



United States
Department of
Agriculture

Forest Service

Northeastern Forest
Experiment Station

Research Paper
NE-578

1986



Simulated Yields for Managed Northern Hardwood Stands

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Manuscript received for publication June 6, 1985.

Abstract

Board-foot and cubic-foot yields developed with the forest growth model SIMTIM are presented for northern hardwood stands grown with and without management. SIMTIM has been modified to include more accurate growth rates by species, a new stocking chart, and yields that reflect species values and quality classes. Treatments range from no thinning to intensive quality product management over a range of sites.

Introduction

Yield tables that show merchantable stand volumes by age are basic to the practice of even-age timber management. They provide estimates of future volumes that are useful in regulating the yields from a forest, estimating rotation ages, and calculating management options.

Most yield tables are for fully stocked unmanaged stands. They were developed by measuring volumes in a series of well-stocked stands of different ages, and then graphing or regressing volume over age—usually for separate site classes. Although useful for extensive management, unmanaged stand yield tables cannot be used to estimate yields or rotations for managed or thinned stands.

In the United States, few forest stands have been managed long enough for the development of managed yield tables for any forest type. The best alternative is computer simulation models. A computer model was developed for northern hardwoods in New England that included substantial data on stocking and growth response (Solomon 1977a,b,c). From this model, managed yield tables have been developed that show thinning and harvest yields (board feet and cubic feet) by species and quality classes for three site index classes and five thinning regimes. The species composition of the stands used to predict yields depicts northern hardwoods as composed of less than 25 percent softwoods and approximately equal amounts of beech, birches, maples, and other

associated hardwood species (Table 1). The merchantability limits were 4 inches inside bark for 5-inch-d.b.h. pulpwood and 6 or 8 inches inside bark at the smallest end for softwood and hardwood sawtimber, respectively. The log rule used was the International 1/4-inch saw kerf for 9.0-inch-d.b.h. softwood and 11.0-inch-d.b.h. hardwood sawlogs.

The Model

The original model was described for managed and unmanaged sapling (SIMSAP) and poletimber-sawtimber (SIMTIM) northern hardwood stands (Solomon 1977a). The overall framework of the model continues to be a distance-independent average-stand model, though numerous changes have been made. Input consists of site index, specifications on the thinning regime, and the stand characteristics of age, basal area, quadratic mean stand diameter, and percent of basal area by size, species, and quality. The model projects all of these stand characteristics by positioning the stand within the northern hardwood stocking chart (Fig. 1) and relating stand development to stocking. The lines in Figure 1 are developed from trees within the main crown canopy of northern hardwood stands. The main crown canopy is defined as all trees on the plot that are not overtopped or suppressed. The revised model incorporates additional growth data, growth rates by species, a new stocking guide, and conversion to board feet and cubic feet.

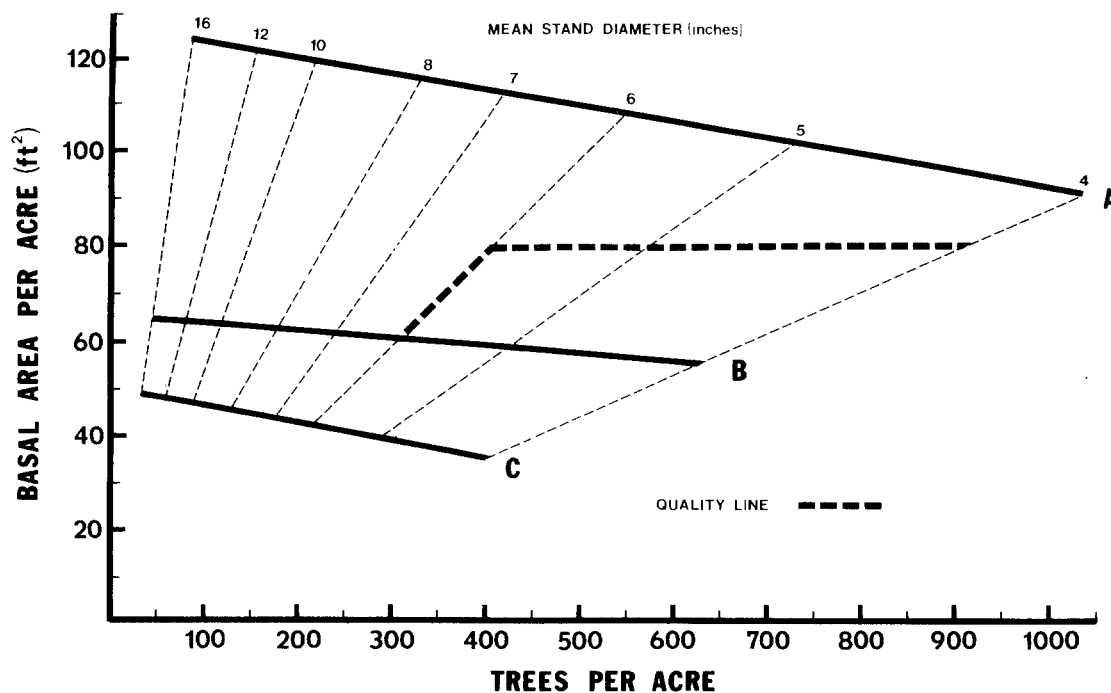


Figure 1.—Stocking chart for northern hardwoods is based on trees in the main crown canopy. The A line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response per acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand. The quality line defines the stocking measure in young stands for maintaining quality development.

The model SIMTIM is written in Fortran-77 and can be used interactively or by batch on any main-frame, microcomputer, or minicomputer that is MS/DOS compatible and has a minimum of 128K bytes of storage. Use of the model requires input for the following:

Job No—Indicates number of jobs or different sets of stand conditions to be used as input (1 to 999).

Title—Eighty characters used to separate jobs and identify management to be conducted on each stand.

Site—Site index of stand (site must be between 40 and 80).

POLEN—Average number of trees per acre in stand (25 to 1,500 trees).

BA—Basal area in square feet to nearest hundredth square foot (20 to 130 ft²).

POLED—Quadratic mean stand diameter to nearest tenth of an inch (4 to 20 inches).

YEARS—Stand age in years.

SPQU—List species composition by quality classes of I, II, or III in following order: beech, yellow birch, sugar maple, red maple, paper birch, aspen, white ash, conifer, other. One quality class per line expressed to nearest tenth of a percent.

SPQUC—Order of removal of species from the quality class 3 x 8 matrix. Numbers from 1 to 24 are arranged in priority of removal.

THSPLT—Point in SPQUC for user to switch from complete species-quality class removal to proportional removal of remaining species quality classes. This maintains species composition and quality of species.

ITHIN—Regulates thinning by basal area in stocking chart:

0—No thinning

1—Thin when stand reaches A line

2—Thin when stand reaches user-specified basal area above B line. Enter amount of basal area above B line to begin thinning.

QTH—Thinning to quality line in Figure 1:

1—Thin to B line for all mean stand diameters.

2—Thin to 80 ft² up to 6-inch quadratic mean diameter, then thin to B line for stands with quadratic mean diameters greater than 6 inches.

PBMAX—Paper birch removal:

0—Paper birch mortality is removed between age 80 and 100. Removal is shown in thinnings after age 70.

1—User harvests paper birch.

THDBH—Quadratic mean diameter to the nearest tenth of an inch for thinning to begin.

XHARV—Quadratic mean diameter to the nearest tenth of an inch for final harvest.

XROT—Maximum age in years for final harvest.

IX—Any odd 9-digit random number used in mortality.

INTRVL—Reports given at specified intervals (years).

SAW—Percentage of sawtimber in stand.

Stand Growth

The amount of stocking, represented by the basal area, number of trees, and quadratic mean stand diameter, can be followed through time with the stocking chart (Fig. 1). The growth simulation within the model computes the number of trees per acre at both the A line and B line. The A line represents a fully stocked stand without any form of management. The B line is based on optimum stand growth from different northern hardwood growth studies. The number of trees at both the A line and the B line can be presented as a function of the natural logarithmic value of the quadratic mean stand diameter:

$$\text{A-line number of trees} = e^{(9.491 - 1.786 \cdot \ln \text{QMD})}$$

$$\text{B-line number of trees} = e^{(9.082 - 1.887 \cdot \ln \text{QMD})}$$

where

QMD = the diameter at breast height of the tree of average basal area.

The C line represents a managed stand with minimum level of acceptable growing stock (sawlog potential) that will grow to the B line in 10 years. The quality line maintains a higher level of basal-area stocking for a smaller quadratic mean diameter. Thinning a stand to the quality line provides clear bole form on younger, smaller high-quality species.

The stand growth components of accretion and ingrowth (ft²/acre/year) can be expressed as:

$$\text{Accretion} = 2.153 + 0.005 (\ln \text{BA}) - 0.0076 (\text{SAW})$$

$$\text{Ingrowth} = 3.200 - 0.643 (\ln \text{BA}) - 0.0012 (\text{SAW})$$

where

BA = Residual basal area in square feet

SAW = Percentage of stand in sawtimber-size trees

Accretion = Dbh increment in basal area of trees present at the initial inventory, plus ingrowth accretion.

Ingrowth = Trees that grew larger than threshold size (5.0 inches) between inventories.

The R^2 values were 0.73 and 0.97; the standard errors of the mean were 0.0187 and 0.0138, respectively. These growth equations are based on information from managed stands of northern hardwoods (Marquis 1969; Solomon 1977b). The residual basal areas ranged from 20 to 100 ft² for these stands that were 20 to 80 years old. The percentage of sawtimber ranged from zero to 60. Stand mortality increases as the basal area and mean stand diameter increase.

Thus, as the stand grows from the B line to the A line, mortality increases. Our estimate of actual stand mortality is based on the assumption that mortality at minimum stocking (the B line) is zero, and that mortality of a stand above the B line is in some way proportional to its position between the A line and B line.

$$\text{Stand mortality} = \left(\frac{\text{BA} - \text{BAB}}{\text{BAA} + \text{MF} - \text{BAB}} \right)^X \cdot (\text{GG} - \text{BAGA})$$

where

BA = basal area of stand

BAB = basal area at B line

BAA = basal area at A line

GG = gross growth

BAGA = annual net basal-area growth at A line

MF = mortality factor

X = a random exponent between 1 and 1.5.

When $X = 1$, mortality is computed in direct proportion to the position of the stand between the A line and B line. When X is greater than 1, the mortality rate increases as the A line is approached and passed. The mortality factor (MF) ranged from -2.5 for stands with basal areas of 60 ft² or less up to 2.0 for stands with 100 ft² or more.

Species Growth

Stand growth provides the forest manager with an estimate of the growth of northern hardwood stands. However, as species composition changes, the growth rate of any species may increase or decrease. Growth rates by species were computed and followed through the model as the user controls species composition (Marquis 1969; Solomon 1977b). Thus, stand growth, as computed from accretion, ingrowth, and mortality, is proportioned into species growth rate based on the residual basal area of the stand, size class, and percent of species composition. Therefore, changing species composition does not change stand growth, but changes the amount of growth allotted to individual species.

Yields

The growth rates of the combined species were compared to the stand growth and calculated as board-foot and cubic-foot yields at the time of harvest. Intermediate thinnings also are reported as a separate part of the total yield of the managed stand. Square feet of basal area is converted to both cubic feet and board feet based on the quadratic mean stand diameter (Leak 1980). Thus, the yields by species are based on the percentage of a species in the total basal area. The cubic feet per square foot of basal area give the total cubic feet; similarly, the board feet per square foot give the board feet. Then the board feet divided by the board feet/cubic feet ratio gives the amount of cubic feet in the sawtimber yields. By subtracting this amount from the total yield, we can estimate amount of cubic feet in pulp, cull, or extra sawtimber.

Thinning Options

The major species that made up the northern hardwood stand used to construct the model and presented in the yield tables were:

Yellow birch—*Betula alleghaniensis* Britton

Sugar maple—*Acer saccharum* Marsh.

White ash—*Fraxinus americana* L.

Paper birch—*Betula papyrifera* Marsh.

Other:

Red maple—*Acer rubrum* L.

Beech—*Fagus grandifolia* Ehrh.

Aspen—*Populus tremuloides* Michx.

Conifer

Hemlock—*Tsuga canadensis* (L.) Carr.

Red spruce—*Picea rubens* Sarg.

To provide forest managers with examples of yields from northern hardwood stands, five thinning regimes were modeled:

1. No thinning: The stands were allowed to develop naturally.
2. Quality-line thinning (Fig. 1): Up to 6 inches quadratic mean diameter; stands that reached the A line were thinned to 80 ft² of residual basal areas. The higher basal area in the smaller sized and younger

stand assured more height growth and increased natural pruning. Above 6 inches quadratic mean stand diameter, stands were thinned to B line whenever the basal area reached 30 ft² above the B line (approximately two-thirds of the distance from B line to A line).

3. 7-inch thinning: Stands were thinned to B line after mean stand diameter reached 7 inches and whenever the basal area exceeded the B line by 30 ft². The delay in the start of thinning to 7 inches quadratic mean stand diameter allowed for an increase in merchantable-size products prior to the start of thinning. A comparison to the more frequent thinning methods can be made.
4. 9-inch thinning: Stands were thinned to B line after quadratic mean stand diameter reached 9 inches and whenever the basal area exceeded the B line by 30 ft². The delay in the start of thinnings to 9 inches quadratic mean stand diameter allowed for an increase in merchantable size products prior to the start of thinnings. This thinning method might be used in remote areas or stands where frequent harvesting is not desirable.
5. A-line thinning: Stands were thinned once to 80 ft² of residual basal area, between 5 and 6 inches mean stand diameter. Above 6 inches mean diameter, the stands were thinned to B line whenever the basal area reached the A line.

All runs began at 4.0 inches mean stand diameter, 91 ft² of basal area per acre, and ages of 25, 30, and 35 years, respectively, for site indexes 70, 60, and 50 feet (site index for sugar maple at breast-height age 50). Stands were grown to 18.0 inches quadratic mean stand diameter.

Initial species composition varied by site index, based on available information on the relation of species to habitat (Leak 1978). The general form of the model recognizes three quality classes. Quality I stems are those with the potential to produce at least one sawlog now or in the future. Quality II stems are those with no sawlog potential. Quality III is cull. The proportion of basal area in potential quality I, II, and III stems was set at approximately 60, 30, and 10 percent, respectively (Table 1). To investigate yields from managed stands, quality II and III were combined. Also, to follow the yield by low- or high-value species, the high-value species of white ash, sugar maple, yellow birch, and paper birch were analyzed separately. The low-value species were grouped into a single category of "other".

Results

The yield tables in both gross board feet and gross cubic feet by site index and thinning method are in Tables 6–21. In this section we provide general interpretations about the influence of thinning on yield and quality; no deductions were made for defect or cull.

Cubic-foot production (thinned plus residual volumes) up to a quadratic mean diameter of 14 inches increased by approximately 30 to 50 percent by thinning compared to no thinning (Table 2). The amount of increase varied moderately with thinning intensity—the number of thinnings and the time of the first entry. By contrast, board-foot production up to 14 inches quadratic mean stand diameter was increased no more than 12 to 14 percent by thinning (Table 3). Almost no differences were observed among methods of management. One-third to one-half of the total cubic-foot or board-foot production comes from thinning.

The important differences in productivity among thinning regimes became evident when the time required to reach a given quadratic mean stand diameter was taken into account. Mean annual increment in cubic feet (volume divided by years) up to 14 inches mean stand diameter was increased by at least 100 percent by quality-line thinning compared to no thinning; mean annual board-foot increment increased by about 50 to 100 percent (Table 3). Annual board-foot increments were about 20 to 40 percent greater under quality-line thinning than under A-line thinning, and cubic-foot yields were 30 to 60 percent greater. The response to thinning, expressed in percent, was greater on the poorer sites.

Age of culmination of mean annual board-foot increment without thinning increased from about 100 to 120 years as site index decreased from 70 to 50 feet; the corresponding mean stand diameter at the point of culmination decreased from 14 to 10 inches as site index decreased (Table 4). The thinning treatments resulted in a slight to moderate increase in culmination age and diameter for site index 50. Thinning slightly decreased culmination age for site 70, but increased the corresponding culmination diameter by as much as 4 inches. On site 60, thinning increased culmination diameter slightly and, in most cases, caused a slight decrease in culmination age. Mean annual board-foot increment was increased through thinning by about 50 to 100 percent on site 50, and by 25 to 50 percent on site 70; there were intermediate gains on site 60.

Age of culmination of mean annual cubic-foot increment was less than 40 to 60 years under no thinning (Table 4). Culmination age and stand diameter were roughly doubled by thinning. Thinning increased mean annual increment by 40 to 60 percent, with the greatest increase on the better sites. However, low-intensity thinning methods had only a slight to moderate increase in mean annual increment. Culmination

ages for board-foot increment under any thinning method are only a little longer than those for cubic-foot increment.

Stand value is reflected by the proportions of high-value species and high-quality stems. On site index 50, the proportion of board-foot volume in high-value species and grade I stems changed from 11 percent without thinning to 14 percent with A-line thinning (Table 5). On sites 60 and 70, the proportion of high-value basal area ranged from about 50 percent without thinning to about 75 percent with thinning. Differences among sites were substantial, primarily because species composition varied between sites. Although thinning produced a substantial increase in high-value yield on sites 60 and 70, differences among thinning regimes were not large. However, consideration should be given to the differences in species composition in Table 1. More yellow birch was in the species composition on site index 60 and more white ash was present on site index 70.

Conclusion

SIMTIM was used to develop a series of managed yield tables for even-aged northern hardwood stands over a range of thinning methods and site indexes. SIMTIM provides estimates of board-foot and cubic-foot yields by species and quality.

Intensive thinning increased total mean annual yields by at least 100 percent for cubic-foot volumes, and by 50 to 100 percent for board-foot volumes. Thinning had little effect on rotation length (culmination of mean annual increment) for board-foot volume, but nearly doubled rotations for cubic-foot volume. Optimum rotations for intensively thinned stands ranged from about 80 to 90 years for cubic-foot production and 90 to 125 years for board-foot production on sites 70 to 50, respectively. Intensive thinning on sites 60 and 70 raised the proportion of quality I high-value species from about 50 to 75 percent.

The managed yield tables for northern hardwoods should prove useful to forest managers as well as those engaged in research on economic returns. An example of the program output is given in Table 21.

The computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program. For cost information, please write: Northeastern Forest Experiment Station, USDA Building-University of Maine, Orono, Maine 04469.

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Table 1.—Initial species composition (at 4.0 inches mean d.b.h.) in percent of basal area, by site index and quality class

Site index	Quality class ^a	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Conifer	Other	All
50	I	27	9	2	11	10	0	2	0	61
	II	14	5	1	5	5	0	0	0	30
	III	4	1	0	2	1	0	0	1	9
60	I	7	23	22	1	5	1	0	0	59
	II	4	11	11	0	3	1	0	0	30
	III	1	4	4	0	1	0	0	1	11
70	I	6	6	23	0	6	17	1	0	59
	II	3	3	11	1	3	9	0	0	30
	III	1	1	4	0	1	3	0	1	11

^a Quality class I: sawlog or veneer potential in at least one 16-foot log; class II: no veneer or sawlog potential; class III: cull trees.

Table 2.—Residual and cumulative thinned volume per acre at 14 inches quadratic mean diameter (QMD), by thinning method and site index

Thinning		Begin QMD	Site index 50			Site index 60			Site index 70		
Method	No.		Thinned	Residual	All	Thinned	Residual	All	Thinned	Residual	All
-----Ft ³ /acre-----											
No thinning	0	—	—	2595	2595	—	3102	3102	—	3579	3579
Quality line	5	5.2	2128	1738	3866	2602	2011	4613	3019	2389	5408
7 inch	3	7.1	1633	1990	3623	1959	2369	4328	2330	2654	4984
9 inch	2	9.1	1284	2069	3353	1570	2374	3944	1766	2839	4605
A line	2	5.2	1880	1485	3365	1002	2991	3993	1156	3459	4615
-----Board feet/acre-----											
No thinning	0	—	—	10959	10959	—	13048	13048	—	15079	15079
Quality line	5	5.2	4596	7502	12098	5633	8449	14082	6650	10139	16789
7 inch	3	7.1	3928	8538	12466	4660	9957	14617	5790	11251	17041
9 inch	2	9.1	3630	8789	12419	4517	9977	14494	5044	12025	17069
A line	2	5.2	5572	6464	12036	1527	12573	14100	1722	14620	16342

Table 3.—Years to reach 14 inches quadratic mean diameter and mean annual increment per acre, by thinning method and site index

Thinning method	Site index 50			Site index 60			Site index 70		
	Years	Board feet	Cubic feet	Years	Board feet	Cubic feet	Years	Board feet	Cubic feet
No thinning	236	46.4	11.0	157	83.1	19.8	102	147.8	35.1
Quality line	124	97.6	31.2	95	148.2	48.6	77	218.0	70.2
7 inch	137	91.0	26.4	101	144.7	42.9	80	213.0	62.3
9 inch	154	80.6	21.8	110	131.8	35.9	86	198.5	53.5
A line	181	66.5	18.6	119	118.5	33.6	88	185.7	52.4

Table 4.—Approximate^a mean annual increment (MAI) to the point of culmination in age and quadratic mean diameter (QMD)

Thinning method	Site 50			Site 60			Site 70		
	Culmination			Culmination			Culmination		
	MAI	Age	QMD	MAI	Age	QMD	MAI	Age	QMD
	<i>Ft³</i>	<i>Years</i>	<i>Inches</i>	<i>Ft³</i>	<i>Years</i>	<i>Inches</i>	<i>Ft³</i>	<i>Years</i>	<i>Inches</i>
No thinning	21.8	< 59	< 6	31.6	< 49	< 6	44.4	< 41	< 6
Quality line	30.9	105	12	48.6	95	14	70.2	77	14
7 inch	25.2	119	12	42.9	101	14	62.3	80	14
9 inch	21.0	129	12	35.9	110	14	53.5	86	14
A line	24.3	98	10	36.5	78	10	53.9	75	12
Thinning method	Board feet			Board Feet			Board feet		
	Culmination			Culmination			Culmination		
	Board feet	Years	Inches	Board Feet	Years	Inches	Board feet	Years	Inches
	<i>Board feet</i>	<i>Years</i>	<i>Inches</i>	<i>Board Feet</i>	<i>Years</i>	<i>Inches</i>	<i>Board feet</i>	<i>Years</i>	<i>Inches</i>
No thinning	46.3	120	10	85.8	114	12	147.8	102	14
Quality line	97.6	124	14	148.2	95	14	227.3	92	18
7 inch	91.0	137	14	144.7	101	14	216.8	89	16
9 inch	80.6	154	14	131.8	110	14	198.5	86	14
A line	67.5	133	12	118.5	119	14	185.7	88	14

^a Culmination determined directly from yield tables in this publication, without interpolation between age or diameter intervals; culmination is defined as the point where MAI is within about 1 ft³ or 7 board feet of maximum.

Table 5.—Percentage board-foot volume (thinned plus standing volume) at a quadratic mean diameter of 14 inches in high-value and low-value species^a and in quality classes I and II^b, by thinning method and site index

Thinning method	Site index 50						Site index 60						Site index 70					
	High value			Low value			High value			Low value			High value			Low value		
	I	II	All	I	II	All	I	II	All	I	II	All	I	II	All	I	II	All
	I	II	All	I	II	All	I	II	All	I	II	All	I	II	All	I	II	All
No thinning	11	7	18	52	30	82	49	34	83	10	7	17	50	34	84	10	6	16
Quality line	12	—	12	88	—	88	83	—	83	17	—	17	79	—	79	21	—	21
7 inch	13	2	15	82	3	85	77	5	82	17	1	18	75	5	80	19	1	20
9 inch	14	3	17	73	10	83	71	12	83	15	2	17	68	12	80	18	2	20
A line	14	4	18	80	2	82	76	8	84	16	—	16	75	8	83	17	—	17

^a High-value species: white ash, sugar maple, yellow birch, and paper birch; low-value species: beech, red maple, conifers, and miscellaneous.

^b Quality class I: sawlog or veneer potential in at least one 16-foot log; class II: no sawlog or veneer potential (includes cull trees).

[illegible]

Table 7.—Residual volumes per acre, by species and quality class (I and II) for no thinning and site index 60

Mean d.b.h. (inches)	Age	Residual basal area	White ash		Sugar maple		Yellow birch		Paper birch		Other		Combined		
			I	II	I	II	I	II	I	II	I	II	I	II	All
	Years	Ft ²	-----Ft ³ /acre-----												
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—
6	49	102	21	21	303	207	340	222	120	96	124	93	908	639	1547
8	67	107	27	27	350	238	401	261	193	154	156	117	1127	797	1924
10	87	110	34	34	451	307	517	338	153	123	202	152	1357	954	2311
12	114	113	45	45	598	408	687	448	—	—	268	201	1598	1102	2700
14	157	116	51	51	687	469	789	515	—	—	309	231	1836	1266	3102
16	196	118	52	52	699	477	802	523	—	—	313	236	1866	1288	3154
18	230	119	53	53	707	482	812	530	—	—	317	238	1889	1303	3192
			-----Board feet/acre-----												
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—
6	49	102	—	—	—	—	—	—	—	—	—	—	—	—	—
8	67	107	49	49	646	441	742	484	357	285	289	218	2083	1477	3560
10	87	110	98	98	1295	883	1487	969	441	352	580	437	3901	2739	6640
12	114	113	163	163	2167	1478	2488	1622	—	—	971	731	5789	3994	9783
14	157	116	218	218	2890	1970	3318	2164	—	—	1295	975	7721	5327	13048
16	196	118	221	221	2936	2002	3371	2198	—	—	1317	991	7845	5412	13257
18	230	119	224	224	2972	2026	3412	2225	—	—	1332	1003	7940	5478	13418

Table 8.—Residual volumes per acre, by species and quality class (I and II) for no thinning and site index 70

Mean d.b.h. (inches)	Age	Residual basal area	White ash		Sugar maple		Yellow birch		Paper birch		Other		Combined		
			I	II	I	II	I	II	I	II	I	II	I	II	All
	Years	Ft ²	-----Ft ³ /acre-----												
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—
6	41	103	372	263	334	218	95	63	150	100	122	104	1073	748	1821
8	55	107	480	339	358	234	107	71	232	154	156	123	1333	921	2254
10	69	110	553	391	398	259	120	80	320	213	200	141	1591	1084	2675
12	85	112	689	486	495	323	149	99	284	189	254	176	1871	1273	3144
14	102	114	923	652	663	432	200	133	—	—	340	236	2126	1453	3579
16	127	117	942	665	677	442	204	136	—	—	347	241	2170	1484	3654
18	157	119	959	677	688	449	207	138	—	—	353	245	2207	1509	3716
			-----Board feet/acre-----												
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—
6	41	103	—	—	—	—	—	—	—	—	—	—	—	—	—
8	55	107	904	638	674	440	201	134	436	291	309	231	2524	1734	4258
10	69	110	1575	1112	1131	738	340	227	910	607	590	402	4546	3086	7632
12	85	112	2506	1769	1800	1174	542	361	1032	688	949	640	6829	4632	11461
14	102	114	3881	2740	2787	1818	839	559	—	—	1464	991	8971	6108	15079
16	127	117	3961	2796	2845	1856	856	571	—	—	1494	1011	9156	6234	15390
18	157	119	4029	2844	2894	1888	871	581	—	—	1520	1028	9314	6341	15655

Table 9.—Residual and cumulative thinned^a volume per acre for quality-line thinning and site index 50

Mean d.b.h. (inches)	Residual basal area Age	White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined						
		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual				
		I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	All	I	II	All			
		-----Ft³/acre-----																										
4	35	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
6	57	99	—	—	—	—	—	23	11	—	10	106	59	—	14	184	92	—	202	581	102	—	226	226	894	264	1158	
8	74	65	—	—	—	—	13	11	23	—	54	69	97	—	99	106	182	—	356	304	694	—	522	490	1012	996	—	996
10	89	92	—	—	—	—	13	11	36	—	54	69	143	—	99	106	135	—	356	304	1294	—	522	490	1012	1608	—	1608
12	105	87	—	—	—	—	24	11	36	—	99	69	140	—	142	106	—	—	765	304	1549	—	1030	490	1520	1725	—	1725
14	124	78	—	—	—	—	37	11	34	—	149	69	131	—	142	106	—	—	1310	304	1573	—	1638	490	2128	1738	—	1738
16	147	66	—	—	—	—	50	11	29	—	199	69	111	—	142	106	—	—	1905	304	1329	—	2296	490	2786	1469	—	1469
18	162	82	—	—	—	—	50	11	36	—	199	69	139	—	142	106	—	—	1905	304	1659	—	2296	490	2786	1834	—	1834
-----Board feet/acre-----																												
4	35	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	57	99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
8	74	65	—	—	—	—	17	—	44	—	71	—	188	—	133	—	354	—	505	—	1386	—	726	—	726	1972	—	1972
10	89	92	—	—	—	—	17	—	104	—	71	—	407	—	133	—	384	—	505	—	3799	—	726	—	726	4694	—	4694
12	105	87	—	—	—	—	50	—	129	—	200	—	506	—	254	—	—	—	1707	—	5774	—	2211	—	2211	6409	—	6409
14	124	78	—	—	—	—	98	—	141	—	388	—	552	—	254	—	—	—	3856	—	6809	—	4596	—	4596	7502	—	7502
16	147	66	—	—	—	—	151	—	119	—	597	—	466	—	254	—	—	—	6433	—	5755	—	7435	—	7435	6340	—	6340
18	162	82	—	—	—	—	151	—	149	—	597	—	582	—	254	—	—	—	6433	—	7181	—	7435	—	7435	7912	—	7912

^a Six thinnings at mean d.b.h. 5.2, 6.0, 7.8, 10.0, 12.7, and 15.9.

Table 10.—Residual and cumulative thinned^a volume per acre for quality-line thinning and site index 60

Mean d.b.h. (inches)			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined					
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual			
			Age	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	All	I	II
Years Ft ²			-----Ft ³ /acre-----																									
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	48	93	—	—	24	24	—	51	353	177	—	117	386	106	—	18	129	77	—	83	142	—	—	269	269	1034	384	1418
8	61	66	15	24	32	—	201	228	406	—	212	222	421	—	78	95	158	—	85	83	172	—	591	652	1243	1189	—	1189
10	72	91	15	24	53	—	201	228	668	—	212	222	643	—	78	95	254	—	85	83	294	—	591	652	1243	1912	—	1912
12	83	85	33	24	58	—	414	228	745	—	417	222	679	—	159	95	222	—	179	83	335	—	1202	652	1854	2039	—	2039
14	95	75	55	24	63	—	701	228	811	—	678	222	738	—	207	95	33	—	309	83	366	—	1950	652	2602	2011	—	2011
16	107	91	55	24	79	—	701	228	1004	—	678	222	913	—	207	95	—	—	309	83	453	—	1950	652	2602	2449	—	2449
18	119	78	81	24	67	—	1026	228	855	—	973	222	777	—	207	95	—	—	455	83	386	—	2742	652	3394	2085	—	2085
			-----Board feet/acre-----																									
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	48	93	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	61	66	23	—	58	—	305	—	756	—	319	—	783	—	119	—	293	—	129	—	321	—	895	—	895	2211	—	2211
10	72	91	23	—	153	—	305	—	1910	—	319	—	1840	—	119	—	728	—	129	—	840	—	895	—	895	5471	—	5471
12	83	85	73	—	213	—	927	—	2695	—	918	—	2454	—	357	—	802	—	405	—	1211	—	2680	—	2680	7375	—	7375
14	95	75	162	—	268	—	2060	—	3408	—	1950	—	3100	—	546	—	135	—	915	—	1538	—	5633	—	5633	8449	—	8449
16	107	91	162	—	332	—	2060	—	4217	—	1950	—	3836	—	546	—	—	—	915	—	1904	—	5633	—	5633	10289	—	10289
18	119	78	269	—	283	—	3424	—	3590	—	3191	—	3266	—	546	—	—	—	1530	—	1621	—	8960	—	8960	8760	—	8760

^a Six thinnings at mean d.b.h. 5.2, 6.1, 7.8, 10.2, 13.1, and 16.5.

Table 11.—Residual and cumulative thinned^a volume per acre for quality-line thinning and site index 70

Mean Residual d.b.h. basal (inches) area Age			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined							
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		All			
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	All	
Years Ft ²			-----Ft ³ /acre-----																											
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	40	93	—	55	422	223	—	87	383	146	—	59	106	—	—	20	159	79	—	94	139	—	—	315	315	1209	448	1657	—	
8	50	67	251	278	538	—	197	233	410	—	54	59	110	—	91	99	190	—	83	94	178	—	676	763	1439	1426	—	1426	—	
10	59	91	251	278	862	—	197	233	594	—	54	59	154	—	91	99	293	—	83	94	319	—	676	763	1439	2222	—	2222	—	
12	68	85	526	278	922	—	385	233	607	—	103	59	148	—	185	99	295	—	186	94	423	—	1385	763	2148	2395	—	2395	—	
14	77	76	853	278	873	—	601	233	580	—	155	59	134	—	290	99	270	—	357	94	532	—	2256	763	3019	2389	—	2389	—	
16	85	92	853	278	1021	—	601	233	683	—	155	59	157	—	290	99	230	—	357	94	777	—	2256	763	3019	2868	—	2868	—	
18	92	78	1173	278	861	—	815	233	578	—	204	59	133	—	352	99	64	—	608	94	810	—	3152	763	3915	2446	—	2446	—	
			-----Board feet/acre-----																											
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	40	93	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
8	50	67	399	—	1033	—	309	—	787	—	84	—	212	—	144	—	366	—	139	—	362	—	1075	—	1075	2760	—	2760	—	
10	59	91	399	—	2466	—	309	—	1700	—	84	—	442	—	144	—	837	—	139	—	955	—	1075	—	1075	6400	—	6400	—	
12	68	85	1207	—	3365	—	862	—	2216	—	227	—	541	—	419	—	1075	—	456	—	1610	—	3171	—	3171	8807	—	8807	—	
14	77	76	2504	—	3668	—	1717	—	2439	—	433	—	565	—	835	—	1136	—	1161	—	2331	—	6650	—	6650	10139	—	10139	—	
16	85	92	2504	—	4289	—	1717	—	2872	—	433	—	660	—	835	—	967	—	1161	—	3415	—	6650	—	6650	12203	—	12203	—	
18	92	78	3849	—	3619	—	2618	—	2430	—	640	—	557	—	1095	—	269	—	2263	—	3571	—	10465	—	10465	10446	—	10446	—	

^a Six thinnings at mean d.b.h. 5.2, 6.2, 7.9, 10.2, 13.1, and 16.6.

Table 12.—Residual and cumulative thinned^a volume per acre for 7-inch thinning and site index 50

Mean Residual d.b.h. basal (inches) area Age			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined					
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual			
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	All	I	II	All
Years Ft ²			-----Ft ³ /acre-----																									
4	35	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	59	103	—	—	—	—	—	20	10	—	—	95	64	—	—	177	106	—	—	506	311	—	—	—	798	491	1289	
8	78	78	—	—	—	—	1	11	27	—	4	67	120	—	8	129	254	—	21	340	773	—	34	547	581	1174	—	1174
10	95	75	—	—	—	—	12	11	33	—	55	67	143	—	66	128	38	—	378	340	1102	—	511	546	1057	1316	—	1316
12	119	64	—	—	—	—	26	11	33	—	116	67	145	—	66	128	—	—	878	340	1186	—	1086	546	1632	1364	—	1364
14	137	89	—	—	—	—	26	11	45	—	116	67	199	—	66	128	—	—	879	340	1746	—	1087	546	1633	1990	—	1990
16	157	78	—	—	—	—	41	11	39	—	181	67	174	—	66	128	—	—	1457	340	1528	—	1745	546	2291	1741	—	1741
18	177	94	—	—	—	—	41	11	49	—	181	67	209	—	66	128	—	—	1457	340	1829	—	1745	546	2291	2087	—	2087
			-----Board feet/acre-----																									
4	35	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	59	103	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
8	78	78	—	—	—	—	1	13	49	—	5	82	219	—	10	159	465	—	27	418	1458	—	43	672	715	2191	—	2191
10	95	75	—	—	—	—	29	13	93	—	128	82	409	—	151	159	107	—	908	419	3244	—	1216	673	1889	3853	—	3853
12	119	64	—	—	—	—	76	13	121	—	339	82	532	—	151	159	—	—	2689	419	4478	—	3255	673	3928	5131	—	5131
14	137	89	—	—	—	—	76	13	190	—	339	82	836	—	151	159	—	—	2689	419	7512	—	3255	673	3928	8538	—	8538
16	157	78	—	—	—	—	139	13	166	—	616	82	732	—	151	159	—	—	5176	419	6573	—	6082	673	6755	7471	—	7471
18	177	94	—	—	—	—	139	13	199	—	616	82	876	—	151	159	—	—	5176	419	7869	—	6082	673	6755	8944	—	8944

^a Four thinnings at mean d.b.h. 7.1, 9.1, 11.6, and 14.6.

Table 13.—Residual and cumulative thinned^a volume per acre for 7-inch thinning and site index 60

Mean Residual d.b.h. basal (inches) area Age			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined						
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual				
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	All	I	II	All	
Years Ft²			-----Ft³/acre-----																										
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	49	102	—	—	21	21	—	—	303	207	—	—	340	222	—	—	120	96	—	—	124	93	—	—	—	—	908	639	1547
8	64	79	—	18	36	9	—	222	464	—	—	243	506	—	—	125	219	—	—	105	203	—	—	713	713	1428	9	1437	
10	76	76	14	29	42	—	178	222	537	—	188	243	537	—	84	125	238	—	80	105	243	—	544	724	1268	1597	—	1597	
12	90	67	33	29	46	—	426	222	602	—	432	243	595	—	151	125	105	—	193	105	276	—	1235	724	1959	1624	—	1624	
14	101	88	33	29	72	—	426	222	939	—	432	243	924	—	151	125	—	—	193	105	434	—	1235	724	1959	2369	—	2369	
16	114	76	56	29	62	—	737	222	812	—	738	243	800	—	151	125	—	—	337	105	374	—	2019	724	2743	2048	—	2048	
18	128	91	56	29	75	—	737	222	970	—	738	243	954	—	151	125	—	—	337	105	447	—	2019	724	2743	2446	—	2446	
			-----Board feet/acre-----																										
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	49	102	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
8	64	79	—	22	69	17	—	272	885	—	—	297	965	—	—	153	416	—	—	129	387	—	—	873	873	2722	17	2739	
10	76	76	34	50	120	—	435	272	1550	—	459	297	1550	—	206	153	684	—	195	130	700	—	1329	902	2231	4604	—	4604	
12	90	67	101	50	170	—	1305	272	2227	—	1318	297	2202	—	440	153	392	—	594	130	1020	—	3758	902	4660	6011	—	6011	
14	101	88	101	50	302	—	1305	272	3949	—	1318	297	3884	—	440	153	—	—	594	130	1822	—	3758	902	4660	9957	—	9957	
16	114	76	201	50	261	—	2612	272	3415	—	2605	297	3359	—	440	153	—	—	1197	129	1575	—	7055	901	7956	8610	—	8610	
18	128	91	201	50	311	—	2612	272	4077	—	2605	297	4010	—	440	153	—	—	1197	129	1881	—	7055	901	7956	10279	—	10279	

^aFour thinnings at mean d.b.h. 7.1, 9.1, 11.7, and 14.9.

Table 14.—Residual and cumulative thinned^a volume per acre for 7-inch thinning and site index 70

Mean d.b.h. (inches) Age			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined					
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		All	
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Years Ft ²			-----Ft ³ /acre-----																									
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	41	103	—	—	372	263	—	—	334	218	—	—	95	63	—	—	150	100	—	—	122	104	—	—	—	—	1073	748
8	52	77	—	301	595	3	—	226	451	—	—	67	128	—	—	126	249	—	—	114	194	—	—	834	834	1617	3	1620
10	62	74	251	301	683	—	177	226	471	—	49	67	128	—	104	126	272	—	87	114	251	—	668	834	1502	1805	—	1805
12	72	94	251	301	976	—	177	226	659	—	49	67	171	—	104	126	383	—	87	114	448	—	668	834	1502	2637	—	2637
14	80	85	557	301	939	—	384	226	643	—	103	67	158	—	224	126	352	—	228	114	562	—	1496	834	2330	2654	—	2654
16	89	73	880	301	837	—	605	226	576	—	157	67	141	—	305	126	111	—	444	114	629	—	2391	834	3225	2294	—	2294
18	97	88	880	301	994	—	605	226	684	—	157	67	168	—	305	126	35	—	444	114	886	—	2391	834	3225	2767	—	2767
			-----Board feet/acre-----																									
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	41	103	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	52	77	—	381	1096	5	—	285	830	—	—	85	236	—	—	159	458	—	—	144	376	—	—	1054	1054	2996	5	3001
10	62	74	634	391	1961	—	448	285	1352	—	125	85	368	—	263	159	782	—	231	144	752	—	1701	1064	2765	5215	—	5215
12	72	94	634	391	3544	—	448	285	2392	—	125	85	620	—	263	159	1389	—	231	144	1692	—	1701	1064	2765	9637	—	9637
14	80	85	1746	391	3947	—	1199	285	2703	—	320	85	665	—	699	159	1480	—	762	144	2456	—	4726	1064	5790	11251	—	11251
16	89	73	3103	391	3519	—	2128	285	2420	—	549	85	593	—	1040	159	466	—	1707	144	2759	—	8527	1064	9591	9757	—	9757
18	97	88	3103	391	4179	—	2128	285	2874	—	549	85	704	—	1040	159	146	—	1707	144	3899	—	8527	1064	9591	11802	—	11802

^a Four thinnings at mean d.b.h. 7.1, 9.3, 12.1, and 15.3.

Table 15.—Residual and cumulative thinned^a volume per acre for 9-inch thinning and site index 50

Mean d.b.h. (inches)			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined					
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		All	All
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II		
Age																												
Years			Ft ³ /acre																									
4	35	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	59	103	—	—	—	—	—	—	20	10	—	—	95	64	—	—	177	106	—	—	506	311	—	—	—	798	491	1289
8	83	107	—	—	—	—	—	—	24	12	—	—	116	77	—	—	201	121	—	—	664	391	—	—	—	1005	601	1606
10	106	79	—	—	—	—	2	16	40	—	9	102	190	—	2	24	—	—	49	518	1145	—	62	660	722	1375	—	1375
12	129	71	—	—	—	—	19	16	41	—	85	102	191	—	2	24	—	—	518	518	1190	—	624	660	1284	1422	—	1422
14	154	93	—	—	—	—	19	16	59	—	85	102	279	—	2	24	—	—	518	518	1731	—	624	660	1284	2069	—	2069
16	172	80	—	—	—	—	38	16	51	—	175	102	242	—	2	24	—	—	1078	518	1501	—	1293	660	1953	1794	—	1794
18	199	96	—	—	—	—	38	16	61	—	175	102	290	—	2	24	—	—	1078	518	1801	—	1293	660	1953	2152	—	2152
			Board feet/acre																									
4	35	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	59	103	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	83	107	—	—	—	—	—	—	45	22	—	—	213	141	—	—	370	272	—	—	1251	714	—	—	—	1879	1149	3028
10	106	79	—	—	—	—	4	38	115	—	21	244	544	—	5	56	—	—	119	1238	3345	—	149	1576	1725	4004	—	4004
12	129	71	—	—	—	—	58	38	146	—	278	244	691	—	5	56	—	—	1713	1238	4360	—	2054	1576	3630	5197	—	5197
14	154	93	—	—	—	—	58	38	247	—	278	244	1171	—	5	56	—	—	1713	1238	7371	—	2054	1576	3630	8789	—	8789
16	172	80	—	—	—	—	139	38	214	—	656	244	1016	—	5	56	—	—	4097	1238	6393	—	4897	1576	6473	7623	—	7623
18	199	96	—	—	—	—	139	38	257	—	656	244	1218	—	5	56	—	—	4097	1238	7667	—	4897	1576	6473	9142	—	9142

^a Three thinnings at mean d.b.h. 9.0, 11.3, and 14.2.

Table 16.—Residual and cumulative thinned^a volume per acre for 9-inch thinning and site index 60

Mean Residual d.b.h. basal (inches) area Age			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined							
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual					
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	All	I	II	All		
			Years Ft ²			-----Ft ³ /acre-----																								
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	49	102	—	—	21	21	—	—	303	207	—	—	340	222	—	—	120	96	—	—	124	93	—	—	—	—	908	639	1547	
8	67	107	—	—	27	27	—	—	350	238	—	—	401	261	—	—	193	154	—	—	156	117	—	—	—	—	1127	797	1924	
10	83	77	—	29	39	—	3	261	531	—	3	287	585	—	2	173	238	—	2	130	241	—	10	880	890	1634	—	1634		
12	98	97	—	29	64	—	3	261	872	—	3	287	960	—	2	173	39	—	2	130	396	—	10	880	890	2331	—	2331		
14	110	89	18	29	67	—	249	261	902	—	273	287	994	—	37	173	—	—	113	130	411	—	690	880	1570	2374	—	2374		
16	125	77	40	29	58	—	550	261	789	—	604	287	868	—	37	173	—	—	250	130	359	—	1481	880	2361	2074	—	2074		
18	192	93	40	29	70	—	550	261	950	—	604	287	1046	—	37	173	—	—	250	130	432	—	1481	880	2361	2498	—	2498		
			-----Board feet/acre-----																											
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	49	102	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
8	67	107	—	—	49	49	—	—	646	441	—	—	742	484	—	—	357	285	—	—	284	218	—	—	—	—	2078	1477	3555	
10	83	77	1	69	113	—	7	631	1545	—	9	693	1700	—	4	418	689	—	3	312	699	—	24	2123	2147	4746	—	4746		
12	98	97	1	69	234	—	7	631	3177	—	9	693	3498	—	4	418	145	—	3	312	1444	—	24	2123	2147	8498	—	8498		
14	110	89	63	69	279	—	862	631	3795	—	950	693	4177	—	126	418	—	—	393	312	1726	—	2394	2123	4517	9977	—	9977		
16	125	77	157	69	243	—	2126	631	3315	—	2342	693	3650	—	126	418	—	—	968	312	1509	—	5719	2123	7842	8717	—	8717		
18	192	93	157	69	294	—	2126	631	3992	—	2342	693	4395	—	126	418	—	—	968	312	1817	—	5719	2123	7842	10498	—	10498		

^a Three thinnings at mean d.b.h. 9.1, 11.6, and 14.7.

Table 17.—Residual and cumulative thinned^a volume per acre for 9-inch thinning and site index 70

Mean Residual d.b.h. basal (inches) area Age			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined							
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		All		All	
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
			-----Ft ³ /acre-----																											
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	41	103	—	—	372	263	—	—	334	218	—	—	95	63	—	—	150	100	—	—	122	104	—	—	—	—	1073	748	1821	
8	55	107	—	—	480	339	—	—	358	234	—	—	107	71	—	—	232	154	—	—	156	123	—	—	—	—	1333	921	2254	
10	67	79	—	367	700	—	—	243	491	—	—	75	142	—	—	185	355	—	—	132	262	—	—	1002	1002	1950	—	1950		
12	76	70	270	367	687	—	189	243	482	—	53	75	132	—	135	185	337	—	117	132	318	—	764	1002	1766	1956	—	1956		
14	86	91	270	367	1007	—	189	243	718	—	53	75	192	—	135	185	324	—	117	132	598	—	764	1002	1766	2839	—	2839		
16	94	77	604	367	898	—	427	243	641	—	117	75	171	—	217	185	62	—	322	132	640	—	1687	1002	2689	2412	—	2412		
18	104	92	604	367	1073	—	427	243	765	—	117	75	204	—	217	185	—	—	322	132	852	—	1687	1002	2689	2894	—	2894		
			-----Board feet/acre-----																											
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	41	103	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
8	55	107	—	—	904	638	—	—	674	440	—	—	201	134	—	—	436	291	—	—	309	231	—	—	—	—	2524	1734	4258	
10	67	79	—	881	2047	—	—	584	1434	—	—	180	414	—	—	445	1038	—	—	316	797	—	—	2406	2406	5730	—	5730		
12	76	70	926	881	2478	—	648	584	1742	—	182	180	477	—	465	445	1216	—	417	316	1190	—	2638	2406	5044	7103	—	7103		
14	86	91	926	881	4233	—	648	584	3017	—	182	180	807	—	465	445	1362	—	417	316	2606	—	2638	2406	5044	12025	—	12025		
16	94	77	2331	881	3774	—	1649	584	2693	—	450	180	720	—	811	445	261	—	1311	316	2800	—	6552	2406	8958	10248	—	10248		
18	104	92	2331	881	4508	—	1649	584	3217	—	450	180	860	—	811	445	—	—	1311	316	3735	—	6552	2406	8958	12320	—	12320		

^a Three thinnings at mean d.b.h. 9.1, 11.5, and 14.7.

Table 18.—Residual and cumulative thinned¹ volume per acre (cubic-foot) for A-line thinning and site index 50

Mean d.b.h. (inches)			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined						
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual				
			Age	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	All	I	II	All
Years			-----Ft ³ /acre-----																										
4	35	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
6	57	92	—	—	—	—	—	—	23	11	—	10	106	59	—	14	184	92	—	202	581	102	—	226	226	894	264	1158	
8	80	105	—	—	—	—	—	—	29	14	—	10	129	71	—	14	261	131	—	202	809	135	—	226	226	1228	351	1579	
10	98	89	—	—	—	—	—	6	16	41	—	27	87	184	—	44	128	26	—	171	348	1306	—	248	579	827	1557	—	1557
12	133	106	—	—	—	—	—	6	16	56	—	27	87	253	—	44	128	—	—	171	348	1804	—	248	579	827	2113	—	2113
14	181	64	—	—	—	—	—	34	16	40	—	153	87	177	—	44	128	—	—	1070	348	1268	—	1301	579	1880	1485	—	1485
16	192	87	—	—	—	—	—	34	16	51	—	153	87	231	—	44	128	—	—	1070	348	1654	—	1301	579	1880	1936	—	1936
18	217	102	—	—	—	—	—	34	16	61	—	153	87	271	—	44	128	—	—	1070	348	1939	—	1301	579	1880	2271	—	2271
			-----Board feet/acre-----																										
4	35	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	57	92	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
8	80	105	—	—	—	—	—	—	54	26	—	—	242	134	—	—	489	244	—	—	1558	254	—	—	—	—	2343	658	3001
10	98	89	—	—	—	—	—	12	31	117	—	55	156	526	—	89	229	73	—	353	293	3829	—	509	709	1218	4545	—	4545
12	133	106	—	—	—	—	—	12	31	203	—	55	156	912	—	89	229	—	—	353	293	6647	—	509	709	1218	7762	—	7762
14	181	64	—	—	—	—	—	126	31	170	—	568	156	762	—	89	229	—	—	4080	293	5532	—	4863	709	5572	6464	—	6464
16	192	87	—	—	—	—	—	126	31	217	—	568	156	973	—	89	229	—	—	4080	293	7067	—	4863	709	5572	8257	—	8257
18	217	102	—	—	—	—	—	126	31	254	—	568	156	1140	—	89	229	—	—	4080	293	8280	—	4863	709	5572	9674	—	9674

^a Three thinnings at mean d.b.h. 5.2, 8.3, and 14.0 inches.

Table 19.—Residual and cumulative thinned^a volume per acre for A-line thinning and site index 60

Mean Residual d.b.h. basal (inches) area Age			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined							
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		All	I	II	All
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II						
Years Ft²			-----Ft³/acre-----																											
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	48	93	—	—	24	24	—	51	353	177	—	117	386	105	—	18	129	77	—	83	142	—	—	269	269	1034	383	1417		
8	65	105	—	—	34	34	—	51	444	222	—	117	489	135	—	18	217	130	—	83	195	—	—	269	269	1379	521	1900		
10	78	88	5	35	46	—	62	280	607	—	68	255	628	—	31	156	286	—	27	83	276	—	193	809	1002	1843	—	1843		
12	94	103	5	35	69	—	62	280	915	—	68	255	947	—	31	156	115	—	27	83	417	—	193	809	1002	2463	—	2463		
14	119	112	5	35	89	—	62	280	1165	—	68	255	1206	—	31	156	—	—	27	83	531	—	193	809	1002	2991	—	2991		
16	141	76	45	35	60	—	575	280	794	—	599	255	822	—	31	156	—	—	261	83	362	—	1511	809	2320	2038	—	2038		
18	158	92	45	35	73	—	575	280	961	—	599	255	995	—	31	156	—	—	261	83	439	—	1511	809	2320	2468	—	2468		
			-----Board feet/acre-----																											
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
6	48	93	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
8	65	105	—	—	64	64	—	—	840	420	—	—	926	254	—	—	411	246	—	—	370	—	—	—	—	2611	984	3595		
10	78	88	10	73	133	—	129	477	1744	—	141	289	1806	—	64	287	823	—	57	—	794	—	401	1126	1527	5300	—	5300		
12	94	103	10	73	252	—	129	477	3310	—	141	289	3427	—	64	287	416	—	57	—	1511	—	401	1126	1527	8916	—	8916		
14	119	112	10	73	373	—	129	477	4896	—	141	289	5070	—	64	287	—	—	57	—	2234	—	401	1126	1527	12573	—	12573		
16	141	76	175	73	254	—	2285	477	3334	—	2375	289	3453	—	64	287	—	—	1042	—	1522	—	5941	1126	7067	8563	—	8563		
18	158	92	175	73	308	—	2285	477	4039	—	2375	289	4182	—	64	287	—	—	1042	—	1844	—	5941	1126	7067	10373	—	10373		

^a Three thinnings at mean d.b.h. 5.2, 8.4, and 14.7 inches.

Table 20.—Residual and cumulative thinned^a volume per acre for A-line thinning and site index 70

Mean Residual d.b.h. basal (inches) area Age			White ash				Sugar maple				Yellow birch				Paper birch				Other				Combined							
			Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		Thin		Residual		All	I	II	All
			I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II						
Years Ft²			-----Ft³/acre-----																											
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	40	93	—	55	422	223	—	87	383	146	—	59	106	—	—	19	159	79	—	94	139	—	—	314	314	1209	448	1657		
8	53	105	—	55	591	313	—	87	443	169	—	59	127	—	—	19	251	126	—	94	193	—	—	314	314	1605	608	2213		
10	63	89	79	378	815	—	58	259	562	—	17	59	154	—	34	152	339	—	26	94	301	—	214	942	1156	2171	—	2171		
12	75	103	79	378	1051	—	58	259	718	—	17	59	194	—	34	152	454	—	26	94	468	—	214	942	1156	2885	—	2885		
14	88	111	79	378	1348	—	58	259	920	—	17	59	249	—	34	152	325	—	26	94	617	—	214	942	1156	3459	—	3459		
16	104	115	79	378	1542	—	58	259	1052	—	17	59	285	—	34	152	—	—	26	94	706	—	214	942	1156	3585	—	3585		
18	114	80	747	378	1052	—	514	259	718	—	140	59	194	—	34	152	—	—	332	94	533	—	1767	942	2709	2497	—	2497		
			-----Board feet/acre-----																											
4	25	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	40	93	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
8	53	105	—	—	1110	588	—	—	832	318	—	—	238	—	—	—	472	236	—	—	382	—	—	—	—	—	3034	1142	4176	
10	63	89	161	660	2332	—	118	351	1609	—	34	—	442	—	70	272	969	—	56	—	899	—	439	1283	1722	6251	—	6251		
12	75	103	161	660	3812	—	118	351	2602	—	34	—	703	—	70	272	1645	—	56	—	1766	—	439	1283	1722	10528	—	10528		
14	88	111	161	660	5663	—	118	351	3866	—	34	—	1045	—	70	272	1365	—	56	—	2681	—	439	1283	1722	14620	—	14620		
16	104	115	161	660	6481	—	118	351	4424	—	34	—	1196	—	70	272	—	—	56	—	3067	—	439	1283	1722	15168	—	15168		
18	114	80	2969	660	4421	—	2035	351	3017	—	552	—	816	—	70	272	—	—	1385	—	2322	—	7011	1283	8294	10576	—	10576		

^a Three thinnings at mean d.b.h. 5.2, 8.4, and 16.3.

**Table 21.—Example of model output at the end of poletimber-sawtimber-harvest phase
for a typical northern hardwood stand**

Quality-line thinning

Stand Number 1 started with: Site = 60

Number of trees/acre = 1,050

Basal area/acre = 91.00

Quadratic mean diameter = 4.0

Age of stand = 30; percent sawtimber = 15

Quality class	Species								
	BE	YB	SM	RM	PBA	WA	CON	OTHER	TOTAL
1	7.0%	23.0%	22.0%	1.0%	5.0%	1.0%	0.0%	0.0%	59.0%
FT2	6.4	20.9	20.0	0.9	4.5	0.9	0.0	0.0	53.7
2	4.0%	11.0%	11.0%	0.0%	3.0%	1.0%	0.0%	0.0%	30.0%
FT2	3.6	10.0	10.0	0.0	2.7	0.9	0.0	0.0	27.3
3	1.0%	4.0%	4.0%	0.0%	1.0%	0.0%	0.0%	1.0%	11.0%
FT2	0.9	3.6	3.6	0.0	0.9	0.0	0.0	0.9	10.0

ORDER OF SPECIES CLASS REMOVAL BY PRIORITY

24 20 17 23 18 19 21 22 16 12 9 15 10 11 13 14 8 4
1 7 5 2 3 6

ITHIN = 2, thin when stand reaches 30. FT2 above the B line

THINNING SPLOT NUMBER: 17

Q-LINE THINNING (THIN TO 80 FT2) WILL BE USED UP TO DIAMETER 6 INCHES

OPERATOR CONTROLS PAPER BIRCH REMOVAL PRIORITY

DIAMETER AT WHICH THINNING STARTED = 5.0

ROTATION AGE = 400

HARVEST DIAMETER = 18.0

THINNING NO. 1

Number of trees = 132.401 Quadratic mean diameter = 5.19 BA = 19.45

Quality class	Species								
	BE	YB	SM	RM	PBA	WA	CON	OTHER	TOTAL
1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FT2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3.9%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.4%
FT2	3.8	4.6	0.0	0.0	0.0	0.0	0.0	0.0	8.4
FT3	53.2	63.0	0.0	0.0	0.0	0.0	0.0	0.0	116.2
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.0%	3.9%	3.7%	0.0%	1.3%	0.0%	0.0%	1.2%	11.1%
FT2	1.0	3.9	3.7	0.0	1.3	0.0	0.0	1.2	11.1
FT3	13.3	53.7	51.2	0.0	18.2	0.0	0.0	16.4	152.9
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Mean diameter for age 49 = 6.096

Number of trees in stand = 460.79

Basal area of stand = 93.40

Percent sawtimber = 0

A-line number of trees present = 520.4 next yr = 504.7

B-line number of trees present = 303.4 next yr = 294.1

BA at A line = 101.37

BA at B line = 59.07

Table 21. (continued)

Harvest Yield in Percent									
Quality class	Species								TOTAL
	BE	YB	SM	RM	PBA	WA	CON	OTHER	
1	15.2%	37.3%	41.0%	3.3%	0.0%	3.2%	0.0%	0.0%	100.0%
FT2	11.8	29.0	31.9	2.6	0.0	2.5	0.0	0.0	77.7
FT3 1	316.2	777.3	854.3	69.5	0.0	67.2	0.0	0.0	2084.4
BF	1328.8	3266.8	3590.5	292.0	0.0	282.6	0.0	0.0	8760.5
2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FT2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT3 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FT2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT3 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Total Yield from Thinnings									
Quality class	Species								TOTAL
	BE	YB	SM	RM	PBA	WA	CON	OTHER	
FT2	16.2	43.2	45.0	3.6	10.2	3.5	0.0	0.0	121.7
FT3 1	371.2	973.8	1026.2	83.2	207.1	80.5	0.0	0.0	2742.0
BF	1250.3	3192.2	3425.5	279.2	545.5	270.0	0.0	0.0	8962.6
FT2	3.8	11.5	11.6	0.0	5.1	1.6	0.0	0.0	33.7
FT3 2	53.2	168.9	176.4	0.0	77.1	23.7	0.0	0.0	499.2
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT2	1.0	3.9	3.7	0.0	1.3	0.0	0.0	1.2	11.1
FT3 3	13.3	53.7	51.2	0.0	18.2	0.0	0.0	16.4	152.9
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Total Yield									
Quality class	Species								TOTAL
	BE	YB	SM	RM	PBA	WA	CON	OTHER	
FT2	28.0	72.1	76.9	6.2	10.2	6.0	0.0	0.0	199.5
FT3 1	687.4	1751.1	1880.5	152.7	207.1	147.7	0.0	0.0	4826.4
BF	2579.1	6458.9	7016.0	571.1	545.5	552.6	0.0	0.0	17723.1
FT2	3.8	11.5	11.6	0.0	5.1	1.6	0.0	0.0	33.7
FT3 2	53.2	168.9	176.4	0.0	77.1	23.7	0.0	0.0	499.2
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT2	1.0	3.9	3.7	0.0	1.3	0.0	0.0	1.2	11.1
FT3 3	13.3	53.7	51.2	0.0	18.2	0.0	0.0	16.4	152.9
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The total harvest per acre (including thinnings) is:

Basal area: 244.164

Cubic feet: 5,478.480

Board feet: 17,723.145

Solomon, Dale S.; Leak, William B. **Simulated yields for managed northern hardwood stands.** Res. Pap. NE-578. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1986. 24 p.

Board-foot and cubic-foot yields developed with the forest growth model SIMTIM are presented for northern hardwood stands grown with and without management. SIMTIM has been modified to include more accurate growth rates by species, a new stocking chart, and yields that reflect species values and quality classes. Treatments range from no thinning to intensive quality product management over a range of sites.

ODC: 524.37:62

Keywords: yields; northern hardwoods; growth; model

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