GROWTH AND YIELD OF WELL - STOCKED WHITE SPRUCE STANDS IN ALASKA

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U.S. Forest Service
Research Paper PNW 53
1967

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INTRODUCTION

Normal yield tables are presented here for white spruce (*Picea glauca* (Moench) Voss) in interior Alaska. White spruce accounts for 64 percent of the commercial cubic-foot volume and 81 percent of the commercial board-foot volume of this region (Hutchison 1967).[1] These yield tables, like those prepared by Gregory and Haack (1965) for the two principal hardwoods, paper birch (*Betula papyrifera* Marsh.) and quaking aspen (*Populus tremuloides* Michx.), were prepared to show the range of sites in the interior and the effect of site on stand development. They also provide estimates of yield for the range of sites and ages found in the interior.

Although the many limitations of normal yield tables are recognized (Spurr 1952, pp. 260-261), they are of value for interior Alaska where well-stocked, even-aged stands are common and the forests are not being managed. Forests of the interior are, for the most part, inaccessible and little cutting has taken place except for limited local use near population centers. Intensive forest management is still many years off.

[1] *Names and dates in parentheses refer to Literature Cited on inside back cover.*

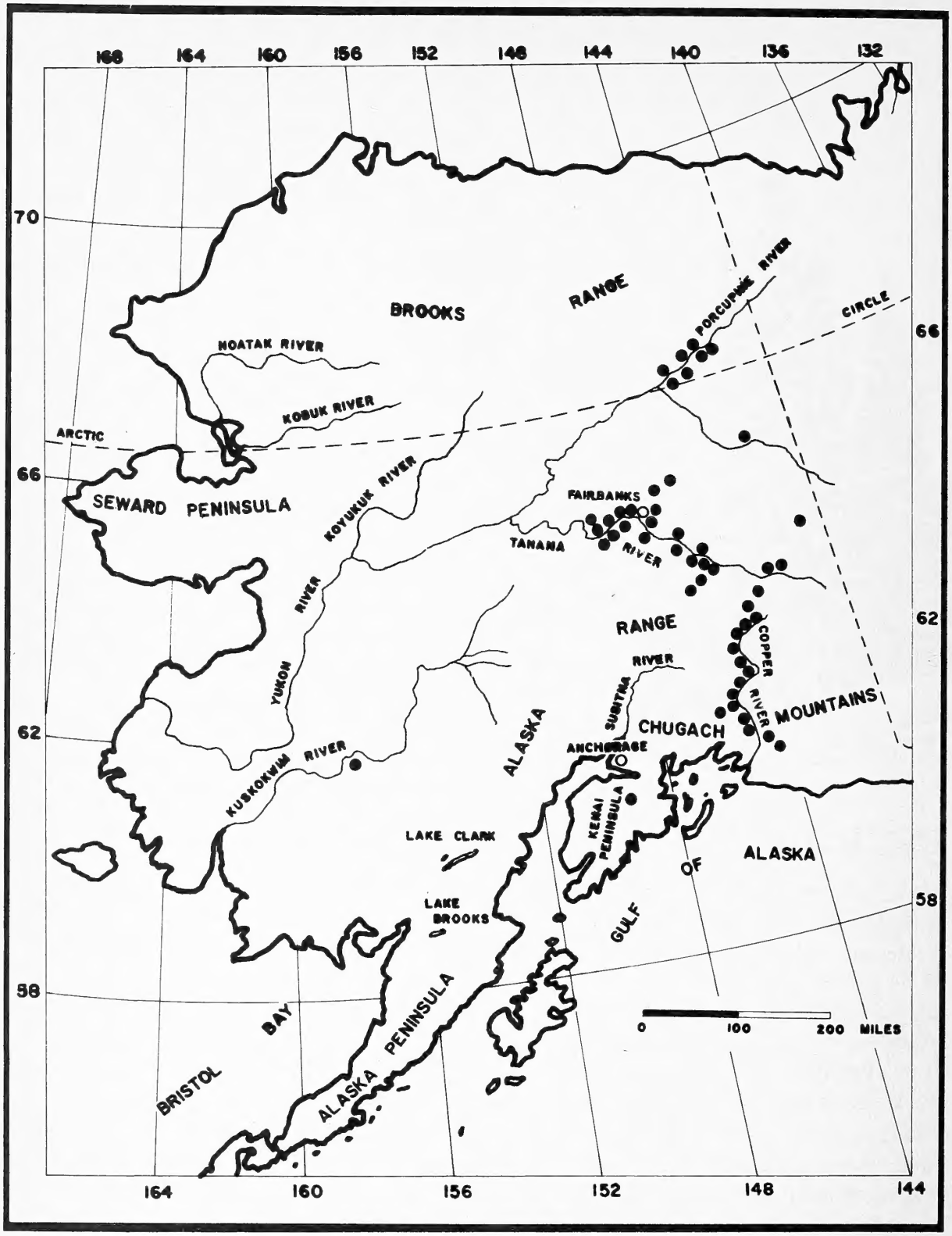

Figure 1. – Location of sample plots. Each black dot represents one or more temporary plots used in this study.

THE FOREST REGION

Alaska's interior comprises some 332,555,000 acres. Sixty-eight percent of this total consists of grassland, brush, swamps, tundra, barren rock, ice, and snow. The remaining 32 percent, or 106,000,000 acres, is forested (Hutchison 1967).

The interior forests are a westward extension of the boreal forests of Canada. Within Alaska, the forests extend westward to about 164° west longitude on the Seward Peninsula and as far north as the Brooks Range. The Chugach Mountains, bordering the Gulf of Alaska and Bristol Bay to the westward, form the southern boundary. The southern limit of forest types common to the interior is near Lake Brooks on the Alaska Peninsula, about latitude 58°N. (fig. 1).

GEOGRAPHY

Interior Alaska is characterized by rugged mountains and broad river valleys; the most prominent feature is the Alaska Range, which arcs northeasterly from near Lake Clark on the west to the St. Elias Range on the east. North of the Alaska Range the principal river valleys are those of the Noatak, Kobuk, Yukon, and Kuskokwim Rivers and their tributaries. The Koyukuk, Porcupine, and Tanana Rivers are tributaries of the Yukon River. South of the Alaska Range, the chief river valleys are those of the Susitna and Copper Rivers and their tributaries (fig. 1).

CLIMATE

Alaska's interior has a climate of extreme contrasts. Winter days are short and extremely cold, and summer days are long and mild. Annual precipitation, north of the Alaska Range and on the Copper River plateau to the south, averages 10 to 13 inches – low for a forested region. The summer months receive the heaviest rainfall – close to 2 inches a month (Watson 1959). Tree growth is greatest during June and July when the days are warm and daylight is nearly continuous. Most of this area is also within the zone of discontinuous permafrost, the occurrence of which tends to keep the water table near the soil surface.

South of the Alaska Range, the Susitna Valley and Kenai Peninsula have warmer winters, cooler summers, receive more precipitation (15 to 30 inches annually), and have fewer growing degree days than do areas to the north of the Range (Funsch 1964).

FORESTS

About 21 percent (22-1/2 million acres) of the interior's forested land is classified as commercial; that is, capable of producing at least 20 cubic feet of wood per acre annually. The remaining 79 percent (83 million acres) consists of sparse and stunted woodlands presently considered noncommercial (Hutchison 1967). White spruce, black spruce (*Picea mariana* (Mill.) B.S.P.), tamarack (*Larix laricina* (Du Roi) K. Koch), paper birch, quaking aspen, balsam poplar (*Populus balsamifera* L.), and black cottonwood (*P. trichocarpa* Torr. & Gray) are the native tree species.

White spruce is the most important forest type, covering 57 percent (12.8 million acres) of the commercial forest land. By comparison, paper birch accounts for 23 percent, aspen for 11 percent, and poplar and cottonwood for 9 percent of the commercial forest land (Hutchison 1967). Black spruce is abundant but rarely reaches commercial size. Tamarack occurs as a minor stand component on poorly drained, noncommercial sites north of the Alaska Range.

The interior forests are susceptible to destruction by fire. Low precipitation, high air temperatures, and long hours of sunshine during the summer increase the hazard of fire, especially in the uplands where natural barriers are few.

As a result of past fire history, the uplands typically are covered with dense, even-aged stands of paper birch and quaking aspen. Aspen is limited chiefly to southern exposures whereas birch predominates on northeast- and northwest-facing slopes (Gregory and Haack 1965). The colder north-facing slopes usually support poor stands of black spruce. Although white spruce occurs in pure, even-aged stands in the uplands below about 1,500 feet, most stands are located on moderately well drained soils of lowland sites adjacent to the rivers.

White spruce reaches its best development along the Tanana River and on the south-facing slopes of the Tanana-Yukon uplands. Site quality is generally poorer elsewhere (table 1). Dense spruce stands grow along the major rivers far north of the Arctic Circle, but their site index is low. For example, along the Porcupine River, sample plot trees seldom exceeded 70 feet in height and 12 inches diameter at breast height (d.b.h.); site index averaged 55 (table 1).

CHARACTERISTICS OF WHITE SPRUCE STANDS

White spruce is a hardy tree species that grows throughout interior Alaska on a variety of sites. Although its best development takes place near the base of slopes and on moderately well drained alluvial soils, its range does extend to the northern, western, and altitudinal limits of tree growth.

Above about 1,500 feet and at the limits of tree growth where there is little competition from hardwoods, white spruce develops in pure or nearly pure, sparsely stocked stands. At lower upland elevations, white spruce regenerates following fire both in pure stands and in mixture with the common hardwoods. The reasons for pure spruce stands at these lower upland elevations are not known. Possibly they develop if fire is severe enough to expose mineral soil, if seed is abundant, and if the area receives adequate moisture for germination and survival.

When the uplands regenerate to a spruce-hardwood mixture, the short-lived hardwoods initially outgrow the spruce and maintain an overstory position for 80 or more years until the hardwoods begin to die out. Only then does the spruce assume the dominant stand position.

Stream meanders, sloughs, wet muskegs, and the occurrence of many islands provide effective fire barriers for river-bottom sites. Because of this, ecological succession possibly accounts for most white spruce stands found growing on the wide alluvial flats of the major rivers, where soil erosion and deposition is active. Mature and overmature stands, 100 to 240 years old, occupy extensive areas along most of the major rivers.

Windthrow as an important cause of destruction of river-bottom stands seems unlikely. Periodic flooding over a hundred years deposits a foot or more of alluvium on the forest floor, and root systems become well anchored. Such river-bottom trees are more likely to be snapped off above the ground by strong winds than uprooted.

Pure stands of white spruce are typically well stocked although they often do not appear so. White spruce in Alaska is characteristically narrow crowned, and even the well-stocked stands do not have closed canopies. Crown cover seldom exceeds 50 to 70 percent.

By age 30 years at breast height, basal area of well-stocked stands will reach 126 square feet or more (table 4) in stands of 1,500 or more trees per acre (table 12). At theoretical rotation age (70-150 years, depending on site) 15 to 30 percent of the trees are sawtimber size (larger than 8.5 inches d.b.h.). Most trees are limby.

White spruce stands remain well stocked for 180 years or more. As the mature trees die and openings appear, brush species, principally Sitka alder (*Alnus sinuata* (Reg.) Rydb.) become established. Remnant spruce may live for 350 years or more. The oldest trees found during this study were along the Tanana River near Fairbanks – they were 329 years old at breast height.

Unless fire again reclaims the site after a stand reaches maturity, a thick insulating layer of organic material accumulates on the soil surface; underlying soils thaw later in the growing season, or may even remain permanently frozen, causing site quality to decrease with time.

GROWTH AND YIELD

TERMS AND MEASURES

Age. – Average breast-height age of the tallest white spruce trees, provided they are not remnants of an earlier stand.

Breast-height age was used because early height development is slow and total age is difficult to determine accurately, particularly in the case of river-bottom stands where alluvial deposits of 1 foot or more may accumulate over the rotation of the stand. Also, decay at ground level in the older stands obscured the annual rings.

Height. – Total height from ground to tip of the tallest tree on a 1/4-acre plot, provided the tree is of average stand age.

Site index. – Height of the tallest tree on a 1/4-acre plot at index age 100 years.

Volume. – Cubic-foot volumes per acre to different merchantability standards, computed with tree volume equations published by Gregory and Haack (1964). Merchantability standards are given in the table headings (tables 17 through 22).

International 1/4-inch board-foot volumes per acre were computed from a tree volume equation (Farr 1967) derived from the same basic data used to develop cubic-foot volume tables (Gregory and Haack 1964). Board-foot volumes per acre are given for trees larger than 8.5 inches, from a 1-foot stump to a 6-inch top inside bark.

Mean annual increment. – Determined by dividing present volume (table 17) by present age. The age of culmination of mean annual increment is the theoretical rotation age. Volume of all trees larger than 4.5 inches d.b.h. is measured in cubic feet from a 1-foot stump to a 4-inch top inside bark.

BASIC DATA

Ninety-nine yield plots were sampled; 97 of these were distributed over the eastern interior, and two were measured along the Kuskokwim River near McGrath (fig. 1). Most of the plots were one-quarter acre in size. Some 1/10- and 1/20-acre plots were used in young stands, and nine 1/3-acre plots were used in older stands on the best sites to insure that at least 100 trees were measured per plot. On 20 of the 1/4-acre plots, the four to six tallest trees were felled and sectioned for height-age determinations to be used in construction of site-index curves.

Table 2 summarizes the distribution of yield plots by age and site index. Well-stocked white spruce stands of site index less than 50 or greater than 100 are rare occurrences in the interior. The four plots in the less than 50 site index class in table 2 were sampled from along the Porcupine River north of the Arctic Circle.

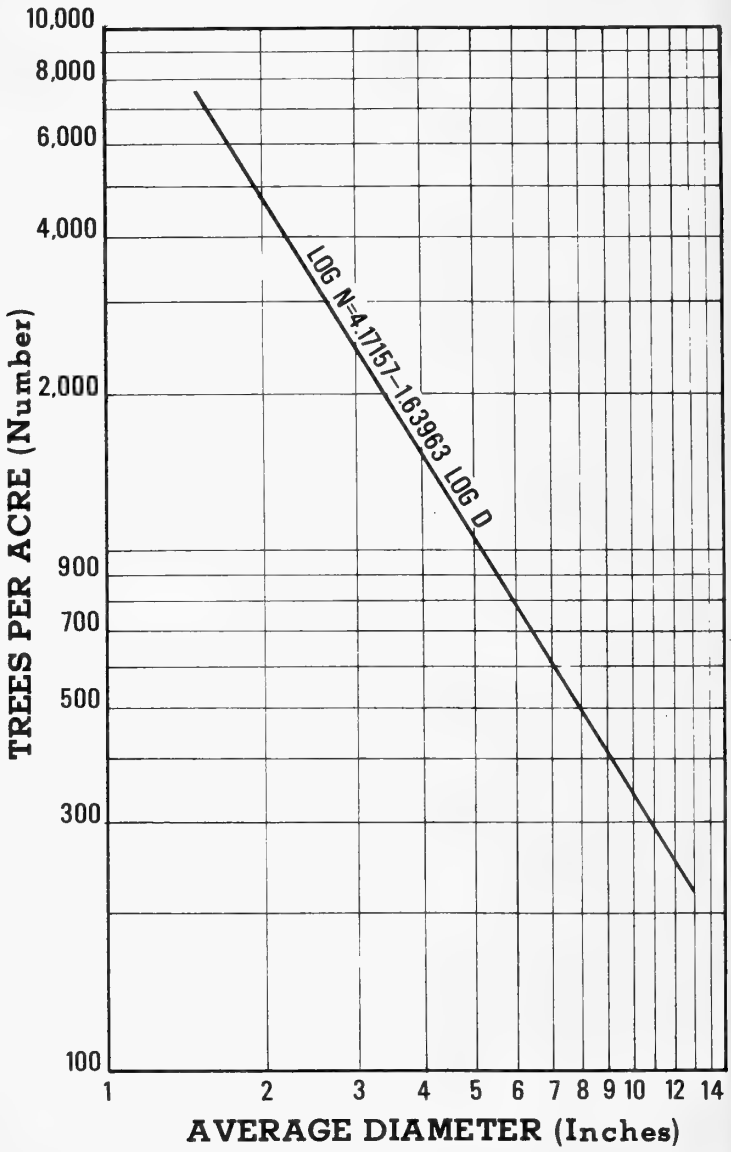

Figure 2. – Relationship of number of white spruce trees per acre and average stand diameter; trees larger than 0.5 inch.

The two plots with site quality greater than 100 were sampled from along the Tanana River about 120 miles east of Fairbanks.

An expression of stocking based on the sample data is shown in figure 2.

Data taken on each plot included:

1. Diameter at breast height of all live trees larger than 0.5 inch, by 1-inch classes.

2. Enough total-height measurements (10 to 20) to construct a reliable height-diameter curve.

3. Breast-height age of at least the six tallest white spruce per plot.

4. A description of the plot including latitude, longitude, aspect, slope, and elevation.

ANALYSES

Site index. – The method of Johnson and Worthington (1963) was used to derive the equation:

White spruce site index = height (0.49638+50.36166/age). Solution of the equation is shown graphically in figure 3 and numerically in table 3. Realignment of the axes, with height as the dependent variable, provides the more traditional solutions (fig. 4, table 4).

Because relative height of the four to six tallest trees per plot shifted with time, Dahms' (1963) method of using the tallest tree at any given stand age was used.

Yield estimates. – Equations to estimate basal area per acre, basal area of the average tree, and volumes per acre (tables 5 through 22) were derived by stepwise regression (Dixon 1965). The basic equation used was:

$$Y_i = b_{i0} + b_{i1}A + b_{i2}A^2 + b_{i3}A^3 + b_{i4}S + b_{i5}S^2 + b_{i6}S^3 + b_{i7}SA + b_{i8}S^2A + b_{i9}SA^2 + b_{i10}S^2A^2 + b_{i11}1/A$$

where:

Y_1 = Basal area per acre for trees larger than 0.5 inch d.b.h.

Y_2 = Basal area per acre for trees larger than 4.5 inches d.b.h.

Y_3 = Basal area per acre for trees larger than 6.5 inches d.b.h.

Y_4 = Basal area per acre for trees larger than 8.5 inches d.b.h.

Y_5 = Average basal area of trees larger than 0.5 inch d.b.h.

Y_6 = Average basal area of trees larger than 4.5 inches d.b.h.

Y_7 = Average basal area of trees larger than 6.5 inches d.b.h.

Y_8 = Average basal area of trees larger than 8.5 inches d.b.h.

Y_9 = Cubic-foot volume per acre for trees larger than 4.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark.

Y_{10} = Cubic-foot volume per acre for trees larger than 6.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark.

Y_{11} = Cubic-foot volume per acre for trees larger than 6.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark.

Y_{12} = Cubic-foot volume per acre for trees larger than 8.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark.

Y_{13} = Cubic-foot volume per acre for trees larger than 8.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark.

Y_{14} = International 1/4-inch board-foot volume per acre for trees larger than 8.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark.

A = Breast-height stand age.

S = Site index.

b_{ij} = Regression constants.

Quadratic mean diameters[2] (diameters of trees of mean basal area) corresponding to Y_5 through Y_8 were calculated.

The average number of trees per acre, N_i, was estimated by solving:

$N_1 = Y_1/Y_5$, $N_2 = Y_2/Y_6$, $N_3 = Y_3/Y_7$, and $N_4 = Y_4/Y_8$

For some combinations of site index and age, the equations for computing partial stand basal area (Y_2, Y_3, and Y_4) give higher values than can be expected for the entire stand (Y_1). Statistically, this is reasonable because the equations were derived independently, by use of stepwise regression. In nature, however, such a condition does not exist. Where the computed Y_2, Y_3, or Y_4 values were higher than those computed for Y_1, the Y_1 values were used. The age at which merging of the equations occurs is given for each site class in tables 6, 7, and 8. Merging ages were computed by setting the equations equal to each other and solving. Merging also occurred between cubic-foot equations Y_9 and Y_{10}.

Equations for calculating tabular values and merging points, and the precision of them in terms of the multiple coefficient of determination (R^2), are given as footnotes to the tables.

Diameter frequencies. – A graphical method of constructing stand tables described by Meyer (1937,

[2] *Curtis, Robert O. Which average diameter? 1967. (In press, J. Forest.)*

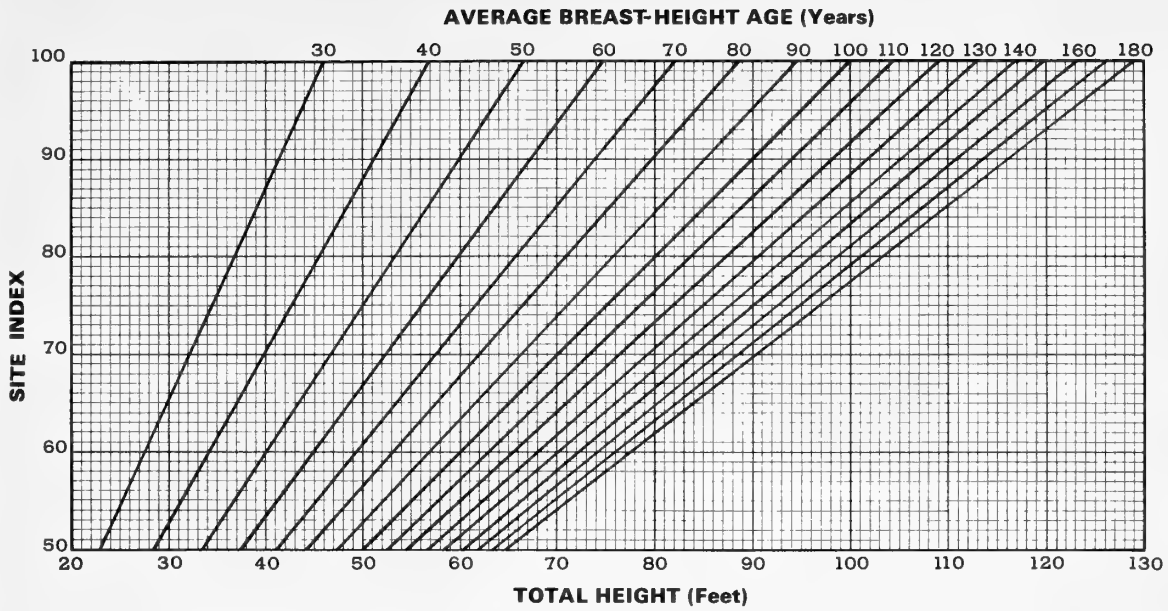

Figure 3. – Site index for white spruce, by breast-height age and height of the tallest white spruce tree per one-fourth acre.

pp. 84-85) was used to develop table 24 which shows, by average stand diameter, the percentage of trees in each 1-inch diameter class. Table 24 may be used with tables 9 and 13 to estimate the number of trees in each diameter class for any site-age combination.

Mean annual increment. – Table 23, which shows mean annual increment per acre for trees larger than 4.5 inches d.b.h., was prepared by dividing the cubic-foot volume by age for each site-age combination in table 17. The age of culmination of mean annual increment is the theoretical rotation age. Sites capable of producing at least 20 cubic feet per acre per year are classified as commercial forest land by Forest Survey; stands producing less are considered noncommercial. An area of site quality 63 would, therefore, be borderline between commercial and noncommercial forest land.

ESTIMATING SITE INDEX

For any white spruce stand that is at least moderately well stocked, site index can be determined by measuring total height of the tallest white spruce tree (per one-quarter acre) of average stand age and estimating breast-height stand age. Stand age must be found by averaging the breast-height age of at least the six tallest white spruce trees per one-quarter acre.

A site index system based on the height of the tallest individual in a stand is easy to apply – an important consideration in comparison with some of the more complicated systems that require 10 to 20 heights of dominants and codominants or dominants alone. Even though the use of more individuals may show a reduction in estimation error, the increase in precision may be small. Dahms (1966) found this to be true of lodgepole pine on the pumice soils of eastern Oregon. The problem encountered in using site index curves based on average height of dominant and codominant trees is that invariably the fieldman will measure heights of just the better dominants.

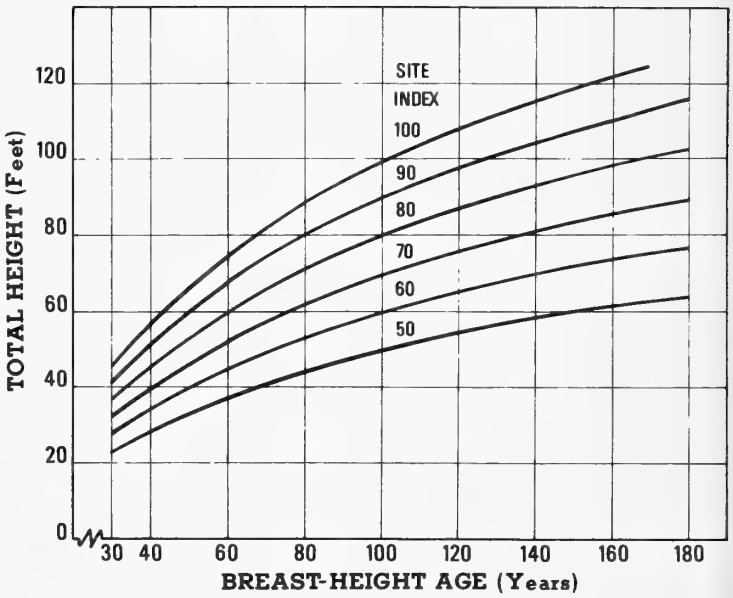

Figure 4. – Height of the tallest white spruce tree per one-fourth acre, by breast-height age and site index.

Table 1. – Site index and number of sample plots by geographical location[1]

Area	No. of plots	Minimum and maximum site index	Average site index
Porcupine River	10	41 – 64	55
Tanana River uplands between Fairbanks and Nenana	12	71 – 100	84
Tanana River:			
West of Fairbanks	10	73 – 94	82
East of Fairbanks	20	73 – 106	90
Copper River plateau:			
North of Glennallen	7	54 – 85	70
South of Glennallen	14	50 – 64	58

[1] *16 of the 99 plots sampled in this study are not included in the table. They were distributed singly or in pairs in other areas of the interior.*

Table 2. – Distribution of white spruce sample plots by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)							Total
	<50	51-60	61-70	71-80	81-90	91-100	>100	
	Number of plots							
31 – 50	0	0	2	2	2	3	1	10
51 – 70	0	0	2	2	2	0	0	6
71 – 90	0	5	1	3	4	1	0	14
91 – 110	0	4	3	7	1	2	1	18
111 – 130	0	1	1	6	1	3	0	12
131 – 150	0	2	3	2	4	2	0	13
151 – 170	2	4	1	3	2	2	0	14
171+	2	4	1	2	3	0	0	12
Total	4	20	14	27	19	13	2	99

Table 3. – Site index for white spruce, by breast-height age and height of the tallest tree, interior Alaska[1]

Breast-height age (years)	Total height (feet)																				
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125
	Feet																					
30	44	54	65	76	87	98	109	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
35	—	48	58	68	77	87	97	106	—	—	—	—	—	—	—	—	—	—	—	—	—	—
40	—	—	53	61	70	79	88	96	105	—	—	—	—	—	—	—	—	—	—	—	—	—
45	—	—	48	56	65	73	81	89	97	105	—	—	—	—	—	—	—	—	—	—	—	—
50	—	—	45	53	60	68	75	83	90	98	105	—	—	—	—	—	—	—	—	—	—	—
55	—	—	—	49	56	64	71	78	85	92	99	106	—	—	—	—	—	—	—	—	—	—
60	—	—	—	47	53	60	67	73	80	87	93	100	107	—	—	—	—	—	—	—	—	—
65	—	—	—	—	51	57	64	70	76	83	89	95	102	—	—	—	—	—	—	—	—	—
70	—	—	—	—	49	55	61	67	73	79	85	91	97	103	—	—	—	—	—	—	—	—
75	—	—	—	—	47	53	58	64	70	76	82	88	93	99	105	—	—	—	—	—	—	—
80	—	—	—	—	—	51	56	62	67	73	79	84	90	96	101	—	—	—	—	—	—	—
85	—	—	—	—	—	49	54	60	65	71	76	82	87	93	98	103	—	—	—	—	—	—
90	—	—	—	—	—	48	53	58	63	69	74	79	84	90	95	100	106	—	—	—	—	—
95	—	—	—	—	—	46	51	56	62	67	72	77	82	87	92	98	103	—	—	—	—	—
100	—	—	—	—	—	—	50	55	60	65	70	75	80	85	90	95	100	105	—	—	—	—
105	—	—	—	—	—	—	49	54	59	63	68	73	78	83	88	93	98	102	—	—	—	—
110	—	—	—	—	—	—	48	52	57	62	67	72	76	81	86	91	95	100	105	—	—	—
115	—	—	—	—	—	—	47	51	56	61	65	70	75	79	84	89	93	98	103	—	—	—
120	—	—	—	—	—	—	46	50	55	60	64	69	73	78	82	87	92	96	101	105	—	—
125	—	—	—	—	—	—	—	49	54	58	63	67	72	76	81	85	90	94	99	103	—	—
130	—	—	—	—	—	—	—	49	53	57	62	66	71	75	80	84	88	93	97	102	—	—
135	—	—	—	—	—	—	—	48	52	56	61	65	70	74	78	83	87	91	96	100	104	—
140	—	—	—	—	—	—	—	47	51	56	60	64	68	73	77	81	86	90	94	98	103	—
145	—	—	—	—	—	—	—	46	51	55	59	63	67	72	76	80	84	89	93	97	101	105
150	—	—	—	—	—	—	—	—	50	54	58	62	67	71	75	79	83	87	92	96	100	104
155	—	—	—	—	—	—	—	—	49	53	57	62	66	70	74	78	82	86	90	94	99	103
160	—	—	—	—	—	—	—	—	49	53	57	61	65	69	73	77	81	85	89	93	97	101
165	—	—	—	—	—	—	—	—	48	52	56	60	64	68	72	76	80	84	88	92	96	100
170	—	—	—	—	—	—	—	—	48	52	55	59	63	67	71	75	79	83	87	91	95	99
175	—	—	—	—	—	—	—	—	47	51	55	59	63	67	71	74	78	82	86	90	94	98
180	—	—	—	—	—	—	—	—	46	50	54	58	62	66	70	74	78	81	85	89	93	97

[1] *Tabular values derived from the equation: $S = H(0.49638 + 50.36166A)$.*

where: S = site index
H = height of the tallest white spruce per one-fourth acre
A = average breast-height age of at least the six tallest white spruce trees.

Table 4. – Height of tallest white spruce, by breast-height age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Feet					
30	23	28	32	37	41	46
40	28	34	40	46	51	57
50	33	40	47	53	60	66
60	37	45	52	60	67	75
70	41	49	58	66	74	82
80	44	53	62	71	80	89
90	47	57	66	76	85	95
100	50	60	70	80	90	100
110	52	63	73	84	94	105
120	55	65	76	87	98	109
130	57	68	79	91	102	113
140	58	70	82	93	105	117
150	60	72	84	96	108	120
160	62	74	86	99	111	123
170	63	76	88	101	114	—
180	64	77	90	103	116	—

[1] *Tabular values were derived from the equation:*

$$H = \frac{S}{0.49638 + 50.36166/A}$$

where: H = *height of the tallest white spruce per one-fourth acre*
S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

Table 5 – Basal area per acre of white spruce larger than 0.5 inch d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Square feet					
30	126	128	130	133	136	139
40	127	130	133	137	141	145
50	129	132	136	141	146	151
60	130	134	139	144	151	158
70	132	136	142	148	156	164
80	133	139	145	152	160	170
90	135	141	148	156	165	176
100	136	143	151	160	170	182
110	138	145	154	164	175	188
120	139	147	157	168	180	194
130	141	150	160	171	185	200
140	142	152	163	175	190	206
150	144	154	166	179	195	212
160	145	156	169	183	200	218
170	147	158	172	187	204	--
180	148	160	175	191	209	--

Basal area = 121.28 + 0.00006036 S^2A

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.445$ *Basis, number of plots = 99*

Table 6. – Basal area per acre of white spurce larger than 4.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Square feet					
30	49	54	60	65	71	77
40	57	64	72	79	86	93
50	65	74	83	91	100	109
60	72	83	93	103	114	124
70	79	91	103	115	126	138
80	86	99	112	125	138	151
90	92	106	120	135	149	163
100	98	113	128	144	159	174
110	103	119	136	152	168	185
120	107	125	142	159	177	194
130	112	130	148	166	184	200
140	115	134	153	172	190	206
150	119	138	158	177	195	212
160	122	142	162	182	200	218
170	124	145	165	186	204	––
180	126	147	168	189	209	––
	Years					
Merging Age	––	––	––	––	132	119

Below merging age: Basal area = 20.89 – (46.018 SA^2 – 19949 SA)10^{-6}

where: S = site index
A = average breast-height age of at least the six tallest white spruce trees.

R^2 = 0.659 Basis, number of plots = 99

Above merging age: same as table 5.

Merging age: 100.39 + (60.36 S^2A – 46.018 SA^2 – 19949 SA)10^{-6} = 0 for site index 83 and higher.

Table 7. – Basal area per acre of white spruce larger than 6.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Square feet					
30	––	––	––	––	12	20
40	8	14	20	28	37	47
50	20	27	36	45	56	69
60	29	38	48	60	73	88
70	36	46	58	72	88	105
80	43	54	68	84	101	121
90	48	61	77	94	114	137
100	54	68	85	105	127	152
110	58	74	93	115	139	167
120	63	80	101	124	151	181
130	67	86	108	134	163	195
140	72	92	116	143	174	206
150	76	97	123	152	186	212
160	80	103	130	162	197	218
170	84	108	137	171	204	––
180	87	113	144	180	209	––
	Years					
Merging age	––	––	––	––	164	136

Below merging age: Basal area = 38.01 + 0.0001313 S^2A – 1729.7/A

where: S = site index
A = average breast-height age of at least the six tallest white spruce trees.

R^2 = 0.744 Basis, number of plots = 98

Above merging age: same as table 5.

Merging age: 83.27 – (71 S^2A)10^{-6} + 1729.7/A = 0

Table 8. – Basal area per acre of white spruce larger than 8.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Square feet					
30	––	––	––	––	1	10
40	––	––	––	3	14	27
50	––	––	1	14	28	43
60	––	––	9	24	41	60
70	––	2	17	35	54	76
80	––	8	25	45	67	92
90	––	14	33	56	81	109
100	2	20	42	66	94	125
110	6	26	50	77	107	142
120	10	32	58	87	121	158
130	14	38	66	98	134	174
140	19	44	74	108	147	191
150	23	50	82	119	160	207
160	27	56	90	129	174	218
170	31	62	98	140	187	––
180	35	67	106	150	200	––
	Years					
Merging age	––	––	––	––	––	155

Below merging age: Basal area = -38.89 + 0.000164 S^2A

where: S = site index
A = average breast-height age of at least the six tallest white spruce trees.

R^2 = 0.821 Basis, number of plots = 89

Above merging age: same as table 5.

Merging age = $1545446/S^2$

Table 9. – Quadratic mean diameter of white spruce larger than 0.5 inch d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Inches					
30	2.6	2.8	3.1	3.4	3.7	4.0
40	2.8	3.1	3.5	3.9	4.3	4.7
50	3.0	3.4	3.8	4.3	4.8	5.3
60	3.2	3.6	4.2	4.7	5.3	5.9
70	3.3	3.9	4.5	5.2	5.8	6.4
80	3.5	4.2	4.9	5.6	6.3	7.0
90	3.7	4.5	5.2	6.0	6.8	7.6
100	3.9	4.7	5.6	6.4	7.3	8.2
110	4.1	5.0	5.9	6.9	7.8	8.8
120	4.3	5.3	6.3	7.3	8.3	9.3
130	4.5	5.6	6.6	7.7	8.8	9.9
140	4.7	5.8	7.0	8.1	9.3	10.4
150	4.9	6.1	7.3	8.5	9.8	11.0
160	5.1	6.4	7.6	9.0	10.3	11.6
170	5.3	6.6	8.0	9.4	10.8	––
180	5.4	6.9	8.3	9.8	11.2	––

Basal area of average tree = $[2068800 + 17.794\ S^2A + 0.25688\ S^2A^2 - 0.9056\ SA^2]\ 10^{-8}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.884$ *Basis, number of plots = 99*

Table 10. – Quadratic mean diameter of white spruce larger than 4.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Inches					
30	5.2	5.3	5.4	5.6	5.8	6.0
40	5.3	5.4	5.6	5.9	6.1	6.4
50	5.3	5.6	5.8	6.1	6.5	6.8
60	5.4	5.7	6.0	6.4	6.8	7.2
70	5.5	5.8	6.2	6.7	7.2	7.7
80	5.6	6.0	6.5	7.0	7.6	8.1
90	5.7	6.2	6.7	7.3	7.9	8.6
100	5.8	6.3	6.9	7.6	8.3	9.1
110	5.9	6.5	7.2	7.9	8.7	9.5
120	6.0	6.6	7.4	8.2	9.1	10.0
130	6.0	6.8	7.7	8.6	9.5	10.5
140	6.1	7.0	7.9	8.9	9.9	11.0
150	6.2	7.2	8.2	9.2	10.4	11.5
160	6.3	7.3	8.4	9.6	10.8	12.0
170	6.4	7.5	8.7	9.9	11.2	—
180	6.5	7.7	9.0	10.3	11.6	—

Basal area of average tree = $[13252000 + 16.542\ S^2A + 0.27128\ S^2A^2 - 11.995\ SA^2]\ 10^{-8}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.889$ *Basis, number of plots = 99*

Table 11. – Quadratic mean diameter of white spruce larger than 6.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Inches					
30	––	––	––	––	7.0	7.3
40	––	––	6.7	7.1	7.4	7.8
50	––	6.7	7.0	7.4	7.8	8.2
60	6.5	6.8	7.2	7.7	8.2	8.7
70	6.6	7.0	7.5	8.0	8.5	9.1
80	6.7	7.2	7.7	8.3	8.9	9.5
90	6.9	7.4	8.0	8.6	9.2	9.8
100	7.0	7.6	8.2	8.8	9.5	10.2
110	7.1	7.7	8.4	9.1	9.8	10.6
120	7.3	7.9	8.6	9.3	10.1	10.9
130	7.4	8.1	8.8	9.6	10.4	11.2
140	7.5	8.2	9.0	9.8	10.7	11.5
150	7.6	8.4	9.2	10.1	11.0	11.9
160	7.8	8.5	9.4	10.3	11.2	12.2
170	7.9	8.7	9.6	10.5	11.5	––
180	8.0	8.9	9.8	10.7	11.7	––

Basal area of average tree = $[1689800 + 3.9936\ S^2A]\ 10^{-7}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.858$ *Basis, number of plots* = 98

Table 12. – Quadratic mean diameter of white spruce larger than 8.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Inches					
30	––	––	––	––	8.8	9.0
40	––	––	––	8.9	9.1	9.3
50	––	––	8.8	9.1	9.4	9.7
60	––	––	9.0	9.3	9.6	10.0
70	––	8.8	9.2	9.5	9.9	10.3
80	––	9.0	9.3	9.7	10.1	10.6
90	––	9.1	9.5	9.9	10.4	10.9
100	8.8	9.2	9.6	10.1	10.6	11.2
110	8.9	9.3	9.8	10.3	10.8	11.4
120	9.0	9.4	9.9	10.5	11.1	11.7
130	9.1	9.6	10.1	10.7	11.3	12.0
140	9.2	9.7	10.2	10.9	11.5	12.2
150	9.3	9.8	10.4	11.0	11.7	12.5
160	9.3	9.9	10.5	11.2	12.0	12.7
170	9.4	10.0	10.7	11.4	12.2	––
180	9.5	10.1	10.8	11.6	12.4	––

Basal area of average tree = $[3408300 + 3.3832\ S^2 A]\ 10^{-7}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.769$ *Basis, number of plots = 89*

Table 13. – Average number of white spruce per acre larger than 0.5 inch d.b.h., by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Number					
30	3,512	2,944	2,480	2,101	1,806	1,566
40	3,060	2,477	2,034	1,687	1,427	1,228
50	2,706	2,127	1,705	1,395	1,170	1,002
60	2,403	1,844	1,454	1,182	985	840
70	2,160	1,621	1,262	1,020	846	721
80	1,946	1,440	1,112	892	739	629
90	1,771	1,289	986	789	654	556
100	1,620	1,164	885	706	584	497
110	1,488	1,058	800	637	527	449
120	1,374	969	728	578	479	409
130	1,272	888	666	529	438	374
140	1,186	819	614	487	403	345
150	1,107	760	567	450	373	320
160	1,036	706	527	418	347	298
170	972	660	491	390	324	—
180	916	618	459	364	303	—

[1] *Tabular values derived by dividing table 5 values by basal area of average tree (table 9).*

Table 14. – Average number of white spruce per acre larger than 4.5 inches d.b.h., by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Number					
30	334	356	371	381	388	392
40	379	401	414	421	422	418
50	419	437	446	446	441	431
60	451	467	468	461	450	433
70	480	488	482	468	449	428
80	504	503	489	469	443	417
90	523	513	491	462	433	404
100	536	518	489	454	420	388
110	548	519	482	442	405	371
120	555	518	472	429	388	354
130	559	512	461	413	372	331
140	560	504	448	398	352	312
150	558	494	433	380	333	294
160	555	483	418	363	315	278
170	549	469	400	346	299	—
180	542	454	384	328	284	—

[1] *Tabular values derived by dividing table 6 values by basal area of average tree (table 10).*

Table 15. – Average number of white spruce per acre larger than 6.5 inches d.b.h., by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Number					
30	--	--	--	--	45	69
40	--	--	81	103	124	143
50	--	112	135	152	169	187
60	127	149	168	186	201	215
70	151	171	190	207	223	234
80	173	190	209	225	236	248
90	185	204	223	236	248	259
100	201	217	233	247	258	267
110	208	226	242	255	265	275
120	218	234	250	261	271	279
130	224	242	255	267	277	283
140	233	248	262	271	280	283
150	238	252	266	275	284	276
160	243	258	270	280	287	270
170	248	261	273	283	284	--
180	250	264	276	286	278	--

[1] *Tabular values derived by dividing table 7 values by basal area of average tree (table 11).*

Table 16. – Average number of white spruce per acre larger than 8.5 inches d.b.h., by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Number					
30	—	—	—	—	2	23
40	—	—	—	7	32	56
50	—	—	3	30	58	84
60	—	—	21	51	81	109
70	—	6	38	70	102	131
80	—	19	54	88	120	150
90	—	32	68	104	137	168
100	5	43	82	119	153	184
110	14	55	95	132	167	198
120	23	66	107	145	180	212
130	32	76	118	157	191	223
140	40	86	128	168	203	234
150	48	95	137	178	213	244
160	56	104	148	188	223	246
170	64	112	157	197	232	—
180	71	120	165	205	240	—

[1] *Tabular values derived by dividing table 8 values by basal area of average tree (table 12).*

Table 17. – Cubic-foot volume per acre of white spruce larger than 4.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	––	––	––	––	92	544
40	––	––	141	602	1,092	1,611
50	––	263	742	1,257	1,807	2,393
60	192	675	1,201	1,769	2,379	3,032
70	485	1,007	1,578	2,199	2,870	3,590
80	726	1,287	1,904	2,578	3,309	4,096
90	933	1,533	2,197	2,924	3,715	4,569
100	1,117	1,756	2,465	3,245	4,096	5,018
110	1,283	1,961	2,716	3,550	4,461	5,450
120	1,437	2,153	2,954	3,841	4,812	5,868
130	1,580	2,335	3,183	4,122	5,154	6,277
140	1,715	2,510	3,403	4,396	5,487	6,678
150	1,845	2,678	3,617	4,663	5,814	7,072
160	1,969	2,841	3,826	4,925	6,137	7,462
170	2,089	3,000	4,031	5,183	6,455	––
180	2,205	3,155	4,232	5,437	6,769	––

Volume = $-158.90 + 24.953\,S + 0.0035378\,S^2A - 85625.0/A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.883$ *Basis, number of plots = 98*

Table 18. – Cubic-foot volume per acre of white spruce larger than 6.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	––	––	––	––	92	544
40	––	––	141	567	923	1,320
50	––	169	509	902	1,347	1,844
60	12	358	766	1,237	1,771	2,367
70	143	546	1,022	1,572	2,194	2,891
80	274	734	1,279	1,907	2,618	3,414
90	405	923	1,535	2,242	3,042	3,937
100	535	1,111	1,792	2,577	3,466	4,461
110	666	1,300	2,048	2,911	3,890	4,984
120	797	1,488	2,304	3,246	4,314	5,507
130	928	1,676	2,561	3,581	4,738	6,031
140	1,059	1,865	2,817	3,916	5,162	6,554
150	1,190	2,053	3,074	4,251	5,586	7,072
160	1,320	2,242	3,330	4,586	6,010	7,462
170	1,451	2,430	3,587	4,921	6,434	––
180	1,582	2,618	3,843	5,256	6,769	––
	Years					
Merging ages	––	––	42	39	36	34
	––	––	––	––	172	150

Between merging ages: $Volume = -772.96 + 0.0052336S^2A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.844$ *Basis, number of plots = 98*

Below the low and above the high merging ages: same as table 17.

Merging age: $-614.06 + 0.0016958S^2A - 24.953S + \frac{85625.0}{A} = 0$

Table 19. – Cubic-foot volume per acre of white spruce larger than 6.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	––	––	––	––	38	329
40	––	––	––	104	451	839
50	––	––	48	431	865	1,350
60	––	––	298	758	1,279	1,861
70	––	84	548	1,084	1,692	2,371
80	––	267	798	1,411	2,106	2,882
90	––	451	1,049	1,738	2,519	3,392
100	73	635	1,299	2,065	2,933	3,903
110	201	819	1,549	2,392	3,347	4,414
120	329	1,003	1,799	2,718	3,760	4,924
130	456	1,187	2,050	3,045	4,174	5,435
140	584	1,370	2,300	3,372	4,587	5,946
150	712	1,554	2,550	3,699	5,001	6,456
160	839	1,738	2,800	4,026	5,415	6,967
170	967	1,922	3,050	4,353	5,828	––
180	1,095	2,106	3,301	4,679	6,242	––

Volume = $-1203.2 + 0.0051063\ S^2A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.894$ *Basis, number of plots = 89*

Table 20 – Cubic-foot volume per acre of white spruce larger than 8.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	--	--	--	--	--	--
40	--	--	--	--	78	492
50	--	--	--	56	519	1,037
60	--	--	--	405	961	1,582
70	--	--	182	754	1,402	2,127
80	--	--	449	1,102	1,843	2,672
90	--	78	716	1,451	2,285	3,216
100	--	274	983	1,800	2,726	3,761
110	--	470	1,249	2,148	3,167	4,306
120	--	667	1,516	2,497	3,609	4,851
130	84	863	1,783	2,846	4,050	5,396
140	220	1,059	2,050	3,195	4,491	5,941
150	356	1,255	2,317	3,543	4,933	6,485
160	492	1,451	2,584	3,892	5,374	7,030
170	628	1,647	2,851	4,241	5,815	--
180	765	1,843	3,118	4,589	6,257	--

Volume = -1687.2 + 0.0054484 S^2A

where: S = site index
A = average breast-height age of at least the six tallest white spruce trees.

R^2 = 0.855 Basis, number of plots = 98

Table 21. – Cubic-foot volume per acre of white spruce larger than 8.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	--	--	--	--	--	--
40	--	--	--	--	--	387
50	--	--	--	--	413	902
60	--	--	--	305	830	1,416
70	--	--	93	634	1,246	1,931
80	--	--	346	963	1,663	2,446
90	--	--	598	1,293	2,080	2,960
100	--	181	850	1,622	2,497	3,475
110	--	366	1,102	1,952	2,914	3,990
120	--	552	1,354	2,281	3,331	4,504
130	1	737	1,607	2,610	3,748	5,019
140	130	922	1,859	2,940	4,165	5,534
150	258	1,107	2,111	3,269	4,582	6,048
160	387	1,293	2,363	3,599	4,998	6,563
170	516	1,478	2,615	3,928	5,415	--
180	644	1,663	2,868	4,257	5,832	--

Volume = $-1671.90 + 0.0051469\ S^2A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.860$ *Basis, number of plots* = 89

Table 22. – Board-foot volume per acre of white spruce larger than 8.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Board feet[1]					
30	––	––	––	––	––	––
40	––	––	––	––	––	2,349
50	––	––	––	––	2,500	5,375
60	––	––	––	1,864	4,951	8,402
70	––	––	623	3,801	7,403	11,428
80	––	––	2,106	5,738	9,855	14,455
90	––	––	3,590	7,675	12,306	17,482
100	––	1,138	5,073	9,612	14,758	20,508
110	––	2,228	6,556	11,549	17,209	23,535
120	––	3,317	8,039	13,486	19,661	26,561
130	79	4,407	9,522	15,424	22,112	29,588
140	835	5,496	11,005	17,361	24,564	32,615
150	1,592	6,586	12,488	19,298	27,015	35,641
160	2,349	7,675	13,971	21,235	29,467	38,668
170	3,105	8,765	15,454	23,172	31,918	––
180	3,862	9,855	16,937	25,109	34,370	––

Volume = $-9757.8 + 0.030266\ S^2A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.854$ *Basis, number of plots = 89*

[1] *International ¼-inch rule.*

Table 23. – Cubic-foot mean annual increment per acre for white spruce larger than 4.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark, by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	––	––	––	––	3.1	18.1
40	––	––	3.5	15.1	27.3	40.3
50	––	5.3	14.8	25.1	36.1	47.9
60	3.2	11.3	20.0	29.5	39.6	50.5
70	6.9	14.4	22.5	31.4	41.0	51.3
80	9.1	16.1	23.8	32.2	41.4	51.2
90	10.4	17.0	24.4	32.5	41.3	50.8
100	11.2	17.6	24.6	32.4	41.0	50.2
110	11.7	17.8	24.7	32.3	40.6	49.5
120	12.0	17.9	24.6	32.0	40.1	48.9
130	12.2	18.0	24.5	31.7	39.6	48.3
140	12.2	17.9	24.3	31.4	39.2	47.7
150	12.3	17.8	24.1	31.1	38.8	47.1
160	12.3	17.7	23.9	30.8	38.4	46.6
170	12.3	17.6	23.7	30.5	38.0	––
180	12.2	17.5	23.5	30.2	37.6	––

[1] *Tabular values were derived by dividing table 17 values by breast-height age.*

Table 24. – Relative frequency distribution of white spruce by 1-inch diameter classes and average d.b.h., interior Alaska

Average d.b.h.[1] (inches)	Diameter class (inches)[2]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Percent of trees in stand																			
2	50	33	11	4	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	36	27	19	10	5	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	17	23	22	18	10	6	2	2	--	--	--	--	--	--	--	--	--	--	--	--
5	10	15	18	19	15	11	6	4	1	1	--	--	--	--	--	--	--	--	--	--
6	6	9	13	16	16	15	11	7	4	2	1	--	--	--	--	--	--	--	--	--
7	3	7	10	13	14	15	12	10	8	3	3	1	1	--	--	--	--	--	--	--
8	1	6	7	7	11	13	14	12	10	7	5	3	1	1	1	--	--	--	--	--
9	--	3	5	7	7	12	12	14	11	10	7	5	3	2	1	1	--	--	--	--
10	--	1	5	6	7	7	11	11	11	11	10	7	5	4	2	1	1	1	--	--
11	--	--	3	4	6	7	8	10	11	11	10	8	7	5	4	2	2	1	--	--
12	--	--	1	4	4	5	5	10	10	10	11	10	9	7	6	4	1	1	1	1

[1] *Includes all d.b.h. larger than 0.5 inch.*
[2] *Midpoint of class (e.g., 8 = 7.6 through 8.5 inches).*

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Site index curves and normal yield tables are presented for even-aged stands of white spruce (*Picea glauca* (Moench) Voss) in interior Alaska. Site is based on height of the four tallest trees per acre at index age 100 years. Yields are related to combinations of the variables site index and age.

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