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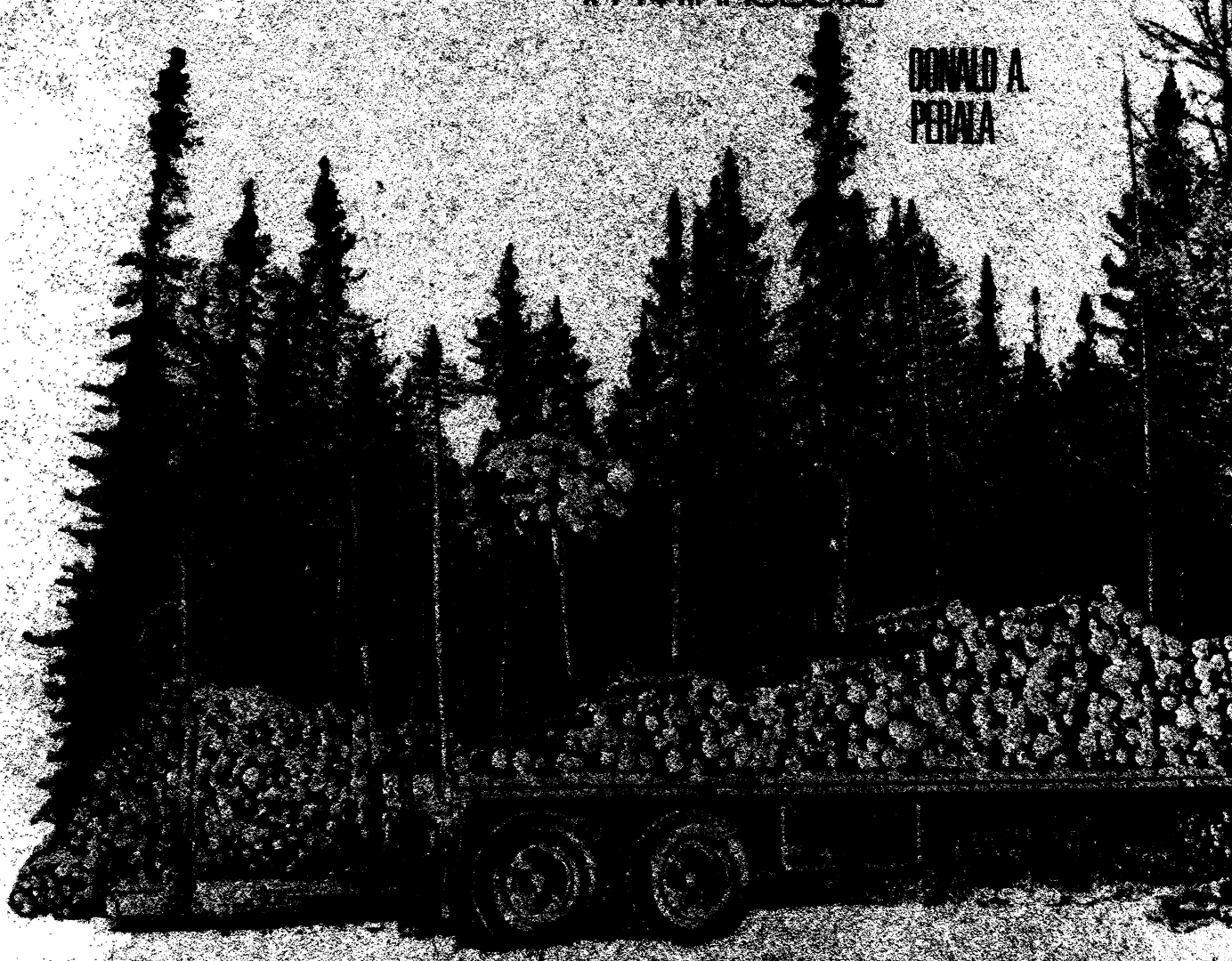
growth and yield of BLACK SPRUCE on Organic Soils in Minnesota

DONALD A. PERALA



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GROWTH AND YIELD OF BLACK SPRUCE ON ORGANIC SOILS IN MINNESOTA

Donald A. Perala

Black spruce (*Picea mariana* (Mill.) B.S.P.) is the dominant timber species on lowland organic soils in northern North America; it ranges from Labrador and the northeastern United States to the Bering Strait. Within the contiguous United States, black spruce is most abundant in the Lake States, where it occupies 2 million acres of commercial timber land. Two-thirds of this acreage is in Minnesota, where the type is limited to the northeastern third of the State.

Black spruce forms virtually pure stands in peatland areas occupying former glacial lakes, such as Lake Agassiz. Even-aged stands are commonly initiated after a fire. The species is tolerant of its own shade, and the stands eventually become uneven-aged through seeding, layering, and eventual deterioration of the original stand that provides openings for reproduction. Black spruce stands suffer high mortality throughout their development.

Black spruce has a straight bole with little taper, a narrow, symmetrical crown, and short, slender branches. It attains heights exceeding 80 feet, averages 5 to 9 inches in diameter at maturity, and is used almost exclusively for pulpwood. The wood is light in color and produces high-quality paper. The silvical characteristics of black spruce are presented in greater detail by Heinselman (1957b), Fowells (1965), and Vincent (1965).

The ability to forecast growth and yield is fundamental to timber management. This paper presents the analysis of growth and yield information from a number of study plots in black spruce stands growing on organic soils in northern Minnesota. Furthermore, growth and yield data for the merchantable portion of the stand are included, which should be of most use to the land manager. Growth as defined in this paper is periodic net 10-year increment, unless otherwise specified. Yield is defined here as the volume on a given site at a given age and basal area density. No deduction for defect has been assumed for either growth or yield.

METHODS

The data for this study were collected from permanent sample plots in black spruce stands growing on organic soils in north central Minnesota (Koochiching and Itasca counties). The growth analysis is based on 128 observations on 84 plots. These plots, along with others unsuited for growth analysis, contributed 291 yield observations. The remeasurement interval was mostly 5 years, but ranged from 4 to 14 years (table 1). All growth observations were adjusted to reflect a 5-year period. All plots were 0.1 acre, in essentially pure, unthinned,[1] disease- and insect-free black spruce stands of even-aged origin.

Plot summaries produced the following variables for basal area projection analysis:

1. Initial total age (T_O) – obtained from increment cores taken from dominant and codominant sample trees at breast height at the beginning of the growth period. It was determined that 12 years was the average age difference between stump and breast height, and this was added to obtain total age.
2. Site index (S) – obtained from average total age and average total height of dominant and codominant sample trees measured by Abney level. Reference age was 50 years based on site index curves fitted by Gevorkiantz (1957) to the data of Fox and Kruse (1939) (fig. 1).
3. Initial per-acre basal area (G_O) – in square feet for all live trees 3.6 inches d.b.h. and greater at the beginning of the growth period. Diameters were measured by tape to the nearest 0.1 inch.
4. Final per-acre basal area (G_5) – in square feet 5 years later for all live trees 3.6 inches d.b.h. and greater, including ingrowth.
5. Final per-acre basal area plus mortality ($G_5 + G_M$) – as in (4) above except the square foot basal area of all trees 3.6 inches d.b.h. and greater that died during the period was added. Since dead trees were not remeasured, their basal area was considered to be that at the beginning of the period.
6. Final per-acre basal area plus mortality minus recruitment, or ingrowth ($G_5 + G_M - G_R$) – as in (5)

[1] *Ninety-three thinned-plot observations were also included in the yield analysis.*

Table 1. – Data summary for the study of growth and yield of black spruce in Minnesota

Permanent sample plots	Date established	Dates remeasured	Site index 1/	Total age	Basal area density 2/	Number of plots	Number of growth observations 3/
				Years	Sq. ft. per acre		
Big Falls Compartment Study 4/	1948-1950	1954, 1955, 1960	23-44	61-202	51-170	73	107
Noncommercial thinning study 4/	1954	1967	31-34	24-39	11-35	4	4
Section 18 plots 4/	1940	1945, 1950 1960	36-41	84-164	126-184	3	9
Wilderness plots 5/	1947	1952, 1957	31-36	75-84	104-139	4	8

1/ Average total height in feet of dominants and codominants at age 50 years.
2/ Trees 3.6 inches in diameter and larger.
3/ 291 observations were included in the yield analysis.
4/ Maintained in cooperation with the Division of Lands and Forestry, Minnesota Conservation Department.
5/ Maintained in cooperation with the Chippewa National Forest, USDA Forest Service.

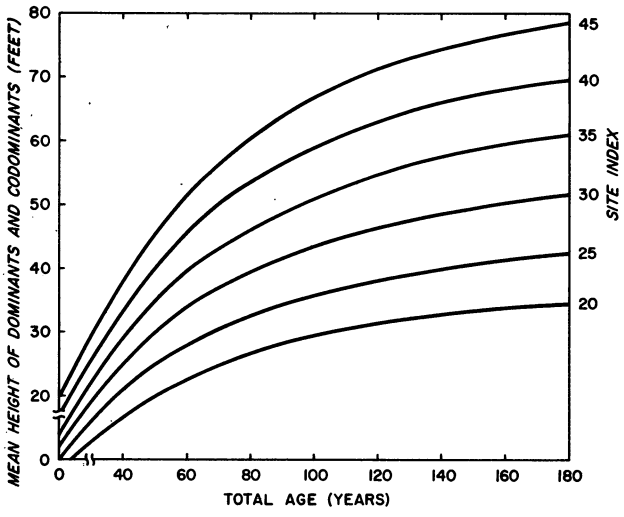

Figure 1. – Site curves for black spruce in the Lake States (Gevorkiantz (1957), Fox and Kruse (1939)).

above except the square foot basal area of trees that grew past the 3.6 inch d.b.h. minimum was not included.

For the yield analysis the following variables were obtained:

1. Per-acre cubic-foot volume (V cubic feet) – the total cubic-foot stem volume, inside bark, of all trees 3.6 inches d.b.h. and greater (based on table 3, Gevorkiantz and Olsen 1955).

2. Per-acre cordwood volume (V cords) – the total gross volume in rough cords to a variable top diameter inside bark of not less than 3 inches of all trees 3.6 inches d.b.h. and greater (based on table 5, Gevorkiantz and Olsen 1955).

3. Total age, site index, and basal area density – obtained the same way as in the growth plots.

The Volume Yield Equations

As a first step, the analysis required the development of regression equations to predict per-acre volume yields in total cubic feet and merchantable cords from site, age, and basal area. Several prediction equations were tested and the one with the best fit to the data (highest R^2 and lowest standard error) was chosen for this study. In general form the equation is

EQUATION 1.

$$l_eV = b_0 + b_1 (l_eS) + b_2 (l_eG) + b_3 T^{-1},$$

where

l_eV = natural, or Naperian, logarithm of volume
l_eS = logarithm of site index in feet
l_eG = logarithm of basal area per acre in square feet
T^{-1} = inverse of total stand age in years.

Rewritten in terms of V rather than l_eV, the equation becomes

EQUATION 2.

$$V = e^{b_0 + b_1 (l_eS) + b_2 (l_eG) + b_3 T^{-1}},$$

where e = natural logarithm base, 2.718....

This prediction equation is essentially the one used by Clutter (1963), except he used "S" rather than the logarithmic transformation "$l_e S$."

Equation 1 was fitted to the cubic foot and cord data. All variables were significant, and after rewriting in the form of Equation 2, resulted in these yield prediction equations:

EQUATION 3.

V cubic feet =

$$e^{1.07542 + .61265\, l_e S + .96861\, l_e G - 9.450\, T^{-1}}$$

EQUATION 4.

V cords =

$$e^{-5.16547 + 1.09987\, l_e S + .95519\, l_e G - 18.716\, T^{-1}}$$

Equation 3 had an R^2 of 0.98 and a standard error of 0.05683 on the logarithmic scale equivalent to 5.8 percent standard error at the mean when converted to natural volume (Spurr 1952, p. 73-74). Equation 4 had an R^2 of .93 with a standard error of 0.10629 (log scale), equivalent to 11.2 percent standard error.

The Basal Area Projection Equations

The growth equations of Buckman (1962) and Clutter (1963) were tested, but proved to be inadequate for black spruce. However, a satisfactory equation was adapted from Evert (1967) and used here:

EQUATION 5.

$$l_e \frac{100\, G_5}{G_0} = b_0 + b_1\, 100\, T_0^{-1} + b_2\, G_0 + b_3\, 100\, G_0 T_0^{-1} + b_4 S$$

where

$l_e \frac{100\, G_5}{G_0}$ = natural logarithm of 100 times the ratio of basal area 5 years later (G_5) to the initial basal area (G_0),

T_0^{-1} = inverse of initial total stand age, and

S = site index.

Rewriting the equation in terms of G_5 gives

EQUATION 6.

$$G_5 = \frac{G_0}{100} \cdot e^{b_0 + b_1\, 100\, T_0^{-1} + b_2 G_0 + b_3\, 100\, G_0 T_0^{-1} + b_4 S}$$

Equation 5 was fitted to the basal area data. All variables except site index were significant, and the final equations resulted, expressed in the form of Equation 6:

EQUATION 7.

$$G_5 = \frac{G_0}{100} \cdot e^{4.63540 + .28818\, 100\, T_0^{-1} + .0005615\, G_0 - .0024652\, 100\, G_0 T_0^{-1}}$$

EQUATION 8.

$$G_5 + G_M = \frac{G_0}{100} \cdot e^{4.64732 + .28443\, 100\, T_0^{-1} + .0007212\, G_0 - .0025269\, 100\, G_0 T_0^{-1}}$$

EQUATION 9.

$$G_5 + G_M - G_R = \frac{G_0}{100} \cdot e^{4.68605 + .07054\, 100\, T_0^{-1} + .0001306\, G_0 - .0006465\, 100\, G_0 T_0^{-1}}$$

Equation 7 expressed 5-year projected net basal area as a function of growth percent, or compound interest. Equation 8, where G_M is 5-year basal area mortality, was developed to estimate 5-year projected gross basal area; by determining the difference between the Equation 7 and 8 predictions, 5-year basal area mortality can be estimated. Equation 9, where G_R is 5-year basal area recruitment, or ingrowth, goes one step further and estimates 5-year projected gross basal area not including ingrowth. The difference between the predictions of Equations 8 and 9 therefore gives an estimate of 5-year basal area ingrowth. Additional analysis provided the following statistics:

Equation	R^2	*SE log scale*	*Percent SE natural scale*
7	.77	.07890	8.2
8	.78	.07379	7.6
9	.66	.02568	2.6

Testing the Equations

A check of 14 black spruce sales near the study area showed Equation 4 volumes compared favorably with actual cords cut (table 2). A 54-acre sale area, of which two-thirds was site indexes 22 to 28 and the rest site index 33, yielded 562 cords; the Equation 4 prediction for this sale was 411 cords, or 73.1 percent of actual. Another area with site indexes ranging from 33 to 42 yielded 1,948 cords, compared with 1,868 predicted, or 95.9 percent of actual. From these checks, it appears that Equation 4 may overestimate volume on the best sites and underestimate it on poor sites. On the other hand, it is suspected that closer utilization on poor sites and underutilization on the best sites occurred, although no formal utilization checks were made on these sales.

To test the basal area projection equations (Equations 7, 8, 9), 5-year projected basal areas from 30 stands not

used in the analysis were summed and compared with summed projected basal areas computed from the equations. The stands ranged in age from 96 to 154 years (mean 135) and had a mean initial basal area of 123.9 square feet. The predicted sums were in close agreement with the actual sums (table 3).

Growth and Yield Tables

Yield (tables 4 and 5) computed from Equations 3 and 4 is presented for each of three site index classes by combinations of basal area and age. Net basal area growth (table 6) during a 10-year period for all sites by initial age and basal area density was computed from Equation 7. Age and basal area density for Equation 7 are specified at the beginning of the growth period and the equation projects basal area for periods of 5 years. Therefore, to obtain 10 years' projected basal area growth, repeated solution of the equation by 5-year increments followed by subtraction of the initial basal area is required.

Volume growth (tables 7 and 8) by site classes for combinations of basal area density and age was computed simply as the difference between the initial yield and the final yield by applying Equations 3 and 4 to basal area projections obtained as above. Projected basal area and yield is given by site classes for 60-year-old stands at initial basal area densities of 20, 60, 100, and 140 square feet, and for 80- to 160-year-old stands at initial densities of 30 to 70 square feet (figs. 2 and 3, and tables 9, 10, 11). In addition, tables 9 to 11 show the contribution of mortality and ingrowth to 10-year projected net basal area as well as current annual increment and mean annual increment in total cubic feet and cords.

DISCUSSION

The yield equations (Equations 3 and 4) provide convenient estimates of volume when site, basal area density, and age of the stand are known. Total cubic foot volume is predicted especially well because diameter distribution has relatively little effect on this measure. However, when volume is estimated in rough cords, or in any other merchantable measure, diameter distribution and mean stand diameter introduce variation unaccounted for by the variables in Equation 4. This limitation should be considered when using Equation 4, which actually expresses yield in cords for stands of "average" diameter distribution and "average" mean diameter for a given age, site, and basal area density.

Table 2. – Comparison of actual and predicted volume yields from 14 black spruce harvest cuts in northern Minnesota

Site index	Age	Basal area	Actual volume	Predicted volume	Predicted as percent of actual
	Years	Square feet	Cords	Cords	
42	120	80	180	196	108.9
38	70-130	60-180	1,386	1,387	100.0
33	80-125	40-140	2,368	2,258	95.4

Table 3. – Comparison of summed actual and predicted basal area growth for 30 black spruce stands in northern Minnesota

Item	Basal area						
	Initial	Final net	Net growth	Final gross	Gross growth	Mortality	Ingrowth
	Square feet						
Actual	3,718.2	4,022.2	304.0	4,118.7	400.5	96.5	50.9
Predicted	3,718.2	4,029.0	310.8	4,123.5	405.3	94.5	73.2
Predicted as percent of actual	100	100.2	102.2	100.1	101.2	97.9	143.8

Table 4. – Minnesota black spruce yield in total cubic feet[1] per acre for trees 3.6 inches d.b.h. and larger (blocks indicate extent of basic data)

SITE INDEX 45

Stand age (years)	Stand basal area, square feet per acre							
	40	60	80	100	120	140	160	180
	Cubic feet per acre							
60	919	1,361	1,798	2,232	2,663	3,092	--	--
80	956	1,416	1,870	2,322	2,770	3,216	3,660	4,103
100	979	1,449	1,915	2,377	2,836	3,293	3,748	4,201
120	994	1,472	1,946	2,415	2,881	3,346	3,807	4,268
140	1,005	1,489	1,968	2,442	2,914	3,383	3,850	4,316
160	1,014	1,502	1,984	2,463	2,939	3,412	3,883	4,352
180	1,021	1,512	1,997	2,479	2,958	3,434	3,909	4,381
200	1,026	1,520	2,008	2,492	2,974	3,452	3,929	4,404
	SITE INDEX 35							
60	788	1,167	1,542	1,914	2,283	2,651	--	--
80	819	1,214	1,604	1,990	2,375	2,757	3,138	--
100	839	1,242	1,642	2,038	2,432	2,823	3,213	3,601
120	852	1,262	1,668	2,070	2,470	2,868	3,264	3,658
140	862	1,276	1,687	2,094	2,498	2,900	3,301	3,700
160	869	1,287	1,701	2,112	2,519	2,925	3,329	3,731
180	875	1,296	1,712	2,125	2,536	2,944	3,351	3,756
200	880	1,303	1,721	2,137	2,549	2,960	3,368	3,776
	SITE INDEX 25							
60	641	949	1,254	1,557	1,858	--	--	--
80	667	988	1,305	1,620	1,932	2,244	--	--
100	683	1,011	1,336	1,658	1,979	2,297	2,614	2,930
120	694	1,027	1,357	1,685	2,010	2,334	2,656	2,977
140	701	1,039	1,373	1,704	2,033	2,360	2,686	3,011
160	707	1,048	1,384	1,718	2,050	2,380	2,709	3,036
180	712	1,054	1,393	1,730	2,064	2,396	2,727	3,056
200	716	1,060	1,401	1,739	2,074	2,408	2,741	3,072

1/ Gross peeled volume entire stem based on table 3, Gevorkiantz and Olsen (1955).

The composite tables by Gevorkiantz and Olsen (1955) used to determine volumes in this study provide an underlying flexibility for predicted volume growth and yield. The growth and yield tables presented here may be adjusted for local differences in species taper, form quotient, bark volume, care in piling, and actual utilization practices in the same manner as outlined by the authors for the composite tables, or through past experience with the tables.

In five checks of 20 to 27 trees each, Gevorkiantz and Olsen found their composite total cubic foot volume table (table 3) to deviate from actual black spruce tree volume by -7.7 to +0.4 percent (mean -2.6 percent). Kirby (1960) also found composite table 3 to underestimate black spruce volume by 2 to 5 percent in Saskatchewan.

According to Gevorkiantz and Olsen, the composite cordwood volume table 5 should need adjustment primarily only for actual utilization practices and care in piling. Other factors are largely compensating, except that adjustments may be necessary if form varies greatly from the average.

Although site index is an important variable for predicting volume yields, it was not significant in the analysis of the basal area projection Equations 7, 8, and 9. Evert (1967, p. 8) also found that site index did not contribute significantly to his basal area regressions, and concluded that "the presence of a certain amount of

Table 5. – Minnesota black spruce yield in cords[1] per acre for trees 3.6 inches d.b.h. and larger (blocks indicate extent of basic data)

SITE INDEX 45

Stand age (years)	Stand basal area, square feet per acre							
	40	60	80	100	120	140	160	180
				Cords per acre				
60	9.3	13.7	18.1	22.4	26.6	30.9	--	--
80	10.1	14.8	19.6	24.2	28.8	33.4	37.9	42.4
100	10.6	15.6	20.5	25.4	30.2	35.0	39.7	44.4
120	10.9	16.0	21.1	26.2	31.1	36.1	41.0	45.9
140	11.1	16.4	21.6	26.7	31.8	36.9	41.9	46.9
160	11.3	16.7	22.0	27.2	32.4	37.5	42.6	47.7
180	11.5	16.9	22.3	27.6	32.8	38.0	43.2	48.3
200	11.6	17.1	22.5	27.8	33.1	38.4	43.6	48.8
				SITE INDEX 35				
60	7.1	10.4	13.7	17.0	20.2	23.4	--	--
80	7.6	11.3	14.8	18.4	21.8	25.3	28.8	--
100	8.0	11.8	15.5	19.2	22.9	26.5	30.1	33.7
120	8.3	12.2	16.0	19.8	23.6	27.4	31.1	34.8
140	8.4	12.4	16.4	20.3	24.1	28.0	31.8	35.6
160	8.6	12.7	16.7	20.6	24.6	28.4	32.3	36.2
180	8.7	12.8	16.9	20.9	24.9	28.8	32.7	36.6
200	8.8	13.0	17.1	21.1	25.1	29.1	33.1	37.0
				SITE INDEX 25				
60	4.9	7.2	9.5	11.7	14.0	--	--	--
80	5.3	7.8	10.2	12.7	15.1	17.5	--	--
100	5.5	8.2	10.7	13.3	15.8	18.3	20.8	23.3
120	5.7	8.4	11.1	13.7	16.3	18.9	21.5	24.0
140	5.8	8.6	11.3	14.0	16.7	19.3	22.0	24.6
160	5.9	8.7	11.5	14.2	17.0	19.6	22.3	25.0
180	6.0	8.9	11.7	14.4	17.2	19.9	22.6	25.3
200	6.1	9.0	11.8	14.6	17.4	20.1	22.8	25.6

1/ Gross rough volume to a variable top d.i.b. of not less than 3.0 inches, based on table 5, Gevorkiantz and Olsen (1955).

Table 6. – Ten-year net basal area growth in square feet per acre on all sites of black spruce in Minnesota for trees 3.6 inches d.b.h. and larger (blocks indicate extent of basic data)

Stand age (years)	Stand basal area, square feet per acre							
	40	60	80	100	120	140	160	180
60	37.0	39.9	36.5	28.6	17.5	4.1	-11.1	--
80	28.2	32.2	31.5	27.0	19.5	9.7	- 2.1	--
100	23.1	27.5	28.2	25.8	20.8	13.7	4.7	- 5.9
120	19.8	24.3	25.9	24.9	21.7	16.6	9.8	1.5
140	17.4	22.0	24.2	24.3	22.4	18.9	13.8	7.3
160	15.7	20.3	22.9	23.7	22.9	20.6	17.7	12.1
180	14.4	19.0	21.9	23.3	23.3	22.1	19.7	16.1

Table 7. – Minnesota black spruce ten-year net total cubic foot growth per acre for trees 3.6 inches d.b.h. and larger

SITE INDEX 45

Stand age (years)	Stand basal area, square feet per acre							
	40	60	80	100	120	140	160	180
				Cubic feet per acre				
60	853	920	849	681	444	160	-162	--
80	668	759	744	644	477	261	1	--
100	556	657	673	617	504	343	140	- 98
120	482	587	623	598	524	406	250	60
140	428	535	585	586	541	459	340	190
160	388	497	557	574	554	499	430	299
180	358	467	534	566	564	535	477	392
				SITE INDEX 35				
60	732	783	728	583	381	137	-139	--
80	573	651	637	552	409	224	1	--
100	477	564	577	529	432	294	120	- 84
120	414	503	534	513	449	348	214	52
140	366	459	502	503	464	393	292	162
160	333	426	477	492	475	428	369	256
180	307	400	458	485	484	458	409	336
				SITE INDEX 25				
60	595	642	592	475	310	112	-113	--
80	466	529	519	449	333	182	1	--
100	388	459	469	431	351	239	98	- 69
120	336	409	434	418	365	283	174	42
140	298	373	408	409	377	320	237	132
160	271	346	388	400	386	348	300	209
180	250	326	373	395	394	373	333	274

basal area at any age is, partly at least, itself a function of site quality." Buckman (1962) cited several references where site index was nonsignificant and discussed the problems associated with relating site index to basal area growth. Both he and Clutter (1963) found considerable positive effect of site index on basal area growth of red pine and loblolly pine.

The projection of basal area with time (fig. 2) points out that Equation 7 provides a self-limiting maximum possible basal area density for any given age, which ranges from about 140 square feet at 60 years to about 210 square feet at 180 years. Also the growth curves are sigmoidal, which is most easily seen by following the lowest initial densities at age 60 and 80. Also the trend is evident for understocked stands to have higher growth rates and approach full stocking. All three of these characteristics are generally accepted principles of stand development and support this equation as a growth predictor for forest stands.

One characteristic of this equation is open to question, however. As stands closely approach the maximum basal area limit, there is a slight trend toward an increasing growth rate. This causes a small increase in periodic volume growth, as shown in tables 9 to 11. Whether this slight increase is real is doubtful. However, the effect is so small that it can be disregarded for all practical purposes.

Black spruce on organic soils has potential for accumulating growth even at very old ages. Fifteen of the study observations were in stands older than 160

Table 8. – Minnesota black spruce ten-year net cordwood growth per acre for trees 3.6 inches d.b.h. and larger

Stand age (Years)	Stand basal area, square feet per acre							
	40	60	80	100	120	140	160	180
				Cords per acre				
				SITE INDEX 45				
60	8.9	9.6	9.0	7.4	5.1	2.3	-0.8	--
80	7.1	8.1	8.0	7.0	5.3	3.1	.5	--
100	6.0	7.1	7.3	6.8	5.6	3.9	1.8	-0.6
120	5.3	6.4	6.8	6.6	5.8	4.6	2.9	.9
140	4.7	5.9	6.4	6.5	6.0	5.1	3.8	2.2
160	4.3	5.5	6.2	6.4	6.1	5.6	4.8	3.4
180	4.0	5.2	5.9	6.3	6.3	6.0	5.3	4.4
				SITE INDEX 35				
60	6.8	7.3	6.8	5.6	3.8	1.8	-0.6	--
80	5.4	6.2	6.1	5.3	4.0	2.4	.4	--
100	4.6	5.4	5.6	5.1	4.2	3.0	1.4	-0.5
120	4.0	4.9	5.2	5.0	4.4	3.4	2.2	.7
140	3.6	4.5	4.9	4.9	4.5	3.9	2.9	1.7
160	3.3	4.2	4.7	4.8	4.6	4.2	3.6	2.6
180	3.0	3.9	4.5	4.8	4.8	4.5	4.0	3.3
				SITE INDEX 25				
60	4.6	5.0	4.7	3.9	2.7	1.1	-0.4	--
80	3.7	4.2	4.2	3.7	2.8	1.6	.3	--
100	3.2	3.7	3.8	3.5	2.9	2.0	1.0	-0.3
120	2.8	3.4	3.6	3.4	3.0	2.4	1.5	.5
140	2.5	3.1	3.4	3.4	3.1	2.7	2.0	1.2
160	2.3	2.9	3.2	3.3	3.2	2.9	2.5	1.8
180	2.1	2.7	3.1	3.3	3.3	3.1	2.8	2.3

years, and only two had negative net growth (barely) over the measurement period. Whether this potential can be realized probably depends largely on wind-caused mortality (Heinselman 1957a) and the incidence and severity of butt rot (LeBarron 1948).

Tables 9 to 11 (column 5) show that ingrowth is an important source of total net merchantable growth for understocked black spruce in both young and old stands. The average periodic net annual per-acre basal area growth was 2.23 square feet. Of this, .58 square feet, or 26 percent, was due to ingrowth. The average periodic gross annual per-acre basal area growth was 2.79 square feet; .56 square feet, or 20 percent, was lost to mortality. Obviously, both ingrowth and mortality must be considered as important components of black spruce productivity.

SUMMARY

Equations have been developed and tables presented here for estimating growth and yield in total cubic feet and cords of the merchantable portion of black spruce stands growing on organic soils in northern Minnesota when basal area density, age, and site index are known. With this basic tool forest managers can more accurately forecast the productivity of black spruce stands growing on organic soils. This information can be valuable too in evaluating the potential of once-forested but now unproductive organic soils if something is known about black spruce site quality. It should be cautioned that growth and yield predictions should not be extrapolated beyond the range of values given here.

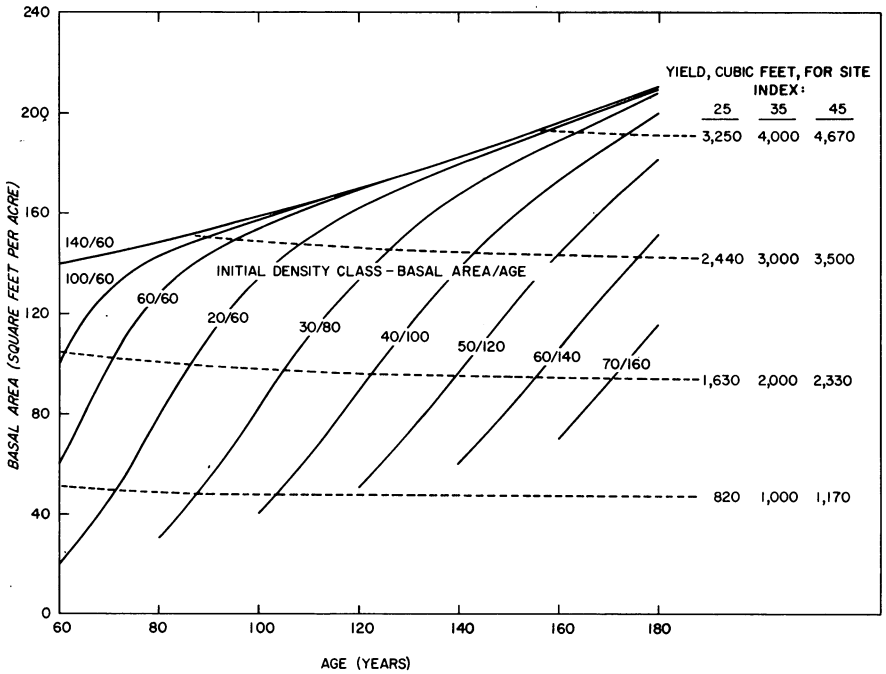

Figure 2. – Per-acre projected basal area and total cubic foot yield of trees 3.6 inches d.b.h. and larger for black spruce site indexes 25, 35, and 45. Example of use: Assume a present basal area of 96 square feet at age 140. The present yield is 1,630 cubic feet for site index 25 (2,000 and 2,330 cubic feet for site indexes 35 and 45, respectively). Assume we wish to project the stand 20 years. Follow the basal area growth curve to age 160. The projected basal area of 144 square feet is read off the left vertical scale and the projected yield is 2,440 cubic feet for site index 25 (3,000 and 3,500 cubic feet for site indexes 35 and 45).

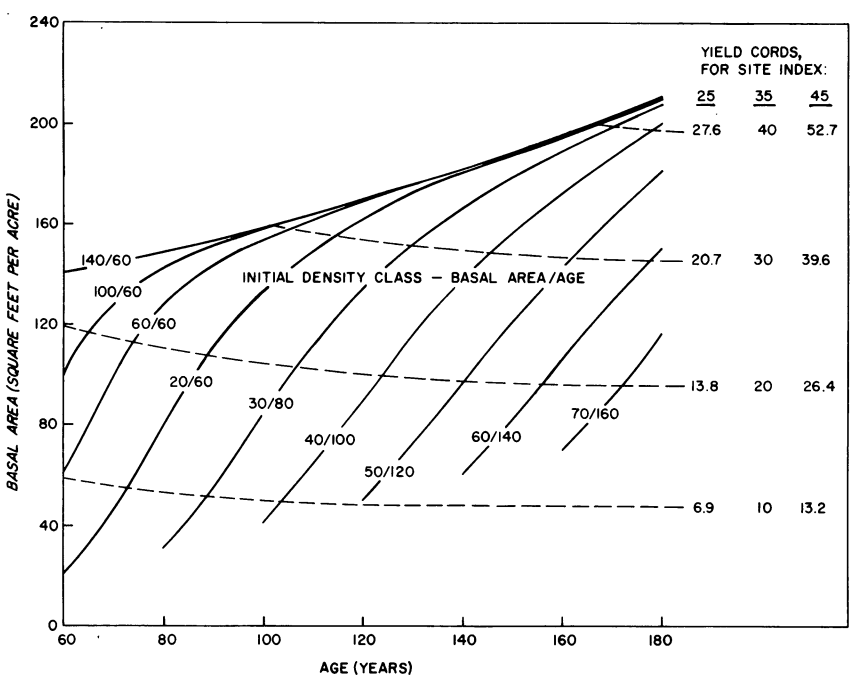

Figure 3. – Per-acre projected basal area and yield in cords for trees 3.6 inches d.b.h. and larger for black spruce site indexes 25, 35, and 45. For example of use, see figure 2.

Table 9. – Projected yield table for site index 45 black spruce in Minnesota by various initial densities and ages (all data are per acre for trees 3.6 inches d.b.h. and larger)

Total age (years)	Height of dominants and codominants	Basal area			Volume			Volume		
		Accumulated	10-year mortality	10-year ingrowth	Accumulated	Current annual increment	Mean annual increment	Accumulated	Current annual increment	Mean annual increment
	Feet	Square feet	Square feet	Square feet	Cubic feet	Cubic feet	Cubic feet	Cords	Cords	Cords
INITIAL BASAL AREA 20 AT AGE 60										
60	51	20.0	--	--	470	--	7.8	4.8	--	0.08
70	56	45.1	0.5	16.2	1,056	58.6	15.1	10.9	0.61	.16
80	60	78.6	1.5	19.4	1,839	78.3	23.0	19.2	.83	.24
90	64	110.3	3.1	14.7	2,587	74.8	28.7	27.3	.81	.30
100	67	133.8	4,9	6.2	3,152	56.5	31.5	33.5	.62	.34
110	69	149.9	6.6	.4	3,549	39.7	32.3	38.0	.45	.34
120	71	161.5	7.9	.0	3,842	29.3	32.0	41.3	.33	.34
130	73	170.7	9.1	.0	4,078	23.6	31.4	44.1	.28	.34
140	74	178.8	10.4	.0	4,288	21.0	30.6	46.6	.25	.33
150	76	186.6	11.4	.0	4,489	20.1	29.9	49.0	.24	.33
160	77	194.3	12.6	.0	4,687	19.8	29.3	51.3	.23	.32
170	78	202.2	13.7	.0	4,888	20.1	28.8	53.6	.23	.32
180	79	210.5	14.9	.0	5,098	21.0	28.3	56.1	.25	.31
INITIAL BASAL AREA 60 AT AGE 60										
60	51	60.0	--	--	1,361	--	22.7	13.7	--	.23
70	56	99.9	1.9	22.4	2,281	92.0	32.6	23.4	.97	.33
80	60	127.7	3.6	9.7	2,942	66.1	36.8	30.6	.72	.38
90	64	143.7	5.2	.5	3,342	40.0	37.1	35.1	.45	.39
100	67	153.8	6.5	.0	3,607	26.5	36.1	38.2	.31	.38
110	69	161.4	7.7	.0	3,812	20.5	34.6	40.7	.25	.37
120	71	168.2	8.7	.0	3,996	18.4	33.3	43.0	.23	.36
130	73	174.7	9.7	.0	4,171	17.5	32.1	45.1	.21	.35
140	74	181.4	10.6	.0	4,348	17.7	31.0	47.2	.21	.34
150	76	188.2	11.7	.0	4,526	17.8	30.2	49.4	.22	.33
160	77	195.4	12.6	.0	4,713	18.7	29.4	51.6	.22	.32
170	78	203.0	13.8	.0	4,907	19.4	28.9	53.8	.22	.32
180	79	211.0	15.0	.0	5,110	20.3	28.4	56.2	.24	.31
INITIAL BASAL AREA 100 AT AGE 60										
60	51	100.0	--	--	2,232	--	37.2	22.4	--	.37
70	56	128.6	3.1	10.0	2,913	68.1	41.6	29.8	.74	.42
80	60	142.6	4.7	.0	3,274	36.1	40.9	34.0	.42	.42
90	64	150.8	6.0	.0	3,502	22.8	38.9	36.8	.28	.41
100	67	157.3	6.9	.0	3,687	18.5	36.9	39.1	.23	.39
110	69	163.2	7.9	.0	3,853	16.6	35.0	41.2	.21	.37
120	71	169.2	8.8	.0	4,019	16.6	33.5	43.2	.20	.36
130	73	175.3	9.8	.0	4,185	16.6	32.2	45.2	.20	.35
140	74	181.7	10.7	.0	4,355	17.0	31.1	47.3	.21	.34
150	76	188.4	11.7	.0	4,531	17.6	30.2	49.4	.21	.33
160	77	195.6	12.6	.0	4,717	18.6	29.5	51.6	.22	.32
170	78	203.1	13.9	.0	4,909	19.2	28.9	53.9	.23	.32
180	79	211.0	15.1	.0	5,110	20.1	28.4	56.2	.23	.31
INITIAL BASAL AREA 140 AT AGE 60										
60	51	140.0	--	--	3,092	--	51.5	30.9	--	.52
70	56	144.1	4.0	.0	3,252	16.0	46.4	33.2	.23	.47
80	60	148.6	5.3	.0	3,408	15.6	42.6	35.3	.21	.44
90	64	153.5	6.2	.0	3,563	15.5	39.6	37.4	.21	.42
100	67	158.6	7.0	.0	3,716	15.3	37.2	39.4	.20	.39
110	69	163.9	8.0	.0	3,870	15.4	35.2	41.3	.19	.38
120	71	169.6	8.8	.0	4,028	15.8	33.6	43.3	.20	.36
130	73	175.6	9.8	.0	4,192	16.4	32.2	45.3	.20	.35
140	74	181.9	10.7	.0	4,360	16.8	31.0	47.4	.21	.34
150	76	188.6	11.7	.0	4,536	17.6	30.2	49.5	.21	.33
160	77	195.6	12.6	.0	4,717	18.1	29.5	51.6	.21	.32
170	78	203.2	13.9	.0	4,912	19.5	28.9	53.9	.23	.32
180	79	211.2	15.1	.0	5,115	20.3	28.4	56.3	.24	.31

Table 9.--Continued

INITIAL BASAL AREA 30 AT AGE 80

Total age (years)	Height of dominants and codominants	Basal area			Volume			Volume		
		Accumulated	10-year mortality	10-year ingrowth	Accumulated	Current annual increment	Mean annual increment	Accumulated	Current annual increment	Mean annual increment
	Feet	Square feet	Square feet	Square feet	Cubic feet	Cubic feet	Cubic feet	Cords	Cords	Cords
80	60	30.0	--	--	723	--	9.0	7.7	--	.10
90	64	54.0	1.0	14.1	1,295	57.2	14.4	13.8	.61	.15
100	67	82.8	2.1	15.1	1,980	68.5	19.8	21.2	.74	.21
110	69	110.9	3.5	11.8	2,650	67.0	24.1	28.5	.73	.26
120	71	134.3	5.5	6.4	3,213	56.3	26.8	34.7	.62	.29
130	73	152.6	7.2	1.4	3,659	44.6	28.1	39.6	.49	.30
140	74	166.8	9.0	.0	4,009	35.0	28.6	43.6	.40	.31
150	76	178.6	10.4	.0	4,303	29.4	28.7	47.0	.34	.31
160	77	188.9	11.8	.0	4,561	25.8	28.5	49.9	.29	.31
170	78	198.4	13.2	.0	4,799	23.8	28.2	52.7	.28	.31
180	79	207.8	14.5	.0	5,035	23.6	28.0	55.4	.27	.31
INITIAL BASAL AREA 40 AT AGE 100										
100	67	40	--	--	979	--	9.8	10.6	--	.11
110	69	63.1	1.5	12.3	1,535	55.6	14.0	16.6	.62	.15
120	71	89.2	2.7	12.2	2,162	62.7	18.0	23.4	.68	.20
130	73	115.0	4.2	9.8	2,782	62.0	21.4	30.2	.68	.23
140	74	137.9	6.1	6.0	3,334	55.2	23.8	36.4	.62	.26
150	76	157.2	8.1	2.2	3,802	46.8	25.3	41.6	.52	.28
160	77	173.4	9.9	.0	4,198	39.6	26.2	46.0	.44	.29
170	78	187.3	11.7	.0	4,539	34.1	26.7	49.9	.39	.29
180	79	199.6	13.5	.0	4,842	30.3	26.9	53.3	.34	.30
INITIAL BASAL AREA 50 AT AGE 120										
120	71	50	--	--	1,234	--	10.3	13.5	--	.11
130	73	72.4	2.1	10.8	1,777	54.3	13.7	19.4	.59	.15
140	74	97.0	3.2	10.3	2,371	59.4	16.9	26.0	.66	.18
150	76	121.4	5.0	8.4	2,960	58.9	19.7	32.5	.65	.22
160	77	143.9	7.0	5.6	3,504	54.5	21.9	38.5	.60	.24
170	78	164.0	9.0	1.8	3,991	48.7	23.5	43.9	.54	.26
180	79	181.6	11.0	.5	4,419	42.8	24.6	48.7	.48	.27
INITIAL BASAL AREA 60 AT AGE 140										
140	74	60	--	--	1,489	--	10.6	16.4	--	.12
150	76	82.0	2.6	9.6	2,024	53.5	13.5	22.3	.59	.15
160	77	105.6	4.0	8.9	2,596	57.2	16.2	28.6	.63	.18
170	78	129.3	5.8	7.4	3,170	57.4	18.6	35.0	.64	.20
180	79	151.8	7.9	5.3	3,714	54.4	20.6	41.0	.60	.23
INITIAL BASAL AREA 70 AT AGE 160										
160	77	70	--	--	1,744	--	10.9	19.3	--	.12
170	78	91.8	3.3	8.6	2,275	53.1	13.4	25.2	.59	.15
180	79	115.0	4.8	8.0	2,839	56.3	15.8	31.5	.63	.18

Table 10. – Projected yield table for site index 35 black spruce in Minnesota by various initial densities and ages (all data are per acre for trees 3.6 inches d.b.h. and larger)

Total age (years)	Height of dominants and codominants	Basal area			Volume			Volume		
		Accumulated	10-year mortality	10-year ingrowth	Accumulated	Current annual increment	Mean annual increment	Accumulated	Current annual increment	Mean annual increment
	Feet	Square feet	Square feet	Square feet	Cubic feet	Cubic feet	Cubic feet	Cords	Cords	Cords
INITIAL BASAL AREA 20 AT AGE 60										
60	40	20.0	--	--	402	--	6.7	3.6	--	0.06
70	43	45.1	0.5	16.2	905	50.3	12.9	8.3	0.47	.12
80	46	78.6	1.5	19.4	1,576	67.1	19.7	14.6	.63	.18
90	49	110.3	3.1	14.7	2,218	64.2	24.6	20.7	.61	.23
100	51	133.8	4.9	6.2	2,702	48.4	27.0	25.4	.47	.25
110	53	149.9	6.6	.4	3,042	34.0	27.6	28.8	.34	.26
120	55	161.5	7.9	.0	3,294	25.2	27.4	31.4	.26	.26
130	56	170.7	9.1	.0	3,496	20.2	26.9	33.5	.21	.26
140	58	178.8	10.4	.0	3,676	18.0	26.2	35.3	.18	.25
150	59	186.6	11.4	.0	3,848	17.2	25.6	37.1	.18	.25
160	60	194.3	12.6	.0	4,018	17.0	25.1	38.9	.18	.24
170	60	202.2	13.7	.0	4,191	17.3	24.6	40.7	.18	.24
180	61	210.5	14.9	.0	4,371	18.0	24.3	42.6	.19	.24
INITIAL BASAL AREA 60 AT AGE 60										
60	40	60.0	--	--	1,167	--	19.4	10.4	--	.17
70	43	99.9	1.9	22.4	1,955	78.8	27.9	17.7	.73	.25
80	46	127.7	3.6	9.7	2,522	56.7	31.5	23.2	.55	.29
90	49	143.7	5.2	.5	2,865	34.3	31.8	26.6	.34	.30
100	51	153.8	6.5	.0	3,092	22.7	30.9	29.0	.24	.29
110	53	161.4	7.7	.0	3,268	17.6	29.7	30.9	.19	.28
120	55	168.2	8.7	.0	3,426	15.8	28.6	32.6	.17	.27
130	56	174.7	9.7	.0	3,576	15.0	27.5	34.2	.16	.26
140	58	181.4	10.6	.0	3,728	15.2	26.6	35.8	.16	.26
150	59	188.2	11.7	.0	3,880	15.2	25.9	37.4	.16	.25
160	60	195.4	12.6	.0	4,040	16.0	25.2	39.1	.17	.24
170	60	203.0	13.8	.0	4,207	16.7	24.7	40.8	.17	.24
180	61	211.0	15.0	.0	4,381	17.4	24.3	42.6	.18	.24
INITIAL BASAL AREA 100 AT AGE 60										
60	40	100.0	--	--	1,914	--	31.9	17.0	--	.28
70	43	128.6	3.1	10.0	2,497	58.3	35.7	22.6	.56	.32
80	46	142.6	4.7	.0	2,807	31.0	35.1	25.8	.32	.32
90	49	150.8	6.0	.0	3,002	19.5	33.4	27.9	.21	.31
100	51	157.3	6.9	.0	3,160	15.8	31.6	29.6	.17	.30
110	53	163.2	7.9	.0	3,304	14.4	30.0	31.2	.16	.28
120	55	169.2	8.8	.0	3,446	14.2	28.7	32.8	.16	.27
130	56	175.3	9.8	.0	3,588	14.2	27.6	34.3	.15	.26
140	58	181.7	10.7	.0	3,734	14.6	26.7	35.9	.16	.26
150	59	188.4	11.7	.0	3,884	15.0	25.9	37.5	.16	.25
160	60	195.6	12.6	.0	4,044	16.0	25.3	39.2	.17	.24
170	60	203.1	13.9	.0	4,209	16.5	24.8	40.9	.17	.24
180	61	212.3	15.1	.0	4,381	17.2	24.5	42.9	.17	.24
INITIAL BASAL AREA 140 AT AGE 60										
60	40	140.0	--	--	2,651	--	44.2	23.4	--	.39
70	43	144.1	4.0	.0	2,788	13.7	39.8	25.2	.18	.36
80	46	148.6	5.3	.0	2,921	13.3	36.5	26.8	.16	.34
90	49	153.5	6.2	.0	3,054	13.3	33.9	28.4	.16	.32
100	51	158.6	7.0	.0	3,186	13.2	31.9	29.9	.15	.30
110	53	163.9	8.0	.0	3,317	13.1	30.2	31.4	.15	.28
120	55	169.6	8.8	.0	3,454	13.7	28.8	32.9	.15	.27
130	56	175.6	9.8	.0	3,594	14.0	27.6	34.4	.15	.26
140	58	181.9	10.7	.0	3,738	14.4	26.7	35.9	.15	.26
150	59	188.6	11.7	.0	3,888	15.0	25.9	37.5	.16	.25
160	60	195.6	12.6	.0	4,044	15.6	25.3	39.2	.17	.24
170	60	203.2	13.9	.0	4,211	16.7	24.8	40.9	.17	.24
180	61	211.2	15.1	.0	4,385	17.4	24.4	42.7	.18	.24

Table 10.--Continued

Total age (years)	Height of dominants and codominants	Basal area: Accumulated	Basal area: 10-year mortality	Basal area: 10-year ingrowth	Volume: Accumulated	Volume: Current annual increment	Volume: Mean annual increment	Volume: Accumulated	Volume: Current annual increment	Volume: Mean annual increment
	Feet	Square feet	Square feet	Square feet	Cubic feet	Cubic feet	Cubic feet	Cords	Cords	Cords
INITIAL BASAL AREA 30 AT AGE 80										
80	46	30.0	--	--	620	--	7.8	5.8	--	.07
90	49	54.0	1.0	14.1	1,110	49.0	12.3	10.4	.46	.12
100	51	82.8	2.1	15.1	1,698	58.8	17.0	16.0	.56	.16
110	53	110.9	3.5	11.8	2,272	57.4	20.6	21.6	.56	.20
120	55	134.3	5.5	6.4	2,755	48.3	23.0	26.3	.47	.22
130	56	152.6	7.2	1.4	3,137	38.2	24.1	30.1	.38	.23
140	58	166.8	9.0	.0	3,437	30.0	24.6	33.1	.30	.24
150	59	178.6	10.4	.0	3,687	25.0	24.6	35.6	.25	.24
160	60	188.9	11.8	.0	3,910	22.3	24.4	37.9	.23	.24
170	60	198.4	13.2	.0	4,114	20.4	24.2	40.0	.21	.24
180	61	207.8	14.5	.0	4,316	20.2	24.0	42.0	.20	.23
INITIAL BASAL AREA 40 AT AGE 100										
100	51	40.0	--	--	839	--	8.4	8.0	--	0.08
110	53	63.1	1.5	12.3	1,316	47.7	12.0	12.6	0.46	.11
120	55	89.2	2.7	12.2	1,853	53.7	15.4	17.8	.52	.15
130	56	115.0	4.2	9.8	2,385	53.2	18.3	22.9	.51	.18
140	58	137.9	6.1	6.0	2,858	47.3	20.4	27.6	.47	.20
150	59	157.2	8.1	2.2	3,260	40.2	21.7	31.5	.39	.21
160	60	173.4	9.9	.0	3,599	33.9	22.5	34.9	.34	.22
170	60	187.3	11.7	.0	3,891	29.2	22.9	37.8	.29	.22
180	61	199.6	13.5	.0	4,151	26.0	23.1	40.4	.26	.22
INITIAL BASAL AREA 50 AT AGE 120										
120	55	50.0	--	--	1,058	--	8.8	10.2	--	.08
130	56	72.4	2.1	10.8	1,523	46.5	11.7	14.8	.46	.11
140	58	97.0	3.2	10.3	2,033	51.0	14.5	19.7	.49	.14
150	59	121.4	5.0	8.4	2,538	50.5	16.9	24.6	.49	.16
160	60	143.9	7.0	5.6	3,004	46.6	18.8	29.2	.46	.18
170	60	164.0	9.0	1.8	3,421	41.7	20.1	33.3	.41	.20
180	61	181.6	11.0	.5	3,788	36.7	21.0	37.0	.37	.20
INITIAL BASAL AREA 60 AT AGE 140										
140	58	60.0	--	--	1,276	--	9.1	12.4	--	.09
150	59	82.0	2.6	9.6	1,735	45.9	11.6	16.9	.45	.11
160	60	105.6	4.0	8.9	2,226	49.1	13.9	21.7	.48	.14
170	60	129.3	5.8	7.4	2,718	49.2	16.0	26.6	.49	.16
180	61	151.8	7.9	5.3	3,184	46.6	17.7	31.1	.45	.17
INITIAL BASAL AREA 70 AT AGE 160										
160	60	70.0	--	--	1,495	--	9.3	14.7	--	.09
170	60	91.8	3.3	8.6	1,950	45.5	11.5	19.1	.44	.11
180	61	115.0	4.8	8.0	2,434	48.4	13.5	23.9	.48	.13

Table 11. – Projected yield table for site index 25 black spruce in Minnesota by various initial densities and ages (all data are per acre for trees 3.6 inches d.b.h. and larger)

Total age (years)	Height of dominants and codominants	Basal area			Volume			Volume		
		Accumulated	10-year mortality	10-year ingrowth	Accumulated	Current annual increment	Mean annual increment	Accumulated	Current annual increment	Mean annual increment
	Feet	Square feet	Square feet	Square feet	Cubic feet	Cubic feet	Cubic feet	Cords	Cords	Cords
INITIAL BASAL AREA 20 AT AGE 60										
60	28	20.0	--	--	328	--	5.5	2.5	--	0.04
70	31	45.1	0.5	16.2	736	40.8	10.5	5.7	0.32	.08
80	33	78.6	1.5	19.4	1,283	54.7	16.0	10.1	.44	.13
90	35	110.3	3.1	14.7	1,804	52.1	20.0	14.3	.42	.16
100	36	133.8	4.9	6.2	2,199	39.5	22.0	17.5	.32	.18
110	37	149.9	6.6	.4	2,476	27.7	22.5	19.9	.24	.18
120	38	161.5	7.9	.0	2,680	20.4	22.3	21.7	.18	.18
130	39	170.7	9.1	.0	2,845	16.5	21.9	23.1	.14	.18
140	40	178.8	10.4	.0	2,991	14.6	21.4	24.4	.13	.17
150	41	186.8	11.4	.0	3,132	14.1	20.9	25.6	.12	.17
160	42	194.3	12.6	.0	3,270	13.8	20.4	26.9	.13	.17
170	42	202.2	13.7	.0	3,410	14.0	20.0	28.1	.12	.16
180	43	210.5	14.9	.0	3,556	14.6	19.8	29.4	.13	.16
INITIAL BASAL AREA 60 AT AGE 60										
60	28	60.0	--	--	949	--	15.8	7.2	--	.12
70	31	99.9	1.9	22.4	1,591	64.2	22.7	12.2	.50	.17
80	33	127.7	3.6	9.7	2,052	46.1	25.6	16.0	.38	.20
90	35	143.7	5.2	.5	2,332	28.0	25.9	18.4	.24	.20
100	36	153.8	6.5	.0	2,516	18.4	25.2	20.0	.16	.20
110	37	161.4	7.7	.0	2,659	14.3	24.2	21.3	.13	.19
120	38	168.2	8.7	.0	2,788	12.9	23.2	22.5	.12	.19
130	39	174.7	9.7	.0	2,910	12.2	22.4	23.6	.11	.18
140	40	181.4	10.6	.0	3,033	12.3	21.7	24.8	.12	.18
150	41	188.2	11.7	.0	3,158	12.5	21.0	25.9	.11	.17
160	42	195.4	12.6	.0	3,288	13.0	20.6	27.0	.11	.17
170	42	203.0	13.8	.0	3,423	13.5	20.1	28.2	.12	.16
180	43	211.0	15.0	.0	3,565	14.2	19.8	29.4	.12	.16
INITIAL BASAL AREA 100 AT AGE 60										
60	28	100.0	--	--	1,557	--	26.0	11.7	--	.20
70	31	128.6	3.1	10.0	2,032	47.5	29.0	15.6	.39	.22
80	33	142.6	4.7	.0	2,284	25.2	28.6	17.8	.22	.22
90	35	150.8	6.0	.0	2,443	15.9	27.1	19.3	.15	.21
100	36	157.3	6.9	.0	2,572	12.9	25.7	20.5	.12	.20
110	37	163.2	7.9	.0	2,688	11.6	24.4	21.6	.11	.20
120	38	169.2	8.8	.0	2,804	11.6	23.4	22.6	.10	.19
130	39	175.3	9.8	.0	2,919	11.5	22.4	23.7	.11	.18
140	40	181.7	10.7	.0	3,038	11.9	21.7	24.8	.11	.18
150	41	188.4	11.7	.0	3,161	12.3	21.1	25.9	.11	.17
160	42	195.6	12.6	.0	3,291	13.0	20.6	27.0	.11	.17
170	42	203.1	13.9	.0	3,425	13.4	20.1	28.2	.12	.16
180	43	211.0	15.1	.0	3,565	14.0	19.8	29.4	.12	.16
INITIAL BASAL AREA 140 AT AGE 60										
60	28	140.0	--	--	2,157	--	36.0	16.2	--	.27
70	31	144.1	4.0	.0	2,269	11.2	32.4	17.4	.12	.25
80	33	148.6	5.3	.0	2,377	10.8	29.7	18.5	.11	.23
90	35	153.5	6.2	.0	2,485	10.8	27.6	19.6	.11	.22
100	36	158.6	7.0	.0	2,592	10.7	25.9	20.6	.10	.21
110	37	163.9	8.0	.0	2,699	10.7	24.5	21.7	.11	.20
120	38	169.6	8.8	.0	2,809	11.0	23.4	22.7	.10	.19
130	39	175.6	9.8	.0	2,924	11.5	22.5	23.7	.10	.18
140	40	181.9	10.7	.0	3,042	11.8	21.7	24.8	.11	.18
150	41	188.6	11.7	.0	3,164	12.2	21.1	25.9	.11	.17
160	42	195.6	12.6	.0	3,291	12.7	20.6	27.0	.11	.17
170	42	203.2	13.9	.0	3,426	13.5	20.2	28.2	.12	.16
180	43	211.2	15.1	.0	3,568	14.2	19.8	29.5	.13	.16

Table 11.--Continued

INITIAL BASAL AREA 30 AT AGE 80

Total age (years)	Height of dominants and codominants	Basal area			Volume			Volume		
		Accumulated	10-year mortality	10-year ingrowth	Accumulated	Current annual increment	Mean annual increment	Accumulated	Current annual increment	Mean annual increment
	Feet	Square feet	Square feet	Square feet	Cubic feet	Cubic feet	Cubic feet	Cords	Cords	Cords
80	33	30.0	--	--	505	--	6.3	4.0	--	.05
90	35	54.0	1.0	14.1	903	39.8	10.0	7.2	.32	.08
100	36	82.8	2.1	15.1	1,381	47.8	13.8	11.1	.39	.11
110	37	110.9	3.5	11.8	1,849	46.8	16.8	14.9	.38	.14
120	38	134.3	5.5	6.4	2,242	39.3	18.7	18.2	.33	.15
130	39	152.6	7.2	1.4	2,552	31.0	19.6	20.8	.26	.16
140	40	166.8	9.0	.0	2,797	24.5	20.0	22.8	.20	.16
150	41	178.6	10.4	.0	3,002	20.5	20.0	24.6	.18	.16
160	42	188.9	11.8	.0	3,182	18.0	20.0	26.2	.16	.16
170	42	198.4	13.2	.0	3,348	16.6	19.7	27.6	.14	.16
180	43	207.8	14.5	.0	3,512	16.4	19.5	29.0	.14	.16
INITIAL BASAL AREA 40 AT AGE 100										
100	36	40.0	--	--	683	--	6.8	5.5	--	0.06
110	37	63.1	1.5	12.3	1,071	38.8	9.7	8.7	0.32	.08
120	38	89.2	2.7	12.2	1,508	43.7	12.6	12.3	.36	.10
130	39	115.0	4.2	9.8	1,941	43.3	14.9	15.8	.35	.12
140	40	137.9	6.1	6.0	2,326	38.5	16.6	19.0	.32	.14
150	41	157.2	8.1	2.2	2,652	32.6	17.7	21.8	.28	.14
160	42	173.4	9.9	.0	2,928	27.6	18.3	24.1	.23	.15
170	42	187.3	11.7	.0	3,166	23.8	18.6	26.1	.20	.15
180	43	199.6	13.5	.0	3,378	21.2	18.8	27.9	.18	.16
INITIAL BASAL AREA 50 AT AGE 120										
120	38	50.0	--	--	861	--	7.2	7.1	--	.06
130	39	72.4	2.1	10.8	1,240	37.9	9.5	10.2	.31	.08
140	40	97.0	3.2	10.3	1,654	41.4	11.8	13.6	.34	.10
150	41	121.4	5.0	8.4	2,065	41.1	13.8	17.0	.34	.11
160	42	143.9	7.0	5.6	2,444	37.9	15.3	20.2	.32	.13
170	42	164.0	9.0	1.8	2,784	34.0	16.4	23.0	.28	.14
180	43	181.6	11.0	.5	3,082	29.8	17.1	25.5	.25	.14
INITIAL BASAL AREA 60 AT AGE 140										
140	40	60.0	--	--	1,039	--	7.4	8.6	--	.06
150	41	82.0	2.6	9.6	1,412	37.3	9.4	11.7	.31	.08
160	42	150.6	4.0	8.9	1,811	39.9	11.3	15.0	.33	.09
170	42	129.3	5.8	7.4	2,211	40.0	13.0	18.3	.33	.11
180	43	151.8	7.9	5.3	2,591	38.0	14.4	21.5	.32	.12
INITIAL BASAL AREA 70 AT AGE 160										
160	42	70.0	--	--	1,216	--	7.6	10.1	--	.06
170	42	91.8	3.3	8.6	1,587	37.1	9.3	13.2	.31	.08
180	43	115.0	4.8	8.0	1,980	39.3	11.0	16.5	.33	.09

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