7	100.0	0	0	0	0	0	0	0	0	23.0	0
8	98.2	0	0	0	0	1.8	0	0	0	27.2	3.2
9	97.3	0.3	0	0	0	2.4	0	0	0	29.7	2.1
10	60.7	34.5	0	0	0	0	0	2.1	2.7	47.9	7.4
11	82.0	18.0	0	0	0	0	0	0	0	39.0	1.3
12	59.4	40.6	0	0	0	0	0	0	0	50.5	3.5
13	82.8	15.3	0	0	0	0	0	0.4	1.5	47.2	4.1
14	83.1	11.1	0	0	0	5.8	0	0	0	43.3	6.8
15	3.8	91.3	0	0	0	4.9	0	0	0	26.3	1.8
16	0	100.0	0	0	0	0	0	0	0	11.5	8.0
17	0	90.8	0	0	0	9.2	0	0	0	43.5	0.5
18	0	100.0	0	0	0	0	0	0	0	37.3	0.6
19	0	100.0	0	0	0	0	0	0	0	15.5	1.5
20	0	82.5	0	0	8.1	3.2	0	0	6.2	40.6	3.3
21	20.0	63.6	0	8.7	0	0	0	0	7.8	51.6	8.8
22	39.0	61.0	0	0	0	0	0	0	0	32.8	7.8
23	0	97.9	0	0	0	0	2.1	0	0	23.8	0.1
24	15.9	69.3	0	6.8	0	0	0	0	8.0	44.0	1.5
25	0.5	98.0	0	1.5	0	0	0	0	0	55.1	5.0
26	47.7	51.4	0	0	0	0.9	0	0	0	53.5	7.5
27	16.9	81.8	0	0	0.7	0	0	0	0.6	55.0	3.9
28	0	91.1	0	0	8.9	0	0	0	0	12.3	3.4
29	14.0	84.0	0	0	0	0	0	1.3	0.7	39.3	1.5
30	3.4	96.6	0	0	0	0	0	0	0	14.5	1.0
31	9.3	83.3	0	0	0	7.4	0	0	0	27.0	5.5
32	0	47.8	0	0	52.2	0	0	0	0	23.0	0
33	0	95.4	0	0	4.6	0	0	0	0	12.9	1.1
34	0	100.0	0	0	0	0	0	0	0	25.5	0.5
35	27.0	65.6	6.2	0	0	0	0	0	1.1	44.4	6.8
36	0	100.0	0	0	0	0	0	0	0	34.8	0.3
37	0	100.0	0	0	0	0	0	0	0	19.0	0
38	16.4	79.1	0	0	0	3.0	0	0	1.5	33.5	2.0
39	25.0	75.0	0	0	0	0	0	0	0	24.0	1.5
40	0	93.5	0	0	0	6.5	0	0	0	34.5	0
41	44.3	55.7	0	0	0	0	0	0	0	57.5	4.0
42	57.3	40.7	0	0	0	2.0	0	0	0	37.5	2.3
43	33.0	0	49.1	13.6	0	0	0	0	4.3	40.3	3.0
44	12.1	0	77.6	8.6	0	0	0	0	1.7	29.0	0
45	0	47.4	0	27.3	0	12.9	0	0	12.4	48.5	4.0
46	0	0	0	0	100.0	0	0	0	0	4.7	2.0

Table 4. Relative density of tree species in the sampled stands based on live trees

Stand no.	Species composition (%)									Live (stems/ha)	Dead (stems/ha)
	Jack pine	Black spruce	White spruce	Balsam fir	Tamarack	Trembling aspen	Balsam poplar	White birch	Other		
1	100.0	0	0	0	0	0	0	0	0	1 881	0
2	100.0	0	0	0	0	0	0	0	0	1 812	0
3	96.0	0	0	0	0	4.0	0	0	0	8 049	0
4	100.0	0	0	0	0	0	0	0	0	812	92
5	66.7	0	0	0	0	33.3	0	0	0	2 827	260
6	100.0	0	0	0	0	0	0	0	0	5 452	0
7	100.0	0	0	0	0	0	0	0	0	3 899	0
8	97.0	0	0	0	0	3.0	0	0	0	8 282	2 290
9	95.4	0.4	0	0	0	4.2	0	0	0	3 342	1 743
10	42.5	53.3	0	0	0	0	0	3.1	1.1	1 458	413
11	40.9	59.1	0	0	0	0	0	0	0	5 429	215
12	40.9	59.1	0	0	0	0	0	0	0	11 575	1 136
13	67.4	31.8	0	0	0	0	0	0.5	0.3	3 406	477
14	81.4	14.0	0	0	0	4.7	0	0	0	1 111	404
15	2.1	96.1	0	0	0	1.8	0	0	0	6 383	330
16	0	100.0	0	0	0	0	0	0	0	8 575	2 304
17	0	94.9	0	0	0	5.1	0	0	0	13 111	64
18	0	100.0	0	0	0	0	0	0	0	6 630	141
19	0	100.0	0	0	0	0	0	0	0	2 197	160
20	0	70.3	0	0	4.1	24.6	0	0	1.0	4 018	180
21	13.1	74.5	0	8.9	0	0	0	0	3.5	2 217	829
22	30.0	70.0	0	0	0	0	0	0	0	1 126	386
23	0	99.6	0	0	0	0	0.4	0	0	12 661	25
24	20.7	65.4	0	9.6	0	0	0	0	4.3	1 024	58
25	0.2	99.7	0	0.1	0	0	0	0	0	6 938	1 628
26	32.5	67.3	0	0	0	0.2	0	0	0	6 282	1 149
27	11.9	87.3	0	0	0.4	0	0	0	0.4	4 544	503
28	0	87.1	0	0	12.9	0	0	0	0	9 356	1 344
29	9.3	89.5	0	0	0	0	0	0.9	0.3	2 430	99
30	0.6	99.4	0	0	0	0	0	0	0	10 638	199
31	4.9	91.3	0	0	0	3.8	0	0	0	865	164
32	0	54.8	0	0	45.2	0	0	0	0	933	0
33	0	99.3	0	0	0.7	0	0	0	0	8 830	166
34	0	100.0	0	0	0	0	0	0	0	5 919	138
35	10.9	78.6	10.0	0	0	0	0	0	0.5	3 553	887
36	0	100.0	0	0	0	0	0	0	0	4 369	8
37	0	100.0	0	0	0	0	0	0	0	7 745	0
38	11.0	86.0	0	0	0	1.7	0	0	1.3	1 481	136
39	4.7	95.3	0	0	0	0	0	0	0	5 046	82
40	0	98.8	0	0	0	1.2	0	0	0	14 111	0
41	23.6	76.4	0	0	0	0	0	0	0	3 278	315
42	30.6	68.6	0	0	0	0.8	0	0	0	3 143	159
43	23.1	0	40.8	26.3	0	0	0	0	9.8	1 609	326
44	5.8	0	84.1	9.7	0	0	0	0	0.4	1 042	0
45	0	37.6	0	50.5	0	5.7	0	0	6.2	1 781	387
46	0	0	0	0	100.0	0	0	0	0	10 080	3 183

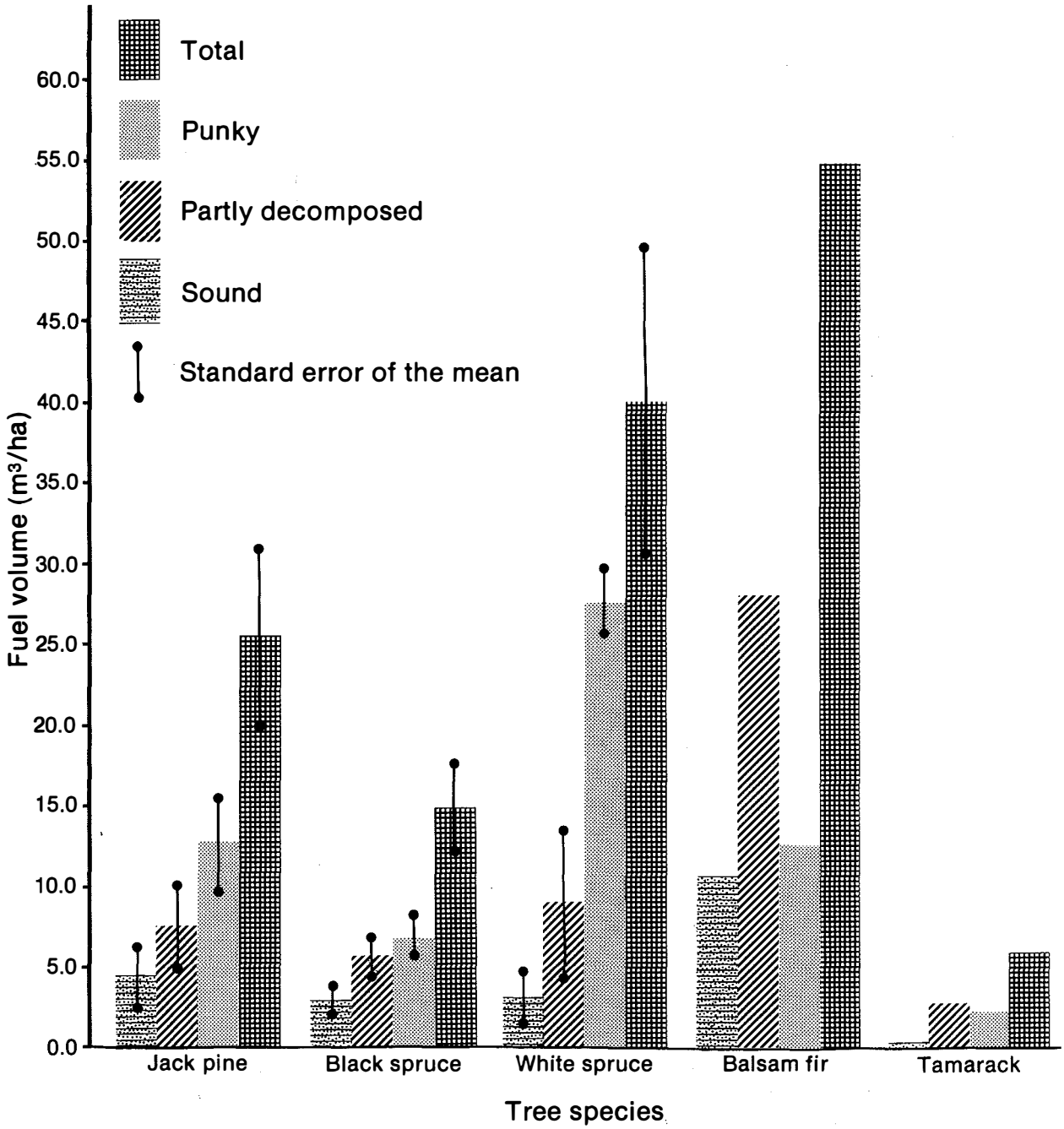

Figure 3. Total downed-dead roundwood fuel volumes according to the main subgroups in central Alberta forests.

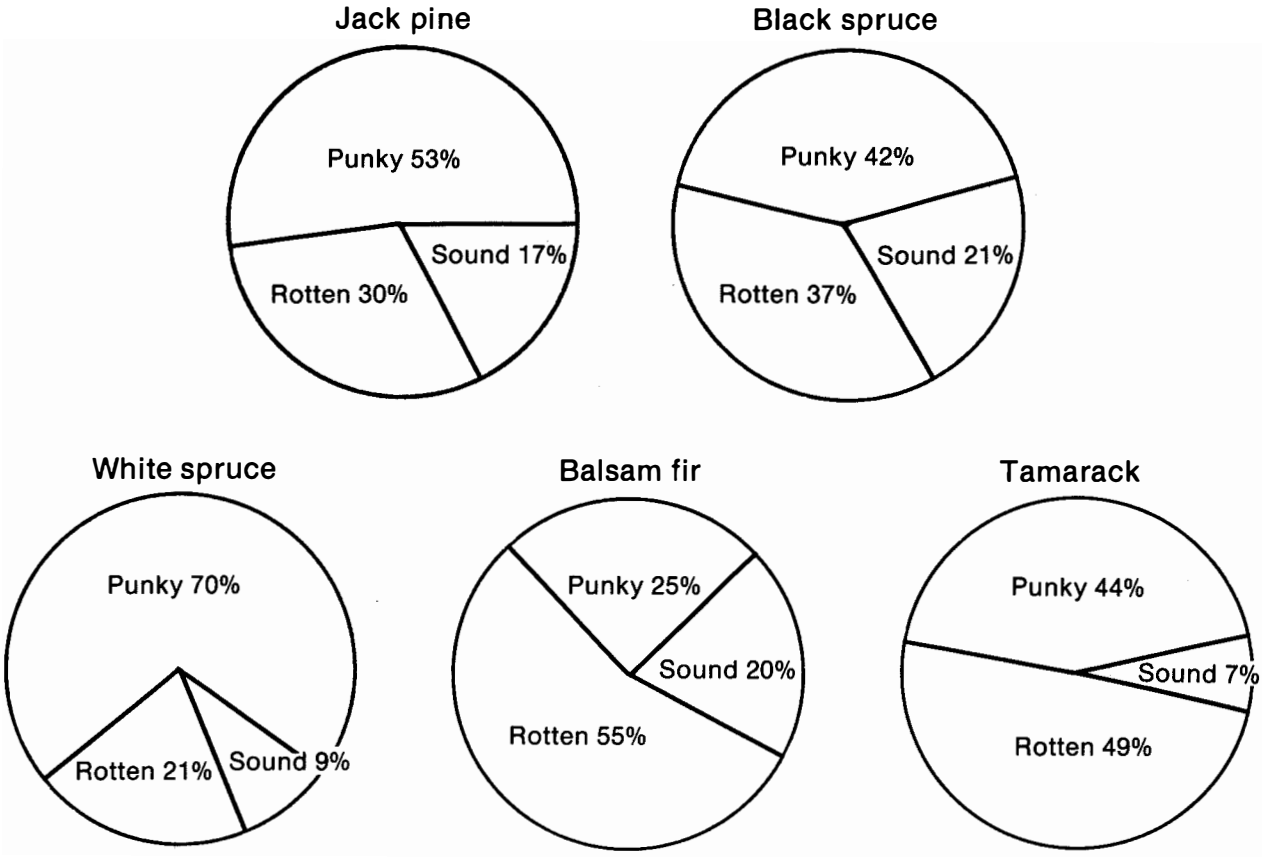

Figure 4. Breakdown of total downed-dead fuel by main fuel condition classes.

Obtaining First Approximations of Fuel Volume Estimates

Descriptive statistics for the sampled variables used in the derivation of the model are listed in Table 5. Although the mean roundwood fuel volume in a main subgroup and its proportional distribution in the three condition classes can be estimated from Figure 3, the fuel volume of a specific forest stand (m^3/ha) may be calculated by using the multiple regression equations presented in Table 6. Volume estimates may be converted to weight estimates by multiplying these with the wood density of the fuel condition class.

The line intersect method used in the study had the advantage of being nondestructive, and it avoided the need for the time-consuming, costly, and often impractical task of obtaining and weighing fairly large quantities of forest debris (Brown 1974; Brown and Marsden 1976). The predictor variables are fairly easy to measure. The estimates provided by the prediction equations are adequate to serve as first approximations for the downed-dead roundwood fuel volumes on the forest floor surface.

ACKNOWLEDGMENTS

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Table 5. Descriptive statistics for the sampled variables used in the model

Variable	Units	Mean	Standard deviation	Model symbol[a]
Basal area — pine	m^2/ha	11.3	12.2	BA. PN
Basal area — spruce	m^2/ha	18.6	14.0	BA. SP
Basal area — remaining (live and dead trees)	m^2/ha	0.8	5.4	BA. REM
Stand density	Stems/ha	5 514	3 967	N.TR
Crown density class[a]	A–D[b]	3.2	—	DEN
Stand height class[a]	0–4	1.8	—	HT
Age	Years	80.5	31.0	AGE
Total fuel volume	m^3/ha	21.9	19.0	—
Sound	m^3/ha	4.0	5.5	—
Partly decomposed	m^3/ha	7.5	7.6	—
Punky	m^3/ha	10.4	9.8	—

[a] Refer to text for description of model symbols and crown density and stand height classes.
[b] Coded as 1–4 in equation.

Table 6. Regression equations for predicting downed-dead roundwood fuel volumes from stand variables in central Alberta forest cover types

Type of fuel	Equation[a]
Sound	$= 0.731 + 0.26615\ BA.PN + 0.10530\ BA.SP + 0.5154\ BA.REM - 0.0004547\ N.TR + 0.008\ DEN - 1.364\ HT + 0.00917\ AGE$
	$(N = 42, Mean = 4.32, R = 0.69, SEE = 4.48, F = 4.41)$
Partially decomposed	$= 0.158 + 0.32211\ BA.PN + 0.10707\ BA.SP + 1.0815\ BA.REM - 0.0003027\ N.TR - 0.169\ DEN - 1.035\ HT + 0.00809\ AGE$
	$(N = 42, Mean = 7.94, R = 0.83, SEE = 4.68, F = 11.17)$
Punky	$= 8.897 + 0.4195\ BA.PN + 0.0571\ BA.SP + 0.3212\ BA.REM - 0.0002947\ N.TR - 2.937\ DEN - 0.981\ HT + 0.09029\ AGE$
	$(N = 42, Mean = 11.02, R = 0.50, SEE = 9.54, F = 1.58)$
Total	$= 9.79 + 1.0077\ BA.PN + 0.2695\ BA.SP + 1.9181\ BA.REM - 0.0010521\ N.TR - 3.098\ DEN - 3.380\ HT + 0.10755\ AGE$
	$(N = 42, Mean = 23.28, R = 0.73, SEE = 14.93, F = 5.40)$

[a] BA.PN is basal area of pine (m^2/ha), BA.SP is basal area of spruce (m^2/ha), and BA.REM is the basal area of the remaining tree species including dead trees (m^2/ha); N.TR is the total number of trees/ha, DEN is the crown density class, HT is the stand height class, and AGE is the dominant age (years) of the tree stand.

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