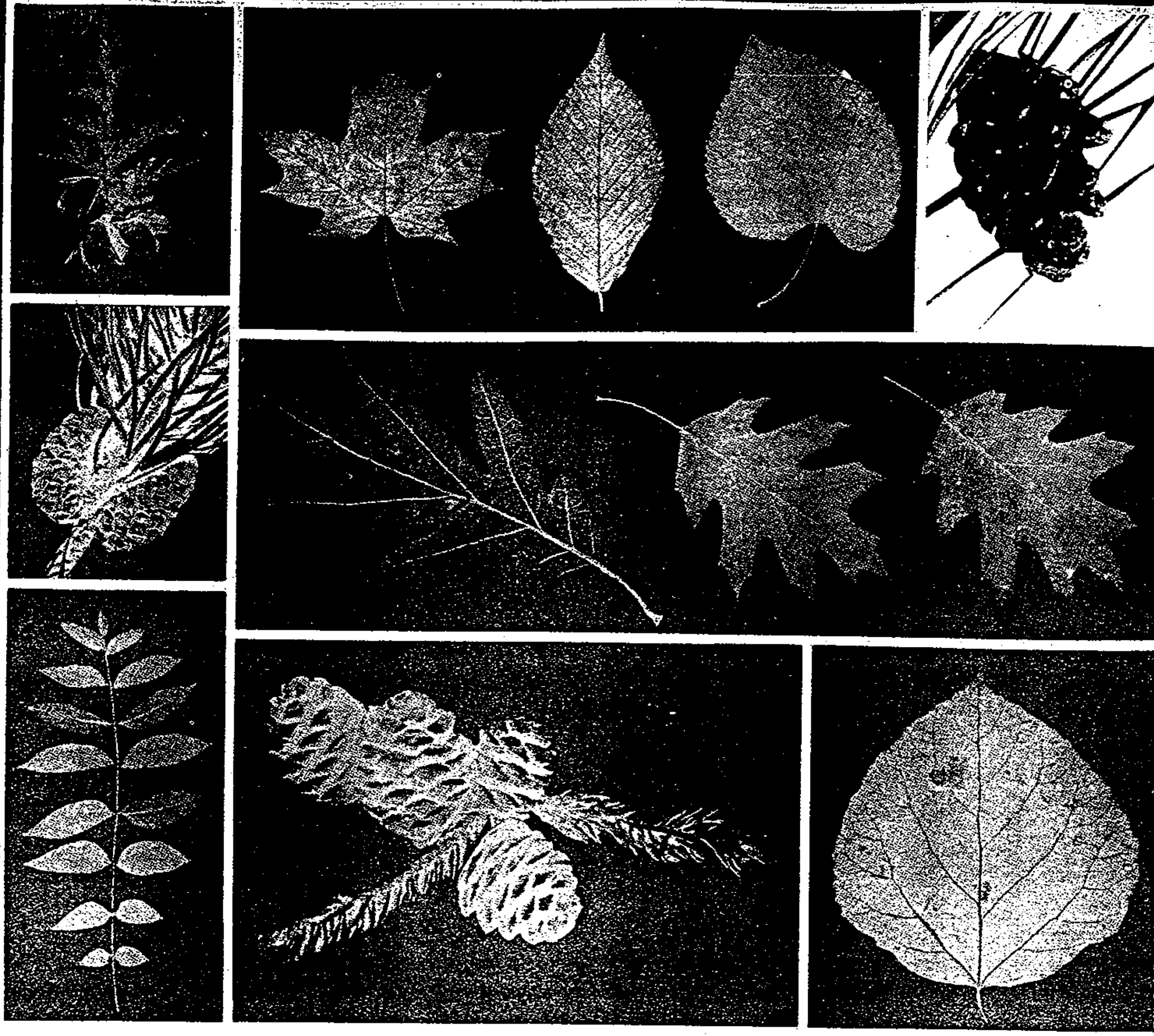

(10.)

manager's handbook for

RED PINE IN THE NORTH CENTRAL STATES

GENERAL TECHNICAL REPORT NC-33

NORTH CENTRAL FOREST EXPERIMENT STATION   FOREST SERVICE   U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

RED PINE
IN THE NORTH CENTRAL STATES

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SILVICAL HIGHLIGHTS

A century ago red pine[1] made up about a third of the 22 million acres of pine forests in Minnesota, Wisconsin, and Michigan; today it covers only a little more than 1 million acres – mostly acreage planted since 1930.

Red pine on the drier sites grows in pure stands and in mixtures with jack pine, aspen, paper birch, and scrub oaks; on the more moist sites with white pine, red maple, red oak, balsam fir, and white spruce. Red pine grows best on well drained sandy to loamy soils but the tree is most common on sandy soils where site index may range from 45 to 75 feet at 50 years of age.

Red pine is shade intolerant and long-lived; some stands reach 200 years of age, and some individual trees about 400 years, but commercial rotation ages are generally between 60 and 120 years. Red pine often succeeds its less tolerant and shorter-lived associates such as jack pine, paper birch, and the aspens; in turn it is succeeded by its more shade tolerant associates that regenerate in the understory more easily. Wildfires occasionally disrupt ecological succession and a few thick-barked, old-growth trees usually survive to establish a pure seedling stand or a mixed stand of red pine and other intolerant species.

Seed production in mature red pine is irregular; heavy crops occur at intervals of 10 years or more. Red pine phenotypes are very homogenous showing little variation over the entire range. In some localities red pine suffers losses from diseases, insects, mammals, and weather, but it generally has fewer natural enemies than its associated species.

MANAGEMENT OBJECTIVES AND NEEDS

Management objectives considered in this handbook are to control the establishment, composition, and growth of red pine forest stands so that intermediate thinnings will provide useful products such as pulpwood, posts, poles, cabin logs, piling, and small sawtimber, and the final harvest will yield high quality sawtimber and veneer. The management of red pine forest stands throughout their rotation for other uses such as recreation, wildlife habitat, and watersheds is also covered and suggestions are given for increasing these benefits.

Although it is possible to grow red pine in either even-aged or uneven-aged stands, even-aged silvicultural systems give better results because red pine grows best in full sunlight.

Red pine seed crops are too variable to depend on for natural regeneration, so seed must be collected during good seed years for direct seeding, growing container seedlings, or growing bare root planting stock. Seedling establishment requires site preparation on areas where slash or vegetation, particularly sod or shrubs, covers the seedbed or planting site. Red pine seedlings often require tending for several years after they are established to release them from regrowth of competing vegetation and protect them from damage by fire, insects, and disease.

Periodic thinning of young stands is recommended to put the growth on the best trees available, maintain

[1] *For scientific names of plants and animals, see Appendix, p. 20.*

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TIMBER MANAGEMENT CONSIDERATIONS

Stand Conditions

Red pine stands and potential red pine sites need to be carefully examined on the ground to best determine their condition, but use of aerial photos, maps, and other sources of information should not be overlooked. The stand – or site – condition, which is the basis for recommendations, includes type, age, size, density, risk, quality, productivity, and operability.

Type

The red pine type includes both pure red pine stands and various mixtures in which red pine is the predominant species. In addition to the species composition of the main stand, important understory tree or shrub species should be evaluated for site preparation needs and multiple use values. Nonstocked areas, poorly stocked red pine stands, and other forest types may be suitable sites to establish red pine seedlings.

Insect control may involve removal of alternate host plants as in the case of sweetfern to control the Saratoga spittlebug; modifying the habitat such as pruning the lower branches to control the European pine shoot moth, and removing the duff to control the pine root collar weevil; or in some cases by using chemicals[2] to protect the trees. An entomologist should be consulted for recommended control measures.

Animal injury to red pine may be caused by deer, hare, porcupine, or mice in local areas. Measures short of animal control may not be sufficient but eliminating protective grass and shrub cover will help reduce hare and mice activity in the area.

Trees with large fire scars may be a risk for wind breakage and decay. They should be salvaged in one of the thinning operations. Young stands are susceptible to fire injury and should be protected with a fire break. A narrow strip of deciduous trees that are less flammable than red pine can be used to break up large blocks of pine. Pruned trees will reduce the risk of ground fires crowning in sapling stands. In pole-size and larger timber periodic understory burning can control build-up of fine fuels and help reduce the risk of wildfire.

Quality

Red pine tree quality is related to size, form, straightness, and a clean bole. In managed stands the poorer quality trees should be removed in the periodic thinnings favoring the best quality crop trees. Even-aged stands managed near the recommended upper limit of stand density will have less taper, smaller branches, and a greater number of trees from which to select the final crop trees. Crop trees should be low risks, free of defects, and vigorous. Stands should have 100 to 150 acceptable crop trees per acre. Clean boles can be obtained by pruning.

Productivity

Site index is used to estimate productivity of the site (see p. 9 and fig. 8, Appendix) but the productivity of the stand depends not only on the site but how well it is being used. The productivity of a stand can be estimated with the aid of the growth and yield tables in the Appendix. Yields in cubic feet, cords, and board feet are shown for site indices 45, 55, 65, and 75 feet at several different ages and for stand densities of 30, 60, 90, 120, 150, and 180 square feet of basal area per acre (tables 5, 7, and 9, Appendix). Current annual growth is also shown for these same stand conditions so that growth of any stand can be projected for the next growth period (tables 6, 8, and 10, Appendix). If projections are made for more than 10 years, it would be best to interpolate a new current annual growth from the table or use the equations given in the table to compute the periodic annual growth for the period.

Operability

Markets, access, and volume of products that can be removed in a thinning or final harvest determine operability. The minimum volume required depends to a large extent on the value of the product so that managing a stand for higher value products will usually make it operable with lower volumes. Harvested volume per landing is more important than the volume per acre in determining operability. One landing of about 1/2 acre is recommended for up to 40 acres in managed stands. Although 40 acres is the recommended area for establishing new stands on large forest ownerships, minimum size for general forest management is 10 acres. Smaller areas can be managed to meet special needs or owner's objectives but costs will usually be higher.

Controlling Composition and Growth

Red pine trees grow best in full sunlight; that is, they are intolerant of overhead shade. In mixed stands with species less tolerant than red pine such as jack pine and aspen, red pine growth is reduced by the shading from the trees that have faster height growth as seedlings and saplings. In mixed stands with more tolerant species red pine may be crowded out by the severe competition. Cultural practices can be used to keep the red pine crop trees free from overhead shade and to provide the needed growing space for rapid growing, high quality trees.

Release

Complete release of red pine seedlings from shrubs and other low competition may be needed by the end of the third growing season. Cutting by hand requires a lot of labor and regrowth of the competition may necessitate several cuttings at 2- or 3-year intervals. The most practical release method where there are more than just a few trees or shrubs is chemical control with broadcast foliage sprays.

Two of the most useful herbicides are 2,4-D and 2,4,5-T. These two chemicals can control most of the

[2] *See Pesticide Precautionary Statement, p. 21.*

Thinning

One of the most important ways stand composition and development can be controlled is by periodic commercial thinnings (fig. 3). Stands should be thinned before they exceed the recommended upper limit of stocking for managed stands (fig. 7, Appendix). A uniform distribution of the best quality trees with at least the minimum recommended stocking for the average stand diameter should be left, but not over half – and preferably less – of the basal area should be removed in any one thinning. Stands managed near the minimum recommended stocking will have the most rapid diameter growth but the opportunity for selecting crop trees will be more limited because of the fewer trees per acre. As a more general guide, pole stands (5 to 9 inches average diameter) should be considered for thinning when the basal area is 140 square feet or more per acre and they should be thinned to leave about 90 square feet.

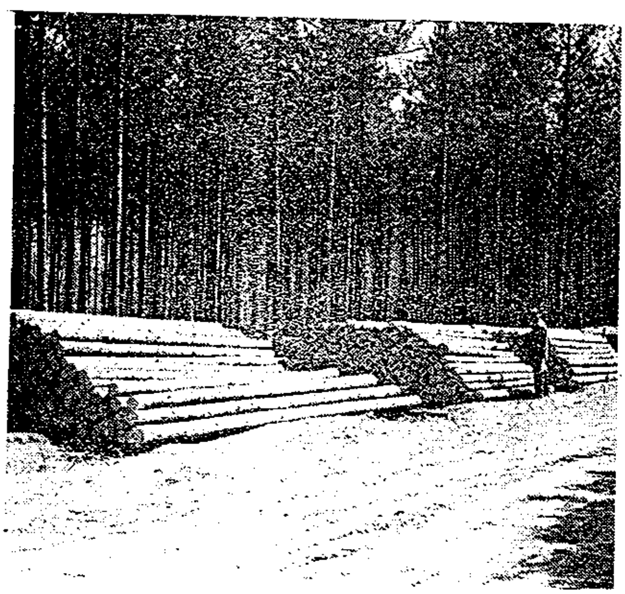


Figure 3. – *Periodic thinning of red pine stands can provide useful products and control the growth and development of the final crop trees.*

If a system of access trails for management of the stand has not already been developed during precommercial thinning, it should be done during the first commercial thinning. Removal of complete rows in plantations may serve as strip roads but more often than not strips should cross some rows to provide the most useful access into and out of the stand from the landing or working area. A convenient spacing for access strips is 50 to 60 feet which will usually leave a good supply of trees between strips from which to select the crop trees.

Thinnings between access strips should generally be from below to remove the smaller, slower growing intermediate and codominant trees and favor the larger crop trees, but high risk, poor quality, or damaged trees should also be removed. In some dense stands where only the largest trees are merchantable, a commercial thinning would require thinning from above. This is preferable to delaying the first thinning in very dense stands because growth loss from crowding may be even greater. Row thinning is also an alternative that may be considered for the first thinning but all other thinnings should be from below.

Sawtimber trees should be thinned periodically to maintain uniform growth rates on the crop trees. Small sawtimber stands (9 to 15 inches average diameter) grow well at densities around 120 square feet of basal area per acre. Larger sawtimber stands also grow well at these densities but the fewer, larger trees will be using less of the growing space because the crown area of large forest grown trees doesn't increase at the same rate as their basal area. Sawtimber stands averaging 15 inches d.b.h. or more can be managed at densities of 150 or even 180 square feet of basal area per acre (150 or fewer trees) without serious crowding.

In mixed stands red pine crop trees should be favored in each thinning but other species should be left where needed to maintain uniform spacing and avoid large openings.

Pruning

Managed red pine stands that are thinned regularly to provide adequate growing space for the crop trees, especially those managed near the minimum recommended stocking, will need artificial pruning to produce high quality, strong, clear wood. Crop trees should be pruned when they are pole size (5 to 9 inches average diameter) (fig. 4). Branches should be cut off flush with the bole to facilitate rapid healing of wounds. Wounds up to 1 inch will heal over in 5 years or less on healthy trees. Prune live branches no higher than half of the tree's total height. Mechanical pruners are more efficient than hand pruning above 12 feet and will usually be necessary to prune higher than 17 feet.

Regulating the Forest

Forest regulation involves long range planning to assure a continuous systematic development of forest stands and a more uniform flow of useful products. Some important aspects of forest regulation are harvesting

Conversion Opportunities

In building the red pine resource for the future, new stands should be established as rapidly as possible so the forest will be fairly well regulated as the stands mature. Red pine should be restored on former pine land that is now poorly stocked or stocked with less desirable species. Conversion of nonstocked brush areas and aspen or oak types to red pine on a regular basis will establish a fully regulated red pine forest in one rotation. Priorities for conversion will vary somewhat with the forest owner's objective and capabilities, but general recommendations are nonstocked areas, poorly stocked mature stands, other mature stands, poorly stocked immature stands, and other immature stands, in that order. Stands with a lot of high risk or low quality trees should be converted before stands with fewer such trees. Conversion of stands that will be merchantable in 20 years or less should be delayed so the harvesting operation can help clear the site and aid the job of site preparation.

Controlling Stand Establishment

Site Evaluation

Before establishing a red pine stand, some estimate of its potential growth on the area should be obtained. If there are red pine trees over 30 years old on the area that have never been suppressed, the best estimate of site index is from site index equations or curves based on the total height and total age of the dominant and codominant trees (fig. 8, Appendix).

Red pine trees starting at about 15 years of age can also provide good estimates of site index based on the following tabulation:

Length of 5 internodes above 8 feet (Feet)	Site index[3] (Feet)
4	38
5	46
6	52
7	56
8	61
9	65
10	68
11	72
12	76

Other growth intercept methods based on 1 to 5 years' growth above breast height (4.5 feet) have been used but estimates of site index are less reliable. Their advantage is that they can be used on red pine trees with only a few years' growth above breast height. The following simplified tabulation shows approximate site index based on average annual height growth for one to five years above breast height:

Average annual height growth above breast height (Inches)	Approximate site index[4] (Feet)
10	45
13	55
17	65
24	75

Considerable variation in annual growth can be expected from year to year so whenever possible the full 5 years' growth should be measured to obtain the average annual growth for estimating site index. Site index will be slightly underestimated when based on 1 year's average and slightly overestimated when based on the average of 5 years' growth using this table.

Site index for red pine can also be estimated from the site index of other trees growing on the area if they have not been suppressed. Jack pine, white pine, white spruce, or aspen site index can be used to estimate red pine site index as in the following generalized tabulation:

Red pine[5]	Jack pine	White pine	White spruce	Aspen
		(Feet)		
45	50	45	35	40
55	60	55	50	60
65	70	65	65	80
75	80	75	80	100

If no suitable trees are available for site index measures, soil properties can be used to estimate red pine site index on sand to sandy loam soils (table 1, Appendix). The factors needed are the depth of the A and B horizons, the percent gravel in the surface 10 inches, and the presence or absence of finer textured soil bands or layers totaling at least 6 inches within 8 feet of the surface. These factors will permit estimates of site

[3] *Based on a revised equation adapted from Alban (1972); site index = 36.9 + 3.356(x) - 192.474 (x)^-2; where x equals length of 5 internodes above 8 feet.*

[4] *Adapted from Day* et al. *(1960), and Schallau and Miller (1966).*

[5] *Adapted from Carmean and Vasilevsky (1971), and Alban (1976).*

Figure 6. – *Controlled summer fires can eliminate most of the woody understory in red pine stands before harvesting and help prepare favorable conditions for establishing red pine seedlings at the end of the rotation.*

Direct seeding has not enjoyed widespread success, but in northeast Minnesota it has been successful on well prepared sites if frequent rain storms occur during the first few months after germination. Seed should be coated with bird and rodent repellants and sown at the rate of 15,000 viable seeds per acre (about 5 ounces) early in the spring to take advantage of snowmelt waters for germination. Somewhat better results have been experienced by covering red pine seed with 1/4 inch of soil but it may be more expedient to broadcast more seed on the surface than to use less seed and cover it. It is easier to cover the seed when sowing 5 to 10 seeds in prepared spots. Even though direct seeding can be successful it generally has not been because of inadequate site preparation, inadequate precipitation, or loss of seeds to birds or rodents.

The most reliable method of establishing a red pine stand is to plant nursery-grown trees. Planting of bare root stock should be done in the spring setting the trees at least as deep as they grew in the nursery. On drier sites planting trees up to 2 inches deeper may be beneficial, but planting trees too deep increases the risk of injury by root collar weevils. The more difficult sites should be planted with bare root transplant stock or large vigorous seedlings. Container-grown trees show promise for planting throughout the growing season.

The spacing of planted trees determines how the trees will develop during their early years and how soon the stand will close in and affect the ground cover. Spacings closer than 5 feet will not provide the minimum growing space recommended for seedlings, and spacings greater than 10 feet will not provide the minimum number of seedlings recommended per acre. The time to reach pole size (5 inches diameter) will vary from 15 to 30 or more years depending mostly on the spacing or number of trees per acre established and to a lesser extent on the site quality (table 2, Appendix). The closer spacings will require cleaning (precommercial thinning) during the sapling stage (2 to 5 inches average diameter) to provide the recommended 50 square feet of growing space for each crop tree, and the wider spacings may need an extra release or two to control grass, shrub, and hardwood competition.

Planting recommendations depend on many things including the forest owner's objective, planting chance, and management intensity. Planting 400 trees per acre (a little more than 10- by 10-foot spacing) will be the least costly, crop trees will have rapid diameter growth, commercial thinnings can be made by the time trees need more growing space, and crown closure will not shade out ground vegetation for about 20 years. Planting 1,600 trees per acre (a little more than 5- by 5-foot spacing) will allow greater flexibility in selecting crop trees and controlling early stand development, crop trees will have less taper and smaller branches, and the stand will have more total volume.

Trees should be planted at wide spacings up to 10 by 10 feet if: all or most of the planted trees have a good chance of surviving, precommercial thinnings are not feasible (or not planned), and favoring ground vegetation is a management objective. On the other hand trees should be planted at close spacings down to 5 by 5 feet if: tree quality such as taper and branch size is important, early crown closure to suppress competition is desired, precommercial and early thinnings are planned to control stand development, and frequent thinnings are wanted throughout the rotation. Most plantations will be established at spacings between these two extremes. Commonly used spacings are 6 by 8 and 6 by 10 feet. Machine planting costs can be reduced by using wider rows and closer spacing of trees in the row but plans for access and future management operations should also be considered at the time of stand establishment.

APPENDIX

Stocking Chart

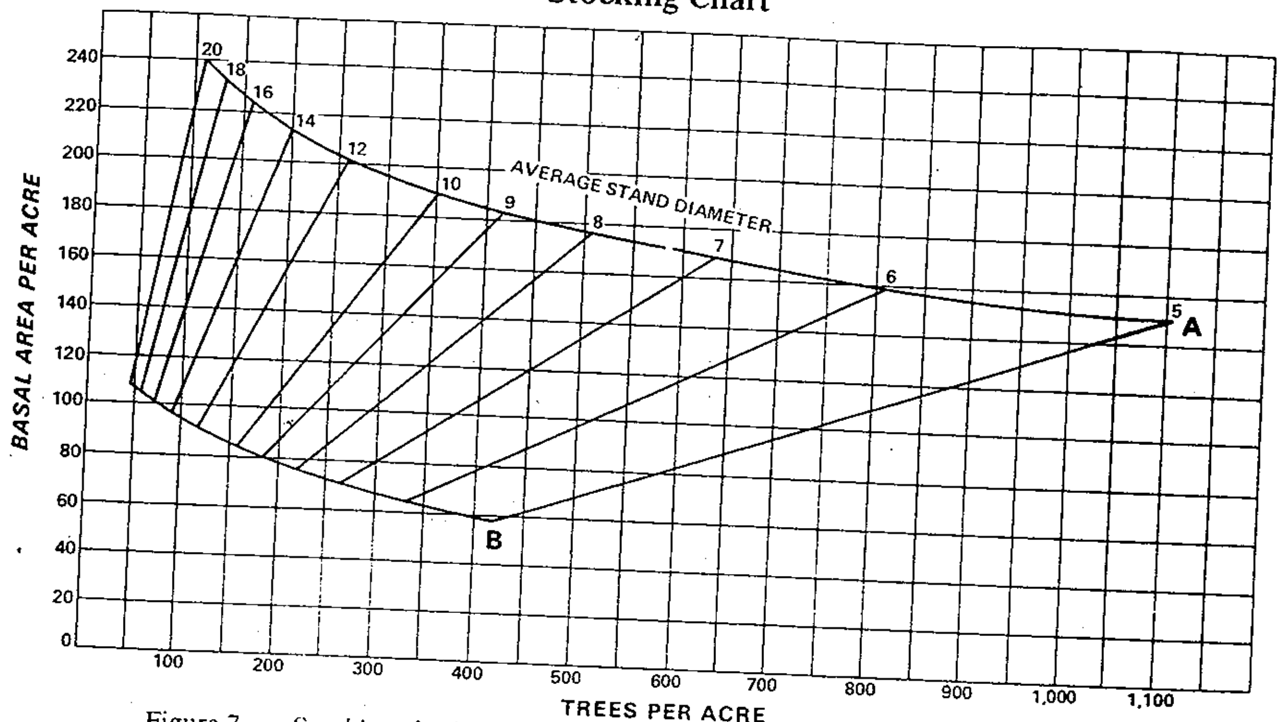


Figure 7. — *Stocking chart for managed red pine stands. Recommended upper limit (A curve) for managed stands is based on 80 percent of Brown and Gervorkiantz (1934) normal yield table with projection to 20 inches based on Woolsey and Chapman (1914). Minimum stocking (B curve) is based on crown width for open-grown trees from Ek (1971).*

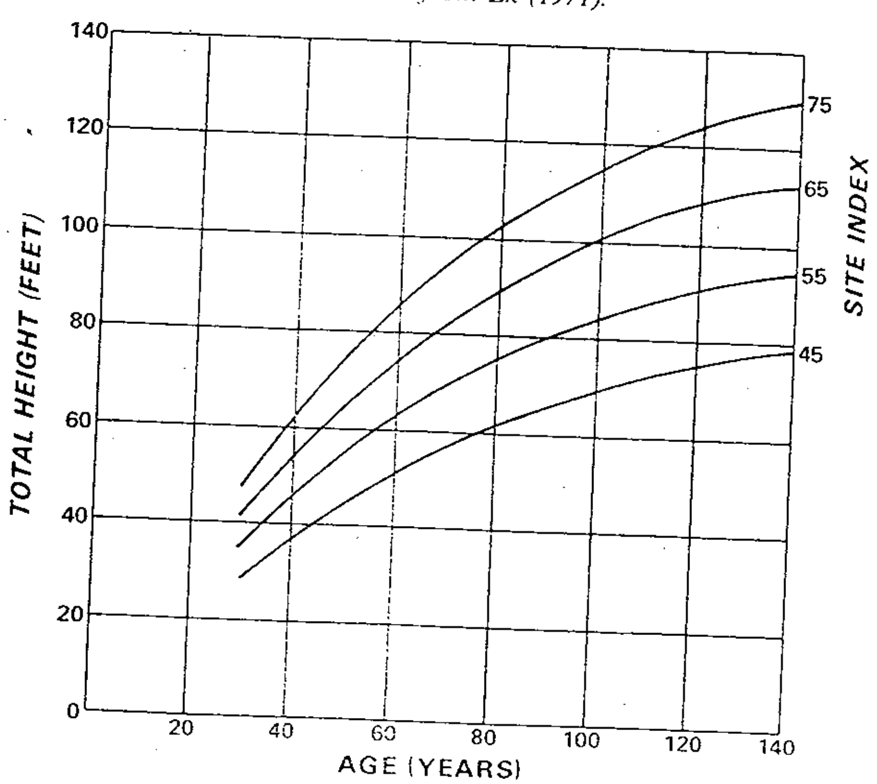


Figure 8. — *Red pine site index curves. Based on the equation: height = site index (1.956 - 2.1757 e -0.01644 (age)) (Lundgren and Dolid 1970).*

Growth and Yield Tables

Table 2. – *Average d.b.h. of young red pine stands*[1]

Total age	Total height	Number of trees per acre: 400	800	1200	1600	2000
Years	*Feet*			*Inches*		
				SITE INDEX 75		
15	21	5.2	4.5	3.9	3.5	3.2
20	30	6.5	5.6	4.9	4.4	4.0
25	38	7.4	6.4	5.6	5.0	4.5
30	46	8.2	7.0	6.1	5.5	5.0
				SITE INDEX 65		
15	19	4.7	4.0	3.5	3.2	2.9
20	26	6.0	5.1	4.5	4.0	3.6
25	33	6.9	5.9	5.2	4.6	4.2
30	40	7.5	6.5	5.7	5.1	4.6
				SITE INDEX 55		
15	16	4.2	3.6	3.2	2.8	2.6
20	22	5.4	4.6	4.0	3.6	3.3
25	28	6.2	5.4	4.7	4.2	3.8
30	34	6.9	5.9	5.2	4.6	4.2
				SITE INDEX 45		
15	13	3.6	3.1	2.7	2.4	2.2
20	18	4.8	4.1	3.6	3.2	2.9
25	23	5.6	4.8	4.2	3.7	3.4
30	28	6.2	5.3	4.8	4.1	3.8

[1]Computed from table 3 as diameter of tree of average basal area.

Table 3. – *Estimated basal area*[1] *of young red pine stands*

Total age	Total height	Number of trees per acre: 400	800	1200	1600	2000
Years	*Feet*			*Square Feet*		
				SITE INDEX 75		
15	21	59	87	101	107	110
20	30	93	136	157	167[2]	171
25	38	121	178	205	218	224
30	46	145	214	246	261	268
				SITE INDEX 65		
15	19	48	71	82	87	89
20	26	78	114	131	140	143
25	33	103	151	174	185	190
30	40	124	183	210	223	229
				SITE INDEX 55		
15	16	38	56	65	69	71
20	22	63	93	107	114	117
25	28	85	125	144	153	157
30	34	103	152	175	186	191
				SITE INDEX 45		
15	13	29	43	49	52	54
20	18	50	73	84	90	92
25	23	68	100	115	122	125
30	28	83	122	141	150	154

[1]Based on the equation $B = 6.565302(S)(1-e^{-.0401718(BHA)})^{1.1677}(1-e^{-.0018854N})$ where B = basal area, S = site index, BHA = breast height age, and N = number of trees established. Breast height age = total age - 10.5 +0.05(site). Equations were developed by A. L. Lundgren from data collected by R. F. Wambach (1967).

[2]Thinnings are recommended for the stands shown enclosed.

Table 5. – *Volume*[1] *in cubic feet per acre for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre: 30	60	90	120	150	180
Years	Feet	*Cunits (100 cubic feet) per acre*[2]					
		SITE INDEX 75					
20	30	3.7	7.3	11.0	14.7	18.4	22.0
40	61	7.5	14.9	22.4	29.9	37.3	44.8
60	86	10.5	21.0	31.6	42.1	52.6	63.2
80	103	12.6	25.2	37.8	50.4	63.0	75.6
100	115	14.1	28.2	42.2	56.3	70.4	84.5
120	124	15.2	30.4	45.4	60.7	75.9	91.1
140	130	15.9	31.8	47.7	63.6	79.6	95.5
160	134	16.4	32.8	49.2	65.6	82.0	98.4
		SITE INDEX 65					
20	26	3.2	6.4	9.5	12.7	15.9	19.1
40	53	6.5	13.0	19.5	25.9	32.4	38.9
60	74	9.0	18.1	27.2	36.2	45.3	54.3
80	89	10.9	21.8	32.7	43.6	54.5	65.4
100	100	12.2	24.5	36.7	49.0	61.2	73.4
120	107	13.1	26.2	39.3	52.4	65.5	78.6
140	112	13.7	27.4	41.1	54.8	68.5	82.2
160	116	14.2	28.4	42.6	56.8	71.0	85.2
		SITE INDEX 55					
20	22	2.7	5.4	8.1	10.8	13.5	16.2
40	45	5.5	11.0	16.5	22.0	27.5	33.0
60	63	7.7	15.4	23.1	30.8	38.6	46.3
80	76	9.3	18.6	27.9	37.2	46.5	55.8
100	85	10.4	20.8	31.2	41.6	52.0	62.4
120	91	11.1	22.3	33.4	44.6	55.7	66.8
140	95	11.6	23.2	34.9	46.5	58.1	69.8
160	98	12.0	24.0	36.0	48.0	60.0	72.0
		SITE INDEX 45					
20	18	2.2	4.4	6.6	8.8	11.0	13.2
40	37	4.5	9.1	13.6	18.1	22.6	27.2
60	51	6.2	12.5	18.7	25.0	31.2	37.4
80	62	7.6	15.2	22.8	30.4	37.9	45.5
100	69	8.4	16.9	25.3	33.8	42.2	50.7
120	74	9.1	18.1	27.2	36.2	45.3	54.3
140	78	9.5	19.1	28.6	38.2	47.7	57.3
160	80	9.8	19.6	29.4	39.2	49.0	58.8

[1] Cubic feet = 0.4085 (Basal area x Height) (Buckman 1962).

[2] Total main stem volume in cunits from 6-inch stump to tip of tree. Estimated cunits to a 4-inch top d.i.b. can be obtained by subtracting

$$1.067\left(\frac{\text{Basal area per acre in sq. ft.}}{\text{ave. tree diameter in inches squared}}\right)$$

Table 6. – *Current annual cubic foot growth*[1] *per acre for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre: 30	60	90	120	150	180
Years	Feet	*Cubic feet*					
		SITE INDEX 75					
20	30	101	131	158	182	203	218
40	61	142	180	210	232	246	253
60	36	147	188	218	237	246	244
80	103	131	174	204	221	225	217
100	115	110	154	184	199	200	188
120	124	85	129	158	172	171	159
140	130	72	117	146	159	156	137
160	134	63	109	139	152	149	130
		SITE INDEX 65					
20	26	80	108	132	152	169	183
40	53	108	140	166	185	198	206
60	74	109	144	168	185	196	195
80	89	92	128	150	168	172	165
100	100	66	104	130	143	143	136
120	107	48	86	112	124	124	110
140	112	30	69	94	106	104	93
160	116	25	64	89	100	96	78
		SITE INDEX 55					
20	22	61	83	103	119	133	144
40	45	80	107	129	145	155	160
60	63	75	106	128	143	151	150
80	76	56	87	109	121	124	118
100	85	36	69	91	103	105	96
120	91	19	48	71	86	86	74
140	95	--	36	58	68	67	54
160	98	--	26	48	57	54	39
		SITE INDEX 45					
20	18	45	63	79	93	105	114
40	37	56	77	94	109	117	121
60	51	47	72	90	101	106	105
80	62	30	56	73	83	86	80
100	69	9	36	53	63	64	59
120	74	--	20	38	46	46	36
140	78	--	6	23	30	32	20
160	80	--	--	20	28	26	14

[1] Cubic feet growth = 0.4085 (basal area growth x height + height growth x basal area + basal area growth x height growth) (Buckman 1962).

Table 9. – *Volume in M board feet per acre*[1] *for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre[2] 30	60	90	120	150	180
Years	Feet	- - - - - - M Board feet	- - - - - -				
SITE INDEX 75							
60	86	5.4	10.8	16.1	21.5	26.9	32.3
80	103	6.4	12.9	19.3	25.8	32.2	38.6
100	115	7.2	14.4	21.6	28.8	35.9	43.1
120	124	7.8	15.5	23.3	31.0	38.8	46.5
140	130	8.1	16.3	24.4	32.5	40.6	48.8
160	134	8.4	16.8	25.1	33.5	41.9	50.3
SITE INDEX 65							
60	74	4.6	9.2	13.9	18.5	23.1	27.8
80	89	5.6	11.1	16.7	22.3	27.8	33.4
100	100	6.3	12.5	18.8	25.0	31.3	37.5
120	107	6.7	13.4	20.1	26.8	33.4	40.1
140	112	7.0	14.0	21.0	28.0	35.0	42.0
160	116	7.2	14.5	21.8	29.0	36.3	43.5
SITE INDEX 55							
60	63	3.9	7.9	11.8	15.8	19.7	23.6
80	76	4.7	9.5	14.2	19.0	23.8	28.5
100	85	5.3	10.6	15.9	21.3	26.6	31.9
120	91	5.7	11.4	17.1	22.8	28.4	34.1
140	95	5.9	11.9	17.8	23.8	29.7	35.6
160	98	6.1	12.2	18.4	24.5	30.6	36.8
SITE INDEX 45							
60	51	3.2	6.4	9.6	12.8	15.9	19.1
80	62	3.9	7.8	11.6	15.5	19.4	23.3
100	69	4.4	8.6	12.9	17.3	21.6	25.9
120	74	4.6	9.2	13.9	18.5	23.1	27.8
140	78	4.9	9.8	14.6	19.5	24.4	29.3
160	80	5.0	10.0	15.0	20.0	25.0	30.0

[1]Board feet = 2.084 (Basal area x Height). Board-foot volume by Scribner Dec. C. log rule for trees 7.6 inches DBH to a 6-inch top d.i.b. (Buckman 1962).

[2]Must be in trees 7.6 inches DBH and larger.

Table 10. – *Current annual board foot growth per acre*[1] *for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre[2] 30	60	90	120	150	180
Years	Feet	- - - - - - - Board feet	- - - - - - - -				
SITE INDEX 75							
60	86	751	959	1112	1211	1255	1245
80	103	670	887	1039	1126	1148	1105
100	115	560	785	936	1016	1023	958
120	124	433	659	807	878	871	812
140	130	365	595	743	810	795	699
160	134	320	556	709	777	762	662
SITE INDEX 65							
60	74	556	737	856	943	999	993
80	89	467	654	766	860	878	841
100	100	339	531	661	728	732	694
120	107	242	440	571	634	630	560
140	112	153	352	482	541	530	472
160	116	127	327	454	509	491	400
SITE INDEX 55							
60	63	382	539	655	732	769	765
80	76	286	445	556	619	635	602
100	85	185	352	466	527	534	488
120	91	95	247	361	436	436	379
140	95	--	184	295	348	340	273
160	98	--	135	244	291	276	201
SITE INDEX 45							
60	51	242	365	457	516	542	537
80	62	155	284	374	425	437	410
100	69	48	182	273	320	325	300
120	74	--	102	192	236	233	183
140	78	--	29	116	155	161	103
160	80	--	--	102	142	131	71

[1]Board foot growth = 2.084 (basal area growth x height + height growth x basal area + basal area growth x height growth) (Buckman 1962).

[2]Must be in trees 7.6 inches DBH and larger.

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key – out of the reach of children and animals – and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

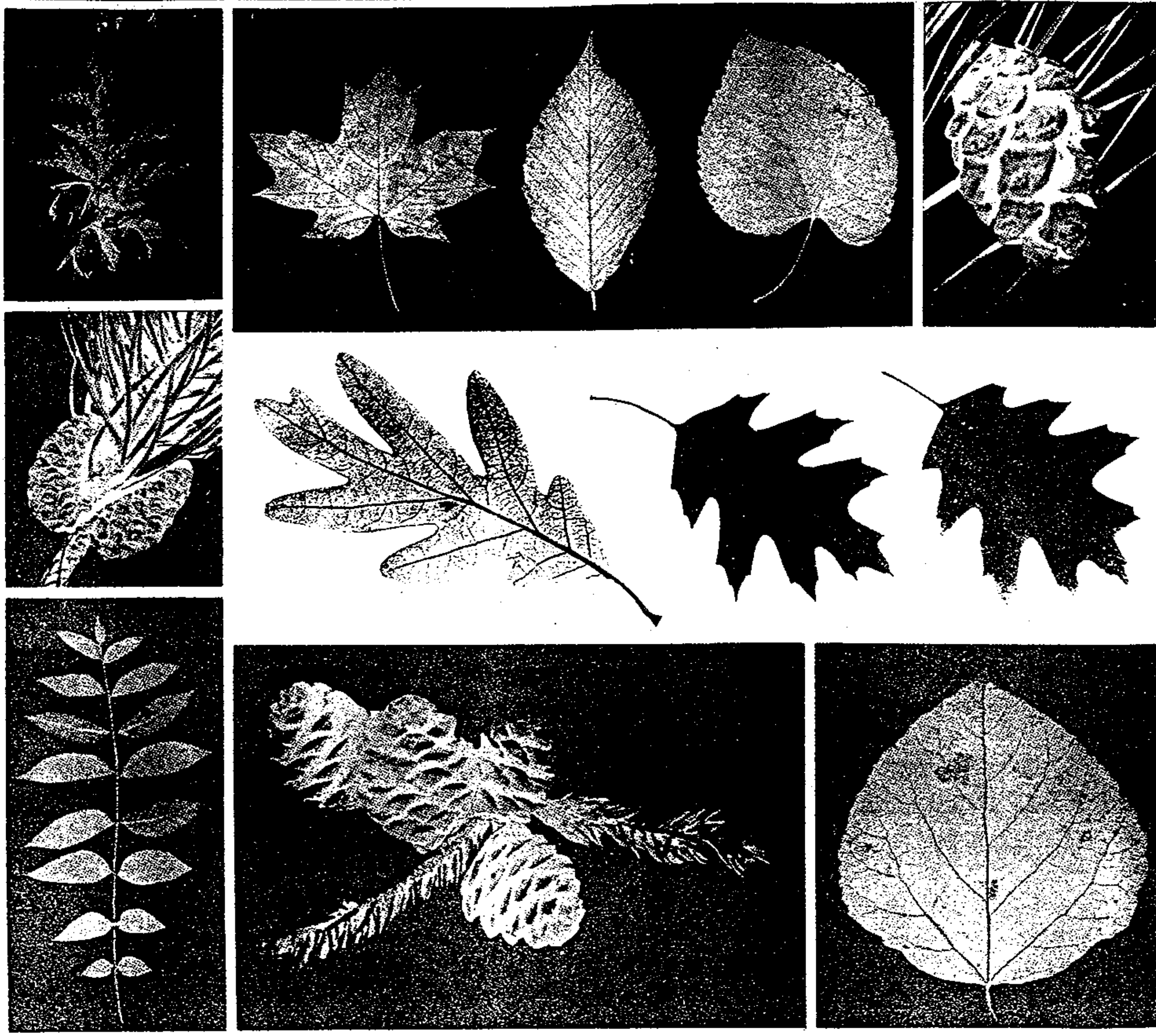
Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

Note: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.



manager's handbook for

OAKS IN THE NORTH CENTRAL STATES

GENERAL TECHNICAL REPORT NC-37

NORTH CENTRAL FOREST EXPERIMENT STATION FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

OAKS IN THE NORTH CENTRAL STATES

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This handbook applies to the broad upland forest association commonly called oak-hickory. The oaks, black, white, northern red, scarlet, chestnut, post, and blackjack predominate, and occur in widely varying mixtures with each other and with many other species (see Appendix V, table 21, for scientific names of plants and animals). Hickories are consistently present in this association but are not generally abundant. The reproduction requirements for hickory are essentially the same as those for oak, and although hickories are inherently slower growers than oaks, they require about the same growing space for good diameter and volume growth. Because oaks are by far most abundant, this guide is written in terms of oaks rather than oak-hickory.

The handbook was prepared to apply specifically to the north central States of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, and Wisconsin. However, the oaks or oak-hickory type occurs extensively over the eastern United States, and the principles on which the handbook is based generally apply wherever oak stands grow. Outside the north central States, however, the recommendations may need to be modified, so they should be applied with caution.

SILVICAL HIGHLIGHTS

Oaks are found over a wide range of soil and topographic conditions, from sandy, rocky soils to heavy clay soils, and from dry upper slopes and ridges to moist lower slopes and coves. Best growth occurs on moist well-drained soils in coves and on middle and lower slopes.

Oaks grow in association with many other tree and shrub species. Among their most important tree associates are the hickories, blackgum, red and sugar maples, yellow-poplar, white ash, black cherry, basswood, and black walnut. Common understory tree and shrub associates include flowering dogwood, sassafras, eastern hophornbeam, American hornbeam, blueberry, hazelnut, and witchhazel.

Oaks start to bear fruit at about age 25. Good seed crops are produced at intervals of 2 to 10 years; there may be complete failures some years. Acorn numbers vary widely by years and by trees within the same stand.

Acorns of species in the white oak group germinate soon after falling; those of species in the red oak group germinate the spring after seedfall. Best germination occurs in mineral soil under a light covering of leaves.

To successfully produce new oak stands after harvest cuttings, relatively large oak stems (advance reproduction) must be present before the old stand is harvested. These stems will generally be sprouts that typically have died back to the ground and resprouted several times. So, the stem is usually many years younger than the root system. When such stems are cut off or damaged during harvest, a new sprout appears that will grow rapidly in full sunlight. These new sprouts are the most desirable

4. Seed source or advance reproduction of other desirable hardwoods present . . . . REMOVE OAK OVERSTORY USING SHELTERWOOD CUT, *or* CLEARCUT (See p. 10, R)

4. Seed source or advance reproduction of other desirable hardwoods absent . . . . .HARVEST AND INTERPLANT WHITE ASH, SUGAR MAPLE, OR OTHER SUITABLE SPECIES (See p. 10, R)

5. Stand basal area two-thirds or more in oak . . . . MANAGE FOR OAK OR MIXED OAK – OTHER HARDWOODS (See p. 9, P)

5. Stand basal area one-third or less in oak . . . . .MANAGE OTHER DESIRABLE HARDWOODS (See p. 9, P)

6. Stand in southern Illinois, southern Indiana, or southern Lower Michigan . . . . (See p. 4, A) . . 7

6. Stand in Ozarks region of Missouri . . . . MANAGE FOR OAKS (See p. 4, A) . . 12

7. Stand mature (more than 50 percent of basal area in trees that have reached the desired size for the site) . . . . . . .CONVERT TO OTHER HARDWOODS OR MIXED OAK – OTHER HARDWOODS (See p. 10, S)

7. Stand immature (less than 50 percent of basal area in trees that have reached the desired size for the site) 8

8. Stand basal area 50 percent or more in oaks . . . . MANAGE FOR OAK OR MIXED OAK – OTHER HARDWOODS (See p. 9, P)

8. Stand basal area less than 50 percent in oaks . . . . .MANAGE FOR MIXED OAK – OTHER HARDWOODS OR OTHER HARDWOODS (See p. 9, P)

9. Oak site index 65 through 74 10

9. Oak site index less than 65 11

10. Stand in southern Illinois, southern Indiana, "Driftless Area" of Minnesota, Wisconsin, and Iowa, or Lower Michigan . . . . MANAGE FOR OAK OR MIXED OAK–OTHER HARDWOODS (See p. 4, B; p. 9, P) . . 12

10. Stand in Ozarks region of Missouri or elsewhere . . . . MANAGE FOR OAKS (See p. 4, B) . . 12

11. Oak site index 55 through 64 . . . . MANAGE FOR OAK OR MIXED OAK–PINE (See p. 4, B; p. 10, Q) . . 12

11. Oak site index less than 55 . . . . CONVERT TO PINE *or* DO NOT MANAGE (See p. 5, C; p. 10, T)

12. Stand mature (more than 50 percent of basal area in trees that have reached the desired size for the site) (See p. 6, D) 13

12. Stand immature (less than 50 percent of basal area in trees that have reached the desired size for the site) (See p. 7, H) . . . 14

13. Oak advance reproduction adequate . . . . HARVEST (See p. 6, E)

13. Oak advance reproduction inadequate . . . . ESTABLISH AND DEVELOP OAK ADVANCE REPRODUCTION (See p. 6, F)

14. More than 50 percent of stand basal area in one size class 15

14. No single size class contains more than 50 percent of stand basal area (See p. 9, K) 19

15. More than 50 percent of stand basal area in saplings or pole size trees (See p. 9, I) . . . REDUCE STOCKING TO NOT LESS THAN 60 PERCENT; THIN AT 10-YEAR INTERVALS

15. More than 50 percent of stand basal area in sawtimber size trees (See p. 9, J) 16

16. Stand fully stocked (total stocking 60 percent or higher) 17

16. Stand understocked (total stocking less than 60 percent) or of poor quality . . . . REHABILITATE *or* REGENERATE (See p. 9, O)

17. More than half of trees at least 80 percent of desired rotation diameter (See p. 9, L) 18

17. More than half of trees less than 80 percent of desired rotation diameter . . . . .THIN *or* WAIT (See p. 9, N)

18. Stocking 80 percent or more . . . . THIN LIGHTLY TO ENHANCE OAK ADVANCE REPRODUCTION (See p. 9, L)

18. Stocking 60 through 79 percent . . . . WAIT (See p. 9, M)

19. More than 50 percent of basal area in saplings and poles . . . . . . COMBINE SAPLINGS/POLES INTO ONE CLASS (See p. 9, K)

19. More than 50 percent of basal area in poles and sawtimber . . . . COMBINE POLES/SAWTIMBER INTO ONE CLASS (See p. 9, K)

TIMBER MANAGEMENT CONSIDERATIONS

Stand Size

A number of factors must be considered when choosing the size of a stand and delineating its boundaries. There is no silvicultural reason to set an upper limit for stand size, but *there are* silvicultural reasons to limit the minimum size. When an old stand is completely removed, the new stand develops in the opening. In every opening there is a zone around the edge in which growth of the new stand is retarded by the surrounding

Table 1. – *Preferred species for management by region and site index*

Region	Site index class	Preferred oaks	Preferred associated species
	Feet		
Missouri Ozarks	75+	N. Red Oak Black Oak White Oak	Black Walnut Hickories
	55-74	Black Oak White Oak N. Red Oak Scarlet Oak	Black Walnut Hickories Shortleaf Pine
	40-54	Scarlet Oak Black Oak White Oak N. Red Oak	Hickories Shortleaf Pine
Southeastern Minnesota, southern Wisconsin, northeastern Iowa	75+	N. Red Oak White Oak	White Ash Sugar Maple American Basswood Butternut Black Walnut
	55-74	N. Red Oak Black Oak White Oak	White Ash Sugar Maple Black Walnut American Basswood White Pine Red Pine
	40-54	Black Oak White Oak Bur Oak	Hickories Red Pine
Lower Michigan	75+	N. Red Oak White Oak	American Basswood Black Cherry White Ash Sugar Maple Black Walnut Yellow Poplar
	55-74	N. Red Oak Black Oak White Oak	White Ash American Basswood Sugar Maple Hickories
	40-54	Black Oak White Oak N. Pin Oak	Aspen Jack Pine Red Pine Red Maple
Southern Illinois, southern Indiana	75+	N. Red Oak Black Oak White Oak	Yellow Poplar White Ash Black Walnut
	55-74	N. Red Oak Black Oak White Oak Chestnut Oak	Yellow Poplar White Ash Black Walnut Hickories
	40-54	Black Oak Chestnut Oak Scarlet Oak White Oak	Hickories

Management for essentially pure oak on these sites should be feasible anywhere in the region, except as noted above. However, special measures may be necessary to ensure establishment and development of adequate oak advance reproduction.

In the Ozarks and in Lower Michigan, mixtures of pine and oak are sometimes present on these sites. It should be feasible to manage these stands as mixtures.

C. The poor sites (site index 40 to 54) are almost exclusively occupied by oaks. Stands are often of poor existing understory will impair the growth of the planted seedlings, its density should be reduced. Seedlings should be planted at the rate of 500 to 600 per acre. Spacing can be irregular and seedlings should not be planted close to large overstory trees. As with natural reproduction, the planted seedlings must be allowed to reach the minimum size necessary before the overstory is finally removed.

Plant the largest oak seedlings available. Seedlings should be at least 1/4-inch in diameter at the root collar. Do not be afraid to cull the smaller ones. The larger seedlings have a much better potential because of their larger root systems. Size is critical in the root system's ability to support vigorous shoot growth after harvest cutting.

Planting oaks after clearcutting has generally been unsatisfactory because the planted seedlings do not grow fast enough to compete with the new sprouts.

Once new seedlings are established, or if advance reproduction is present in sufficient numbers but below the minimum size, they must be allowed to grow in the understory until they reach the minimum size. Oak advance reproduction grows slowly and the development period may be 10 to 20 years or longer. Cultural techniques to enhance oak advance reproduction growth have yet to be developed. Maintaining the overstory at 55 to 60 percent stocking should help. And, if there is an understory of competing woody stems present, its density should probably be reduced by killing the unwanted stems with herbicides.

Controlling Composition

G. The composition of oak-hickory stands can be altered to some degree at any time before a stand reaches large pole or small sawtimber size. However, the best time to control composition is when regeneration is first established. Oaks will be present in new stands in proportion to their occurrence in the advance reproduction. And, the composition of the advance reproduction is often unrelated to that of the overstory. Although one oak species may predominate in the overstory, a different oak may prevail in the understory.

Increasing the amount of one oak species relative to others is difficult. If advance reproduction is well established and adequate for several species, the less desirable species can be removed from the advance reproduction by selective treatment with herbicides. If advance reproduction is scarce and the overstory is well stocked, the species not wanted can be removed from the overstory so no seed of that species will be available. Another alternative is to underplant the wanted species, and at the same time remove the unwanted species from the overstory. In any situation where composition control in the advance reproduction is needed or wanted, the principles applicable to controlling stand establishment must be followed (see p. 6).

Weedings or cleanings may be necessary to control composition and maintain oaks in the new stands. They should be made no later than 10 years after harvest cutting, particularly if oak advance reproduction was barely adequate or stump sprouts were depended on to furnish the oak component of the new stands.

When these weedings or cleanings are made, reduce stump sprout clumps to one or two stems, and release the fastest growing oak stems. Do not attempt to eliminate all undesirable stems. Select potential crop trees on a spacing of about 15 feet and release only those that need it. Generally, dominant and codominant trees should be selected for crop trees. However, some of the better intermediates may be released if necessary to maintain an adequate stocking of oaks.

Controlling Growth

H. Total growth or production of wood in oak stands will be about the same over a wide range of stocking, provided there are enough trees in the stand to fully utilize the site. However, individual tree growth will be greatest near the lower limit of stocking that fully utilizes the site. Although total growth cannot be increased, regulation of stocking by thinning results in growing merchantable products quicker, increased product yields, and shorter rotations.

Thinnings should be started as early in the life of a stand as possible in order to realize the full potential yields of the site (table 3). When thinnings are started at age 10 to 20, and followed by periodic thinnings at about 10-year intervals, the time required to grow trees to a given diameter can be greatly reduced and the greatest yield obtained (see Appendix II, tables 11-19). The first thinning in these young stands and possibly the second may not yield commercial products unless a market for small roundwood exists. If precommercial thinnings are not feasible, the latest effective first thinning age for rapid growth response is 40 or 50 years. Previously unthinned stands older than 50 years can and probably should be thinned, especially on good sites. Although residual trees are not likely to respond very well, merchantable products can be recovered from trees

Leave the best trees spaced as uniformly as possible throughout the stand. In a first thinning at age 20 or later it will probably be impossible to remove all of the undesirable trees and still retain about 60 percent stocking and adequate spacing. Remove as many as possible in the first thinning and the remainder in the second and third thinnings.

Fully stocked, immature stands are prime candidates for thinning. In such stands, the size class that will form the main stand must be chosen and the trees in that size class managed to maturity. In some existing stands, two adjacent size classes (saplings-pole or poles-sawtimber) might have to be combined in order to form a main stand with adequate stocking.

I. If the main stand is saplings or poles, thinnings should not be delayed. Reduce stocking to not less than B level (see Appendix III, fig. 7) and plan to make additional thinnings at about 10-year intervals.

J. If the main stand is sawtimber, the intensity of thinning depends on how well the stand is stocked, how close to maturity the stand is, and on the quality of the growing stock.

If the basal area of acceptable growing stock is above C level (see Appendix III, fig. 7), the stand is worth managing, but if it is below B level it will be several years before the good trees will fully occupy the site. If acceptable growing stock is below C level, the stand cannot be saved without great waste of time and growing space and should be regenerated as soon as adequate advance reproduction exists.

K. When no single size class contains more than 50 percent of the total basal area, combine two adjacent size classes for a manageable stand. In such cases the recommendations for the size class with the most basal area should generally be followed when making intermediate cuts. There are probably exceptions to this general rule, and good professional judgment must be used to make the final decision.

L. If the majority of the trees are 80 percent or greater of the desired rotation diameter for the site (table 2), whether to cut or not depends on stocking and the adequacy of the oak advance reproduction present. If stocking is 80 percent or more, a light thinning can be made and is especially desirable if oak advance reproduction is scarce or small. However, in previously unthinned stands, DO NOT reduce stocking below 70 to 75 percent and do not make large holes in the stand. DO NOT be tempted to make a cut in this type of stand merely because it contains good volumes of desirable trees or to get volume to satisfy cutting goals. Any cutting should be designed more to enhance the establishment or development of advance reproduction rather than growth. Cutting should be restricted to the poorest trees, and primarily the lower crown classes.

M. In stands 60 to 80 percent stocked, wait. These stands will usually have a fairly dense understory. If there is not much oak advance reproduction, some understory control is probably needed, but further reduction of the overstory is probably not necessary or desirable because not enough trees can be removed to benefit the entire stand.

N. If the majority of trees are less than 80 percent of the desired size for the site, the stand should be thinned unless the initial stocking is not much above B level. If the stand shows no evidence of cutting 10 to 20 years previously, do not reduce stocking below 70 percent and take note of oak advance reproduction adequacy. If the stand was cut 10 to 20 years previously, it can be thinned to B-level stocking but heed the warnings in section L. If initial stocking is not much above B level, do nothing unless oak advance reproduction is scarce. In any event, cutting should be light and designed more to increase oak advance reproduction than promote growth of the overstory trees.

O. Sawtimber stands that are understocked (below B level) or of poor quality should be rehabilitated or regenerated as soon as possible. Such stands will likely contain heavy understories, and should be regenerated immediately if oak advance reproduction is adequate. If not, measures must be taken to develop it.

MIXTURES OF OAKS AND OTHER SPECIES

P. Harvesting existing oak stands in the "Driftless Area" of Wisconsin, Minnesota, and Iowa, and in Lower Michigan, southern Illinois, and southern Indiana often results in the new stands of mixed composition. If oaks are few in number but well distributed in these reproduction stands, it may be possible to create a stand with a good oak component by the time it reaches sawtimber size. To do this will require early weeding – possibly as early as age 5 – and careful attention to the oaks that are present.

very poor sites. To establish these northern pines use the guidelines in the jack pine and red pine handbooks (Benzie 1977a, 1977b).

Damaging Agents

Fire

Fire has had an important role in the establishment of existing oak stands throughout the north central States. The recurrent fires that followed cutting of the original timber stands all but eliminated the less fire-resistant species. The oaks were able to survive because of their ability to sprout repeatedly. With the advent of fire protection and control of widespread burning, the present oak stands developed.

Although fire has been a prime factor in the development of the present oak stands, its use as a silvicultural tool for regenerating oak cannot be recommended now. Where it has been tried, it has not been successful in producing the desired results.

Oaks are susceptible to damage by fire at all stages during a rotation. The primary damage is the killing of the cambial tissue at the base of the tree and the subsequent decay of the wood. Many of the cull trees in present oak stands are cull because of fire. For this reason, fire should generally be excluded from oak stands.

Drought

Drought is one of the most seriously damaging agents of oak stands. Twelve- to 16-week periods without rainfall, especially if recurring in successive years, can severely affect oaks for several years. Growth is reduced and weakened trees are often attacked by insects and root rot.

The effects of severe drought are less in thinned stands than in dense stands, however. Thinned stands are more resistant because the trees have better vigor, and even though growth will be lowered, trees can often withstand the attack by secondary agents.

Disease

Heartwood decay by wood rotting fungi is one of the most serious diseases of oaks. Although trees are seldom killed, decay often renders the entire stem unusable for timber products. The primary entry points for decay fungi are fire scars and dead branch stubs. There are many species of wood rotting fungi, but the most important ones are *Poria andersonii, Stereum gausapatum, Stereum frustulatum, Hericium* spp., *Polyporus compactus, Poria cocos, Irpex molli,* and *Polyporus sulphureus.*

Losses from these organisms can be reduced by fire protection and through silvicultural practices. In oak sprout clumps the upper sprouts should be thinned out before heartwood begins to form and the sprouts of lowest origin on the stump retained. In thinnings, one or more sprouts separated from a companion sprout by a low U-shaped crotch can be safely removed. However, sprouts that form a V-shaped crotch should either be left alone or the entire clump cut. Stand density in young stands should be high enough to shade out the lower branches while they are small.

Mortality from oak wilt, a vascular fungus disease, may be locally severe. This disease kills species of both the red and white oak groups. Red oaks usually die within a few weeks after the symptoms first become evident. White oaks are more resistant to the disease because of the presence of tyloses in the vessels and trees usually die over a 2- to 3-year period. The disease spreads from tree to tree through root grafts and is also spread by insects. There are no known control measures that are completely effective.

Less serious diseases that attack oaks are anthracnose, leaf blister, and the canker diseases.

Insects

Many insects attack the oaks. Severe damage and degrade to lumber are caused by the carpenterworm, the white oak borer, the red oak borer, and Columbian timber beetle. Important insects that feed on the leaves include the variable oak leaf caterpillar, gypsy moth, oak leaf roller, oak leaf tier, forest tent caterpillar, and the orange-striped oakworm. These insects are capable of completely defoliating oaks, sometimes over rather large areas. A single defoliation is not serious but may result in weakened trees and a loss of growth. Defoliation each year for 2 or 3 years or more can cause mortality that is sometimes widespread and severe. Volume losses can be high. Insects that attack acorns cause heavy losses and may even destroy the entire crop in years of low production. Acorn weevils are the most destructive of the acorn-attacking insects.

There are no practical insect control measures for use in oak stands. Chemicals can be used to control the defoliators if the cost can be justified (see Pesticide Precautionary Statement, Appendix V). Removal of the low vigor, defective trees during thinnings should help reduce damage from wood boring insects.

should be located and constructed to cause the least landscape disruption possible. Trash should not be allowed to accumulate.

Clearcutting is the most unsightly of any silvicultural operation, but it need not be. It is very important to design clearcuts to fit the topography and general landscape. They should not dominate the landscape, and if they are large, they should be irregular in shape so that only portions are visible from one observation point. Dead snags may be objectionable in some instances, but can be left to provide sites for cavity-nesting birds. Occasionally small groups of trees can be left to add variety.

To maintain visually pleasing conditions around campgrounds, picnic areas, and other areas of high recreation use, the usual silvicultural practices have to be modified. Thinnings should be light and the slash lopped and scattered. Openings can be made for regeneration if they are kept small. Perpetuation of oaks will be difficult at best. Reproduction should be ensured by planting if necessary and care taken to develop the seedlings. Costs will be high but timber production is of secondary importance in these areas.

Table 5. — *White oak site index estimates by 2-foot height and 2-year age intervals*[1] *(McQuilkin 1974)*

Age	Height (feet)																																								
(years)	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
10	46	49	52	54	57	60	62	65	68																																	
12	44	47	49	52	54	57	60	62	65	68																																
14		44	47	49	52	54	57	59	62	64	67	69																														
16			44	47	49	52	54	56	59	61	64	66	68	71																												
18				44	47	49	51	54	56	58	61	63	65	68	70																											
20					44	46	48	51	53	55	57	60	62	64	66	69																										
22					42	44	46	48	51	53	55	57	60	62	64	66	69	71																								
24						43	44	46	48	51	53	55	57	59	62	64	66	68	71																							
26							42	44	46	48	51	53	55	57	59	62	64	66	68	70																						
28								42	44	46	48	50	53	55	57	59	61	64	66	68	70																					
30									42	44	46	48	50	52	55	57	59	61	63	66	68	70																				
32									40	42	44	46	48	51	53	55	57	59	61	64	66	68	70																			
34										40	42	44	46	49	51	53	55	57	59	62	64	66	68	70																		
36											40	42	45	47	49	51	53	55	57	60	62	64	66	68	70																	
38												40	43	45	47	49	51	53	55	57	60	62	64	66	68	70																
40													41	43	45	47	49	51	53	55	58	60	62	64	66	68	70															
42													39	41	44	46	48	50	52	54	56	58	60	62	64	66	68	71														
44														40	42	44	46	48	50	52	54	57	59	61	63	65	67	69	71													
46														39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71												
48															39	41	43	45	47	49	52	54	56	58	60	62	64	66	68	70												
50															38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70											
52																39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71										
54																	40	42	44	46	48	50	52	54	56	58	60	62	63	65	67	69	71									
56																	39	41	43	45	47	49	51	53	55	56	58	60	62	64	66	68	70									
58																		40	42	44	46	48	50	51	53	55	57	59	61	63	65	67	68	70								
60																		39	41	43	45	47	48	50	52	54	56	58	60	61	63	65	67	69	71							
62																			41	42	44	46	48	49	51	53	55	57	58	60	62	64	66	67	69	71						
64																			40	42	43	45	47	49	50	52	54	56	57	59	61	62	64	66	68	69	71					
66																			39	41	43	44	46	48	49	51	53	54	56	58	59	61	63	64	66	68	70					
68																			39	40	42	44	45	47	49	50	52	54	55	57	58	60	61	63	65	66	68	69				
70																				40	41	43	45	46	48	49	51	52	54	55	57	58	60	62	64	65	66	68	69			
72																				39	41	42	44	46	47	49	50	52	53	55	56	58	59	61	63	64	66	67	69	70		
74																				39	40	42	43	45	47	48	50	51	53	54	56	57	59	61	62	64	65	67	68	70		
76																					40	41	43	45	46	48	49	51	52	54	55	57	58	60	62	63	65	66	68	69	71	
78																					39	41	42	44	46	47	49	50	52	53	55	56	58	59	61	63	64	66	67	69	70	
80																					39	40	42	43	45	47	48	50	51	53	54	56	57	59	60	62	64	65	67	68	70	71

[1]All height and age combinations to the left of the line are within the range of the original data; combinations to the right of the line are extrapolations.

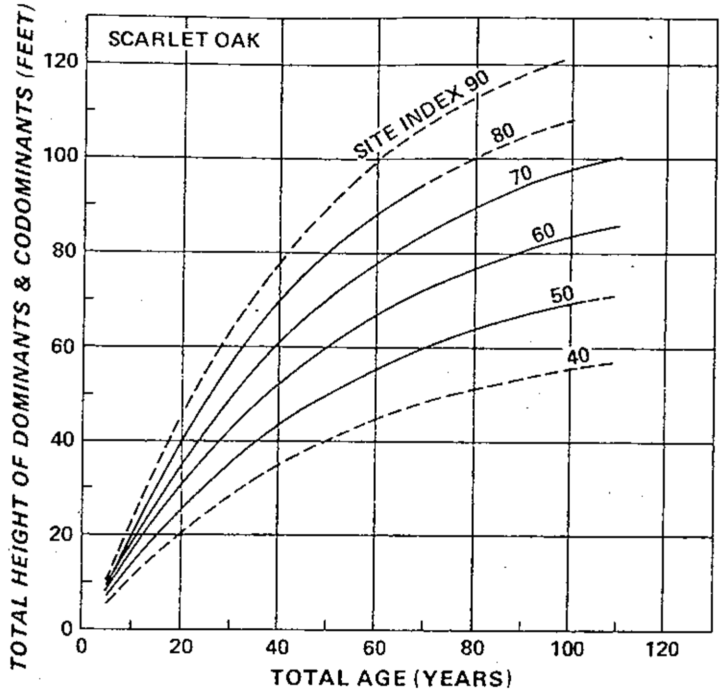

Figure 3. – *Site index curves for scarlet oak in the Central States. These curves are based on stem analyses of 88 dominant and codominant scarlet oaks growing on 25 plots located in the unglaciated portions of southeastern Ohio, eastern Kentucky, southern Illinois, and southern Missouri (Carmean 1971).*

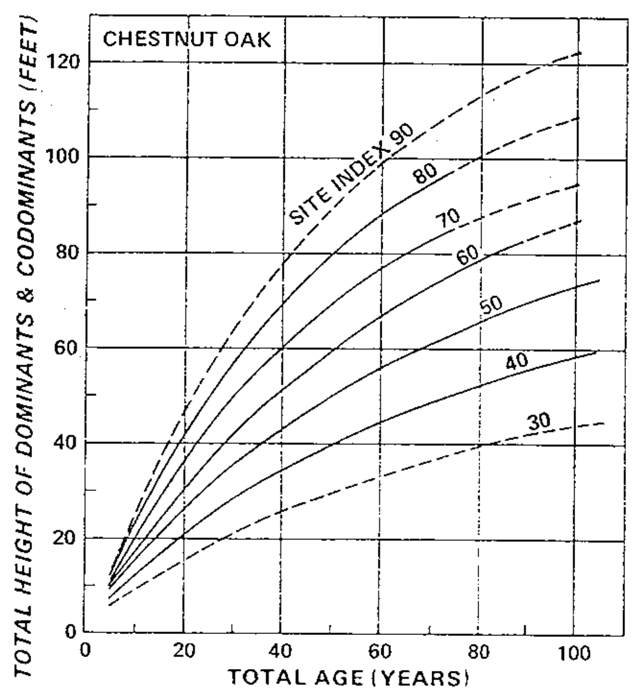

Figure 4. – *Site index curves for chestnut oak in the Central States. These curves are based on stem analyses of 59 dominant and codominant chestnut oaks growing on 18 plots located in the unglaciated portions of southeastern Ohio, eastern Kentucky, and southern Indiana (Carmean 1971).*

Table 6. – *Soil and topographic features affecting site productivity of oak forests in the Lake States (Arend and Scholz 1969)*

Site quality	Site index and growth potential at age 80[1]				Soil features and corresponding topographic features[2]	
	Site index	Number 16-foot logs	Mean annual growth per tree	Periodic annual growth per acre	Soil	Topography
			Cu. ft.	*Bd. ft.*		
Good	70+	2½+	0.4-0.6	200-300	A. Deep, moderately and well-drained silts, loams, and clays where soil depth is 3 feet or more to parent rock; sands where water table is within 4 to 10 feet of the surface.	A. On relatively flat topography, broad ridges, lower slopes, bottoms and valley coves; all north and east slopes where gradients are less than 20 percent; middle north and east slopes where gradients range from 20 to 35 percent.
Medium	55-65	1½-2½	.3- .4	100-200	A. Moderately deep (20 to 36 inches) silts, loams, and clays, or deep sands, with fine-textured bands in subsoil 2 to 6 inches in thickness at depths less than 60 inches. B. Deep sands. C. Deep silts and loams.	A. On relatively flat land, upper and middle north and east slopes where gradients are less than 20 percent; middle north and east slopes where gradients range from 20 to 35 percent. B. On lower slopes in rolling topography. C. On upper and middle south and west slopes where gradients are less than 20 percent.
Poor	40-55	½-1½	.1- .2	Less than 100	A. All shallow soils less than 20 inches in depth and deep porous sands. B. All soils. C. All soils.	A. On flat topography. B. On narrow ridges and upper slopes in hilly topography. C. On middle south and west slopes where gradients exceed 20 percent.

[1]Measurements from dominant trees (red oak group) in unmanaged stands.
[2]Does not apply to prairie soils and loessial deposits.

Table 8. – *Oak site index and soil characteristics in northeastern Iowa (Einspahr and McComb 1951)*

Soil Series	Textural composition A	Textural composition B	Horizon thickness A	Horizon thickness B	Horizon thickness Total	Permeability sub-soil	Natural internal aeration	Moisture condition due to topographical position	Percent slope	Site index
			Inches							
Chaseburg-Judson	Silt loam	Silt clay loam	14	16	D[1]	Moderate	Good	Very good	4	64
Fayette	Silt loam	Heavy silt loam	10	16	D[1]	Moderate	Good	Fair	15	60
Quandahl	Silt loam to sandy loam varying amounts of rock fragments.		14	12	D[1]	Moderate	Good	Good	25	57
Dubuque	Silt loam	Heavy silt loam	10	16	30	Moderate	Good	Fair	18	55
315	Clay loam to sandy loam varying amounts of rock fragments.		--	--	18	Moderate	Good	Good	10	52
Steep stony N-aspect	Clay loam to sandy loam varying amounts of rock fragments.		--	--	--	Rapid	Good	Poor to good	40	52
Chelsea	Loamy sand to sand	--	--	--	D[1]	Very rapid	Good	Fair	10	44
Steep stony S-aspect	Clay loam to sandy loam varying amounts of rock fragments.		--	--	5	Rapid	Good	Very poor to fair	40	37
Zwingle	Clay loam	Heavy clay	12	15	12	Very slow	Very poor	Fair	1	36
Sogn	Silt clay loam	Clay loam	--	--	8	Rapid	Good	Poor	8	33

[1]Greater than 36 inches.

Table 9. – *Predicted site index for white oak in southern Indiana (Hannah 1968)*

Position	Clay content of the lower subsoil horizon (B_2) (in percent)	A_1- and A_2-horizon thickness--inches: 2.0-4.0		4.1-6.0		6.1-8.0		8.1-10.0	
Ridges	Less than 40	51		57		64		73	
	40-60	44		50		56		63	
	More than 60	38		43		48		55	
		North	South	North	South	North	South	North	South
Upper slopes 2-50 percent of distance from ridge	Less than 40	61	55	66	61	72	67	78	75
	40-60	55	48	60	53	65	59	71	65
	More than 60	50	42	54	47	59	52	65	58
Lower slopes 51-99 percent of distance from ridge	Less than 40	66	60	71	65	75	70	80	76
	40-60	60	53	64	57	68	62	73	66
	More than 60	55	46	58	50	62	54	66	59
Bottoms	Less than 40	73		77		80		84	
	40-60	68		71		74		77	
	More than 60	63		66		69		72	

Aspect: North slopes include azimuths from 315 to 135 degrees and south slopes include azimuths from 136 to 314 degrees.

Slope shape: All site-index values are for linear-shaped slopes. For concave-shaped slopes add 2 feet; for convex-shaped slopes substract 2 feet.

Stone content: All site-index values are for relatively stone-free soils (0 to 30 percent stone in the B_2 horizon); for stony soils (31 to 60 percent stone in B_2) substract 2 feet; for very stony soils (more than 60 percent stond in B_2) substract 3 feet.

Texture of the B_3 horizon: Site-index values in the table are for conditions where all subsoil horizons have the same general texture. Four feet should be subtracted from the values for subsoil with less than 40 percent clay if the B_2 of this soil is underlain with a B_3, B_x, or C horizon having 40 to 60 percent clay. Four feet should be substracted from the values for subsoils with 40 to 60 percent clay if the B_2 of this soil is underlain by a B_3, B_x, or C horizon with more than 60 percent clay.

Silt content: All site-index values are for soils with more than 25 percent silt in the B_1 horizon. For soils with less than 25 percent silt substract 4 feet from the indicated site-index values.

APPENDIX II

YIELD TABLES

Table 11. – *Yields per acre for upland oak; no thinning (Gingrich 1971)*

Age	Basal area	Trees	Average tree diameter[1]	Yields		
Years	*Square feet*	*No.*	*Inches*	*Cubic feet*	*Cords*	*Board feet*
SITE INDEX 55						
20	55	2,500	2.0	60	0.6	--
30	75	1,260	3.3	583	5.3	--
40	87	790	4.5	1,320	12.1	--
50	97	480	6.1	2,150	19.7	400
60	104	357	7.3	2,520	22.9	900
70	108	295	8.2	2,730	24.4	2,800
80	112	242	9.2	2,880	25.6	5,400
SITE INDEX 65						
20	59	1,880	2.4	178	1.6	--
30	81	930	4.0	1,200	10.6	--
40	96	505	5.9	1,840	18.2	440
50	105	342	7.5	2,800	26.9	2,150
60	111	262	8.8	3,300	30.8	5,160
70	115	215	9.9	3,700	33.3	7,200
80	117	187	10.7	3,950	35.6	8,200
SITE INDEX 75						
20	70	1,425	3.0	694	6.4	--
30	89	680	4.9	1,670	16.7	--
40	101	400	6.8	2,440	23.7	1,380
50	110	279	8.5	3,315	30.1	4,100
60	114	222	9.7	4,140	37.7	9,288
70	117	187	10.7	4,760	43.0	11,200
80	120	166	11.5	5,160	46.5	12,500

[1]The diameter of the tree of average basal area.

Table 12. – *Yields per acre for upland oak; first thinning at age 10 (Gingrich 1971)*

Age	Residual stand					Cut stand				Cumulative total yields (cut stand plus residual stand)		
	Basal area	Average tree diameter	Yield			Basal area	Yield					
Years	*Square feet*	*Inches*	*Cubic feet*	*Cords*	*Board feet*	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*
SITE INDEX 55												
10	20	1.9	--	--	--	--	--	--	--	--	--	--
20	48	4.1	515	5.0	--	7	25	--	--	540	5.0	--
30	58	5.9	1,190	9.9	240	20	345	4.2	--	1,560	14.1	240
40	64	8.0	1,640	15.0	1,560	19	350	3.6	160	2,360	22.8	1,720
50	71	10.6	1,990	18.3	3,800	16	415	4.4	590	3,125	30.5	4,550
60	75	13.0	2,280	20.7	6,540	16	485	4.9	1,050	3,900	37.8	8,340
SITE INDEX 65												
10	23	2.1	--	--	--	--	--	--	--	--	--	--
20	51	4.5	775	6.8	--	8	125	1.2	--	900	8.0	--
30	59	6.4	1,445	13.1	540	25	370	3.8	--	1,940	18.1	540
40	66	8.6	1,920	18.0	2,280	21	465	3.8	280	2,880	26.8	2,560
50	72	11.0	2,340	21.8	5,250	19	575	5.2	970	3,875	35.8	6,500
60	76	13.7	2,655	24.3	8,940	18	670	5.8	1,810	4,860	44.1	12,000
SITE INDEX 75												
10	25	2.5	--	--	--	--	--	--	--	--	--	--
20	55	5.4	1,060	9.6	--	12	200	1.6	--	1,260	11.2	--
30	62	7.4	1,920	17.5	1,380	30	520	5.2	60	2,640	24.3	1,440
40	71	10.5	2,550	23.0	4,840	22	610	5.6	500	3,880	35.4	5,400
50	75	13.2	3,025	26.8	10,300	22	745	6.8	1,540	5,100	46.0	12,400
60	78	15.5	3,360	29.7	13,200	21	925	7.8	3,540	6,360	56.7	18,840

Table 15. — *Yields per acre for upland oak; first thinning at age 40 (Gingrich 1971)*

Age	Residual stand					Cut stand				Cumulative total yields (cut stand plus residual stand)		
	Basal area	Average tree diameter	Yield			Basal area	Yield					
Years	*Square feet*	*Inches*	*Cubic feet*	*Cords*	*Board feet*	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*
SITE INDEX 55												
40	63	5.0	1,140	10.5	--	24	180	1.6	--	1,320	12.1	--
50	62	7.4	1,538	13.0	900	23	282	3.4	--	2,000	18.0	900
60	67	9.1	1,830	15.6	2,430	15	288	3.1	270	2,580	23.7	2,700
70	72	11.0	2,065	18.6	4,445	12	300	2.7	465	3,115	29.4	5,180
80	74	12.7	2,240	21.6	6,880	12	350	2.8	865	3,640	35.2	8,480
90	76	13.8	2,430	24.8	9,180	9	355	3.0	1,100	4,185	41.4	11,880
SITE INDEX 65												
40	69	6.5	1,600	15.9	440	27	240	2.3	--	1,840	18.2	440
50	66	8.5	1,910	17.7	1,800	28	410	4.0	200	2,560	24.0	2,000
60	70	10.4	2,200	20.7	4,200	18	400	3.6	280	3,270	30.6	4,680
70	74	12.4	2,485	23.1	7,210	16	420	3.7	710	3,955	36.7	8,400
80	77	14.5	2,720	24.8	8,960	15	410	4.0	1,050	4,600	42.4	11,200
90	79	16.5	2,925	26.6	10,710	13	460	4.0	1,630	5,265	48.2	14,580
SITE INDEX 75												
40	73	7.4	2,130	20.2	1,380	28	300	3.0	--	2,440	23.2	1,380
50	68	9.6	2,390	21.8	3,450	31	635	6.2	300	3,325	31.0	3,750
60	73	11.6	2,730	24.9	7,680	19	625	5.2	1,020	4,290	39.3	9,000
70	76	13.8	3,115	28.0	11,200	19	610	4.8	1,620	5,285	47.2	14,140
80	79	16.5	3,480	30.8	14,080	17	590	5.2	2,340	6,240	55.2	19,360
90	81	18.7	3,735	33.7	15,810	15	650	5.3	3,000	7,155	63.4	24,120

Table 16. — *Yields per acre for upland oak; first thinning at age 50 (Gingrich 1971)*

Age	Residual stand					Cut stand				Cumulative total yields (cut stand plus residual stand)		
	Basal area	Average tree diameter	Yield			Basal area	Yield					
Years	*Square feet*	*Inches*	*Cubic feet*	*Cords*	*Board feet*	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*
SITE INDEX 55												
50	69	6.5	1,627	14.9	400	28	523	4.8	--	2,150	19.7	400
60	66	8.4	1,710	14.7	1,350	23	317	3.9	150	2,550	23.4	1,500
70	68	9.3	1,855	15.4	3,585	15	280	3.2	165	2,975	27.3	3,900
80	71	10.5	1,960	18.0	6,160	12	280	2.1	325	3,360	32.0	6,800
90	73	11.5	2,115	20.0	8,240	10	220	2.2	620	3,735	36.2	9,500
100	74	12.7	2,250	22.8	8,900	9	230	1.5	1,240	4,100	40.5	11,400
SITE INDEX 65												
50	75	8.0	2,130	19.6	1,850	30	670	7.3	300	2,800	26.9	2,150
60	68	9.6	2,130	19.5	4,090	29	470	4.4	210	3,270	31.2	4,600
70	70	10.4	2,240	20.6	6,160	18	400	3.7	330	3,780	36.0	7,000
80	74	12.2	2,480	22.8	8,240	14	300	2.6	520	4,320	40.8	9,600
90	77	14.8	2,745	25.2	10,305	12	275	2.7	935	4,860	45.9	12,600
100	79	17.0	3,000	28.5	10,700	10	235	1.8	1,905	5,350	51.0	14,900
SITE INDEX 75												
50	78	9.0	2,590	24.4	3,650	32	725	5.7	450	3,315	30.1	4,100
60	72	11.3	2,700	25.2	6,300	30	655	6.8	1,050	4,080	37.7	7,800
70	75	12.8	2,965	26.8	9,200	19	475	5.2	1,100	4,820	44.5	11,800
80	77	14.1	3,180	29.0	11,500	18	425	4.8	1,500	5,460	51.5	15,600
90	79	16.5	3,620	31.4	13,000	16	420	4.6	1,900	6,320	58.5	19,000
100	81	18.4	3,880	33.0	14,450	14	500	4.9	2,750	7,080	65.0	23,200

Table 19. – *Gross yields per acre of normal oak stands in southwestern Wisconsin (Gevorkiantz and Scholz 1948)*

Age (Years)	Total volume: Cubic feet[1]	Cords[2]	Board feet Scribner[3]
VERY POOR SITE			
20	480	--	--
40	1,050	10	--
60	1,550	19	550
80	2,000	25	2,500
100	2,350	29	4,550
120	2,650	33	6,300
140	2,900	36	7,600
160	3,050	38	8,500
POOR SITE			
20	650	1	--
40	1,350	15	--
60	1,950	25	2,300
80	2,550	32	6,400
100	3,050	38	9,600
120	3,450	42	11,700
140	3,750	46	13,150
160	3,900	49	14,000
MEDIUM SITE			
20	850	2	--
40	1,750	21	300
60	2,550	33	4,700
80	3,300	41	10,200
100	3,900	49	13,600
120	4,350	54	15,800
140	4,750	58	17,300
160	4,950	61	18,500
GOOD SITE			
20	1,000	3	--
40	2,050	25	1,600
60	3,050	39	7,600
80	3,950	50	13,400
100	4,700	59	17,200
120	5,300	66	19,600
140	5,700	71	21,000
160	5,950	74	22,100
VERY GOOD SITE			
20	1,150	4	--
40	2,400	30	2,800
60	3,600	46	10,500
80	4,600	59	16,800
100	5,500	69	21,100
120	6,200	77	23,900
140	6,700	83	25,500
160	7,000	87	26,700

[1]Gross volume, excluding bark, all trees 0.6 inch d.b.h. and larger.

[2]Gross volume, excluding bark to top diameter of 4 inches, all trees 5 inches d.b.h. and larger.

[3]Scaled in 8 foot logs. If scaled in 16-foot logs, reduce table values by 11 percent.

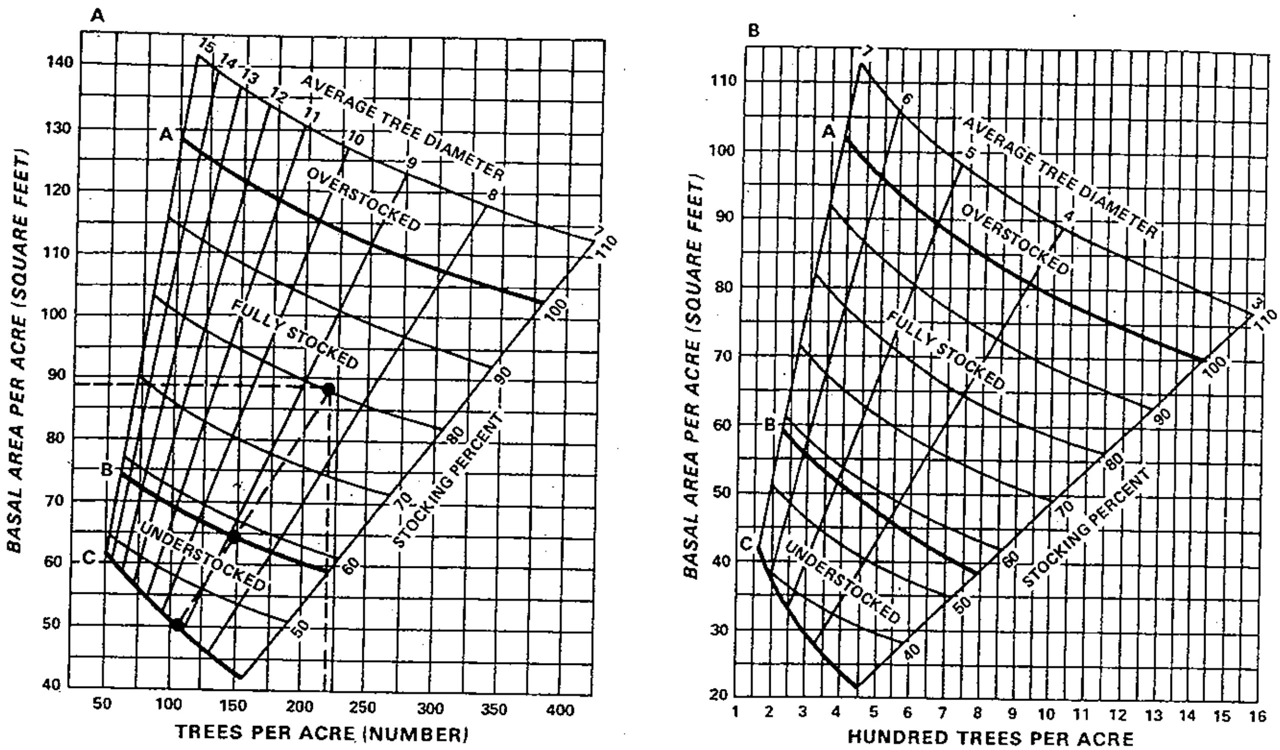

Figure 7. – *Relation of basal area, number of trees, and average tree diameter to stocking percent for upland central hardwoods. For average tree diameters 7 to 15, use the chart at left; for diameters 3 to 7, use the chart at right. (Average tree diameter is the tree of average basal area.) On both charts the area between curves A and B indicates the range of stocking where trees can fully utilize the site. Curve C shows the lower limit of stocking necessary to reach the B level in 10 years on average sites (Gingrich 1971).*

stocked plots to meet minimum stocking requirements at the next lowest percent down from 43 (i.e., 40). Opposite 40 note that 95 stump sprouts are needed to make up the deficiency in advance reproduction.

Stocked 1/735-acre plots (Percent[3])	Stump sprouts required (Number per acre)
59	0
55	19
50	44
45	69
40	95
35	120
30	145
25	170
20	196
15	221
10	246

8. Because the computed value (124) exceeds the tabulation value (95), there will be enough oak stump sprouts to make up the advance reproduction deficiency. Thus, the oak component of the new stand will be adequate and the old stand can be harvested.

9. If the number of expected stump sprouts does not compensate for advance reproduction deficiencies, harvesting should be delayed until adequate oak advance reproduction is established and reaches the minimum size of 4.5 feet in height.

10. Unless the stand is protected or the wildlife controlled, it will probably be impossible to get adequate natural oak reproduction in areas where deer browsing is heavy and where there are high populations of acorn-consuming wildlife. The alternative is to plant oak seedlings and protect them from wildlife.

[3] *If the percent of stocked plots lies between the 5-percent intervals, use the lower figure, e.g., 43 percent stocked plots should be considered 40 percent.*

APPENDIX V
MISCELLANEOUS

Metric Conversion Factors

To convert	*to*	*Multiply by*
Acres	Hectares	0.405
Board feet[1]	Cubic meters	0.005
Board feet/acre[1]	Cubic meters/hectare	0.012
Chains	Meters	20.117
Cords[1]	Cubic meters	2.605
Cords/acre[1]	Cubic meters/hectare	6.437
Cubic feet	Cubic meters	0.028
Cubic feet/acre	Cubic meters/hectare	0.070
Degrees Fahrenheit	Degrees Celsius	[2]
Feet	Meters	0.305
Gallons	Liters	3.785
Gallons/acre	Liters/hectare	9.353
Inches	Centimeters	2.540
Miles	Kilometers	1.609
Miles/hour	Meters/second	0.447
Number/acre	Number/hectare	2.471
Ounces	Grams	28.350
Ounces/acre	Grams/hectare	70.053
Pounds	Kilograms	0.454
Pounds/acre	Kilograms/hectare	1.121
Pounds/gallon	Kilograms/liter	0.120
Square feet	Square meters	0.093
Square feet/acre	Square meters/hectare	0.230
Tons	Metric tons	0.907
Tons/acre	Metric tons/hectare	2.242

[1]The conversion of board feet and cords to cubic meters can only be approximate; the factors are based on an assumed 5.663 board feet (log scale) per cubic foot and a cord with 92 cubic feet of solid material.

[2]To convert °F to °C, use the formula 5/9 (°F-32) or $\frac{°F-32}{1.8}$.

Common and Scientific Names of Plants and Animals

Plants

Anthracnose	*Gnomonia quercina*
Ash, white	*Fraxinus americana*
Aspen	*Populus* spp.
Basswood, American	*Tilia americana*
Blackgum	*Nyssa sylvatica*
Blister, leaf	*Taphina* spp.
Butternut	*Juglans cinerea*
Blueberry	*Vaccinium* spp.
Cankers	*Strumella* spp. *Nectria* spp.
Cherry, black	*Prunus serotina*
Dogwood, flowering	*Cornus florida*
Elm, American	*Ulmus americana*
Hazelnut	*Corylus americana*
Heartrots	*Poria* spp. *Stereum* spp. *Hericuim* spp. *Irpex* spp. *Polyporus* spp.
Hophornbeam, eastern	*Ostrya virginiana*
Hornbeam, American	*Carpinus caroliniana*
Maple, red	*Acer rubrum*
Maple, sugar	*Acer saccharum*
Oak, black	*Quercus velutina*
Oak, blackjack	*Quercus marilandica*
Oak, bur	*Quercus macrocarpa*
Oak, chestnut	*Quercus prinus*
Oak, northern red	*Quercus rubra*
Oak, post	*Quercus stellata*
Oak, scarlet	*Quercus coccinea*
Oak, white	*Quercus alba*
Sassafras	*Sassafras albidum*
Walnut, black	*Juglans nigra*
Wilt, oak	*Ceratocystis fagacearum*
Witchhazel	*Hammamelis virginiana*
Yellow-poplar	*Liriodendron tulipifera*

Animals

Bobcat	*Lynx rufus*
Borer, red oak	*Enaphalodes rufulus*
Borer, white oak	*Goes tigrinus*
Carpenterworm	*Prinoxystus robiniae*
Caterpillar, forest tent	*Malacosoma disstria*
Caterpillar, variable oak leaf	*Heterocampa manteo*
Chipmunk, eastern	*Tamias striatus*
Deer, white-tailed	*Dama virginiana*
Fox, red	*Vulpes vulpes*
Grouse, ruffed	*Bonasa umbellus*
Moth, gypsy	*Porthetria dispar*
Oakworm, orangestriped	*Anisota senatoria*
Oppossum	*Didelphis marsupialis*
Raccoon	*Procyon lotor*
Roller, oak leaf	*Archips semiferanus*
Root rot	*Armillaria mellea*
Skunk	*Mephitis* spp.
Squirrel, fox	*Sciurus niger*
Squirrel, gray	*Sciurus carolinensis*
Tier, oak leaf	*Croesia albicomana*
Turkey, wild	*Meleagris gallopavo*
Weevils, acorn	*Curculis* spp.

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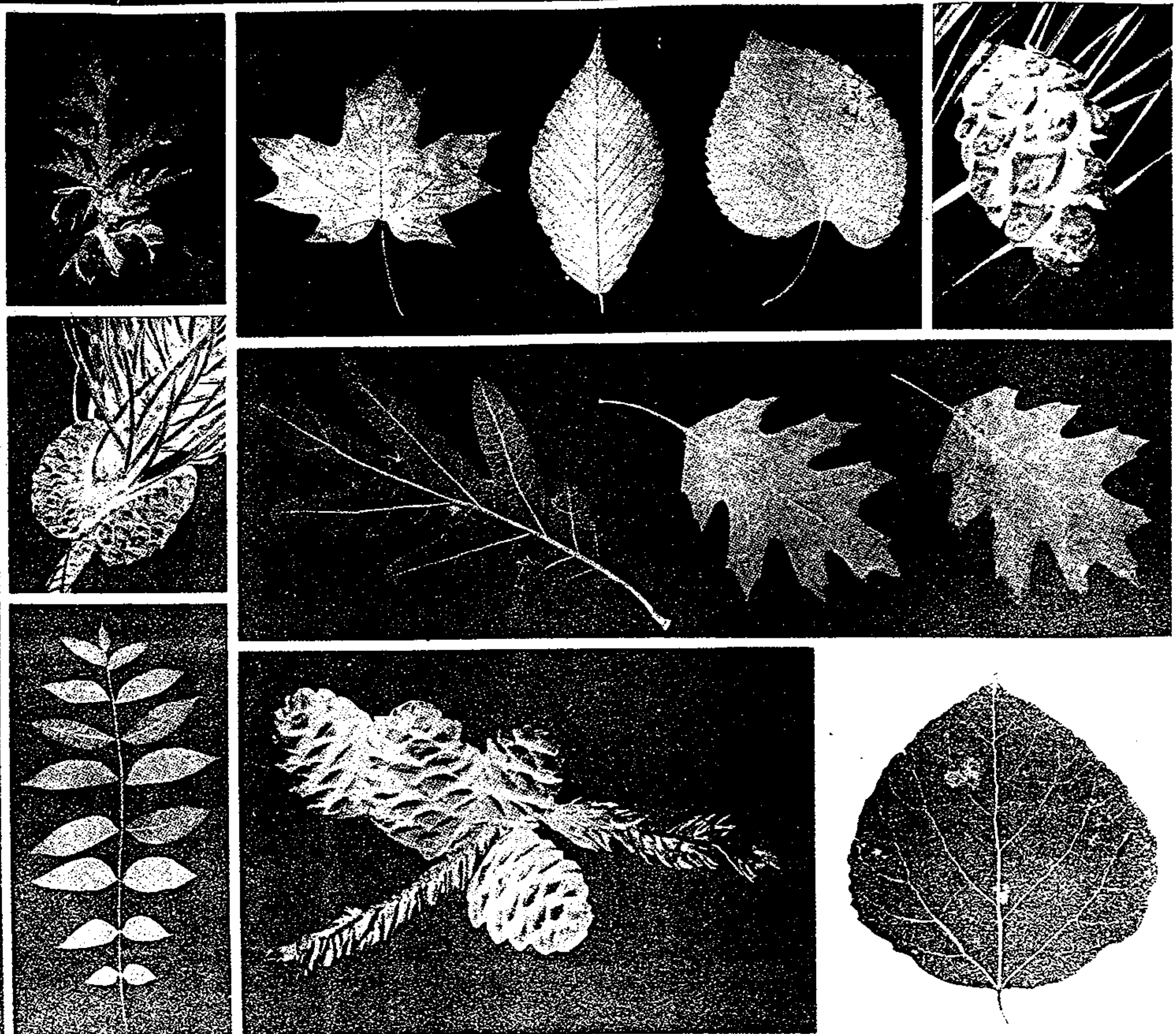


manager's handbook for

ASPEN IN THE NORTH CENTRAL STATES

GENERAL TECHNICAL REPORT NC-36

NORTH CENTRAL FOREST EXPERIMENT STATION FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

ASPEN
IN THE NORTH-CENTRAL STATES

Donald A. Perala, *Silviculturist*
Grand Rapids, Minnesota

SILVICAL HIGHLIGHTS

The bulk of the aspen[1] in the north-central States is in Minnesota, Wisconsin, and Michigan where 13 million acres (one-fourth of the commercial forest land) of aspen type contain 80 percent of the aspen growing stock; the rest of the growing stock is in conifer types (7 percent) and other hardwood types (13 percent). Quaking and bigtooth aspens occur on nearly every soil type but grow best on deep, well drained soils.

Aspens are highly sensitive to shade, soil compaction, fire, and mechanical injury to the root system. The species grows rapidly, thins itself naturally from competition, insects, and diseases, and matures in 30 to 70 years; occasional trees will survive 100 years or more. Without disturbance, aspen stands will be replaced by more tolerant or longer-lived associates.

Aspen typically sprouts many thousands of suckers per acre from the shallow parent root system after a stand has been opened by fire, windthrow, or cutting. The suckers arising from the same tree are genetically identical to the parent and are called a "clone". Suckers of the same clone have uniform characteristics, but suckers of different clones can vary widely – especially in bigtooth aspen. Single clones typically cover 1/10 to 1/5 acre, occasionally up to 4 acres.

MANAGEMENT OBJECTIVES AND NEEDS

About one-third of the aspen-birch forest type in Minnesota, Wisconsin, and Michigan is growing much below potential. The management objectives considered in this handbook are to improve yields of timber, water, or wildlife in this forest type while minimizing impact on the landscape.

The recommended silvicultural system for growing and reproducing aspen is complete clearcutting at rotation age to regenerate pure, fully stocked stands of suckers. In young stands that were not established by complete clearcutting, the residual trees need to be removed as early as possible. One or two thinnings to control stand density are needed to greatly increase the yield and shorten rotations for saw logs and veneer, but thinning is not recommended for fiber production. The manager will need considerable skill and wisdom to balance the output of timber, water, and wildlife while maintaining a pleasing landscape.

KEY TO RECOMMENDATIONS

The following key recommends the management techniques that will improve the yields of timber and water, or increase wildlife for given stand and [illegible] and objectives. Not every possible [illegible] covered in detail, so the manager [illegible] the alternatives that come [illegible]

[1] *For scientific names of plants and animals, see Appendix, p. 27.*

Estimating Site Productivity

Site Index Curves

Site index is commonly determined by comparing the mean total height and age of dominants and codominants with published site index curves. Site indices are expressed in even units of 10 feet at age 50, the class interval being 56 to 65 for site index 60, for example. Use site index curves (see Appendix, fig. 12) to estimate site index for quaking aspen. Up to age 50 the estimates will be reasonably accurate throughout most of the north central area; after age 50 accuracy can drop significantly because of local variation in height growth. The only curves for bigtooth aspen are from northern Lower Michigan (see Appendix, fig. 13). When these curves are used elsewhere for bigtooth aspen, the site index estimates are likely to be less accurate.

The genetic variation between clones can sometimes cause considerable error in aspen site index estimation (see Appendix, fig. 14). To accurately estimate site index where clonal growth differences are pronounced, measure two dominant aspens in each of three clones representative of the stand. The average height of the three clones along with tree age will give reliable site index values. Sampling only the tallest clone or clones could overestimate site index by 5 to 10 percent.

Soil Examination

Site index curves are not reliable for stands less than 20 years old, or in stands where growth was slowed because of fire, or because partial cutting left dense overstories. To estimate site index in such stands, use soil and topographic features instead of heights (see Appendix, tables 1 and 2). Soil surveys by the USDA Soil Conservation Service and other agencies can also be very useful (fig. 1).

Alternative Species

Only site index 60 or better should be considered for aspen timber management although poorer sites can be managed for aspen for other purposes. Conifers are usually more productive than aspen on poorer sites so the land manager may wish to convert to conifers. The land manager may also wish to convert better aspen sites to other species. The following tabulation gives quaking aspen site index values and the corresponding site index for some alternative species:

Figure 1. — *This aspen stand has a measured site index of 42. Since the stand originated after fire, the true site index of the stand is underestimated. A soil examination is needed to accurately assess the potential productivity of the site.*

If quaking aspen site index is:	**Then site index for these species is:** Red pine	Basswood	Paper Birch
40	46	44	40
50	50	50	47
60	54	56	55
70	59	62	62
80	63	68	70

Regenerating Aspen

Basic Requirements

For best aspen sucker regeneration: (1) the soil must be well drained and aerated, and (2) the parent stand must have a minimum aspen density of 50 trees or 20 square feet basal area per acre. To stimulate suckering, allow heat and light to reach the forest floor by removing as much of the overstory as possible, preferably all trees 2 inches or more in d.b.h. (as little as 10 to 15 square feet basal area of residual overstory will slow sucker growth by 35 to 40 percent) (fig. 2). In some cases the understory may also need to be controlled. Harvesting the overstory in summer helps in this regard.

Prescribed burning should be used only by personnel experienced in fire behavior and fire weather. It is recommended only when other site preparation methods are impractical or in poorly stocked, brushy, or sodded stands. Although burning increases suckering, it also tends to slow sucker growth. Harvested stands should be burned within 1 year; the best time is in the spring before growth starts. If snow still lies in the surrounding timber, or if the surrounding timber is hardwood, the burn can be easily confined to the harvested area (see "Prescribed Burning" and table 4 in Appendix).

Stocking Standards

By age 2, when most suckering will have occurred, sucker stands should exceed 85 percent milacre stocking, or about 4,000 to 5,000 stems per acre (fig. 4). As stocking drops below 4,000 per acre at age 2, the chances that the stand will develop to an economically operable density decrease rapidly with small increases in mortality. The development of sucker stands should be checked periodically (see "Forecasting Future Operability" and fig. 15, Appendix).

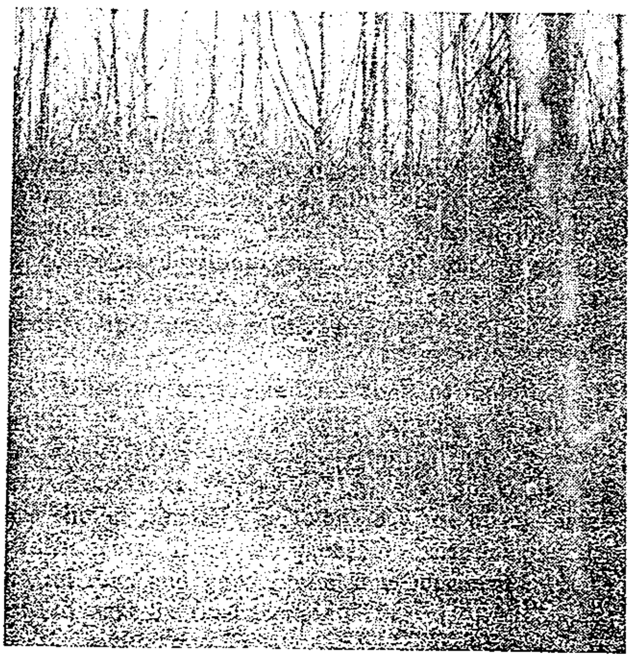


Figure 4. – *Regeneration of dense sucker stands is the best guarantee of high aspen productivity.*

Controlling Composition

Composition

If an aspen stand is properly regenerated at maturity, it will contain other regenerating species; these then may develop as an understory. Overtopping trees left after harvest, however, strongly suppress aspen growth, and should be removed in initial site preparation or by cleanings and thinnings within 10 years.

Growing Conifers with Aspen

Only white spruce and balsam fir can easily be managed concurrently with aspen. In fact it is difficult to manage spruce and fir to the exclusion of aspen, and vice-versa, where they exist together. The total fiber yield may be greater in these mixed stands than if pure stands of any one species are grown (fig. 5).

Figure 5. – *Aspen and balsam fir can be grown together for landscape variety and forest crop diversity.*

Where mature aspen has an understory of immature spruce-fir, clearcut the aspen at age 30 to 50 to release the conifer understory. Openings in the conifer canopy will be large enough to allow good aspen sucker development in scattered patches. Manage the conifers either by group selection, shelterwood, or diameter limits according to age structure and the proportion of aspen. Make shelterwood and diameter limit cuttings to encourage advance spruce-fir regeneration when the aspen component is minor or scattered. Clearcut mature aspen and conifers to regenerate a fully stocked aspen sucker stand. If advance reproduction is sparse, clearcuts should be small (preferably less than 20 acres); large clearcuts should not exceed 200 feet in width and their

Yields can be increased by (1) thinning and (2) adjusting rotation ages to maximize mean annual increment. Both options are recommended for growing sawtimber and veneer; for fiber, only adjusting the rotation age is recommended.

Thinning

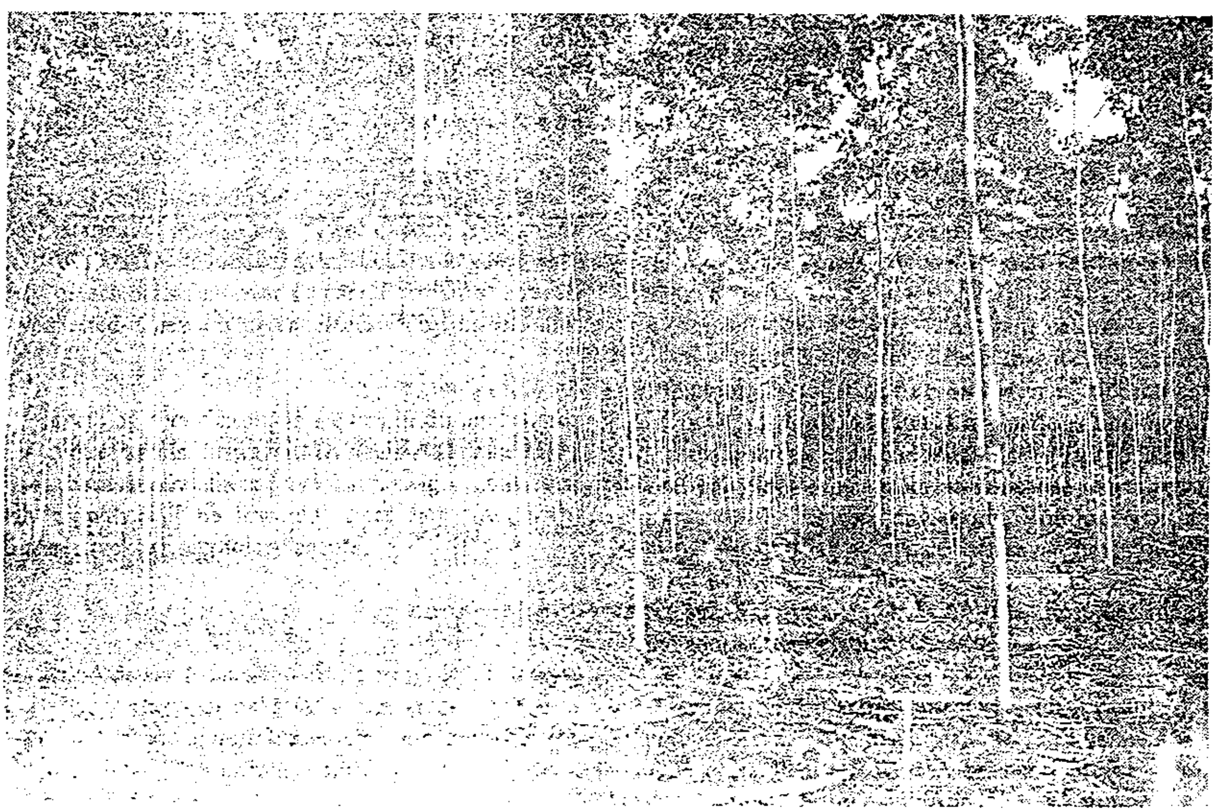
Only well-formed, disease-resistant clones on sites 70 and better can yield significant amounts of sawtimber and veneer. Generally, a single commercial thinning is recommended (schedule A as follows). However, site index 80 or better stands will produce substantially more sawtimber and veneer if precommercially thinned as well (schedule B). In schedule A, thin once at about age 30 when basal area has surpassed 120 to 140 square feet. Leave about 240 trees and 60 to 70 square feet per acre. In schedule B, the precommercial thinning should leave 550 trees per acre at about age 10 when the trees are still small enough to be easily thinned by hand (fig. 7). Thin a second time at about age [illegible] when basal area has surpassed 130 square feet per acre. Leave 200 trees and 80 to 90 square feet per acre. Delay the regeneration cut in either schedule as long as the stand is healthy and shows little sign of heart rot — age 50 to 60 in most cases.

Assuming a regeneration cut at age 55, schedules A and B in site index 80 aspen would average 12 to 14 inches d.b.h., compared to 9.5 inches without thinning. Thinning produces up to 140 percent more veneer and up to 40 percent more sawtimber than without thinning, with the greatest gains from the two-thinning schedule (see Appendix, fig. 17). Thinning can produce the same amount of sawtimber in 10 years less time, or the same amount of veneer in 14 years less time than without thinning.

The smaller trees and tops of crop trees could give these additional yields of whole chips:

Schedule	Commercial thinning	Regeneration cut	Rotation total
	—— (fresh weight, tons per acre) ——		
A	54 (4.3)[4]	63	117
B	41 (5.7)	65	106

[4] *Mean diameters in parentheses.*



[illegible] 550 trees per acre.

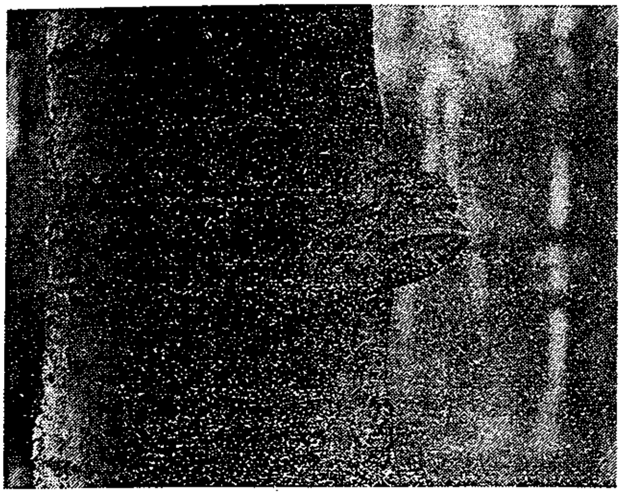


Figure 9. – *Conk of* Phellinus igniarius – *the main deterrent to growing aspen to old ages.*

Insects

Once past the juvenile stage, aspen is seldom killed directly by insects. However, insects such as the poplar borer may enhance mortality by weakening the tree or providing infection courts for pathogens. A number of other wood borers can damage and kill young suckers. Pole-size and mature stands are more susceptible to defoliating insects such as the forest tent caterpillar and the large aspen tortrix. Even repeated defoliation does not cause much direct mortality, except on sites with high water tables – the main effect is temporary loss in growth. No direct insect control is now practiced in aspen although dense sucker stands should be regenerated to minimize borer damage.

Fire

Aspen stands are relatively low in flammability and fires are easily controlled. However, even surface fires can either kill or injure aspens and cause significant growth loss and early stand breakup. Fire should be excluded from aspen stands except for regeneration and even then excessively hot fires should be avoided.

Weather

New spring growth can be killed by frost, but growth resumes and little permanent damage results. Aspen is prone to windthrow or breakage, particularly when weakened by boring insects or disease. Young sucker stands can be seriously damaged and sometimes killed back by hail.

Improperly Timed Silvicultural Practices

Soil compaction from heavy machines can reduce future aspen yields 5 to 10 percent by lowering soil aeration required for vigorous suckering. The potential for compaction is most severe on wet soils having a high clay content, and is minimal on dry sandy soils. Disperse skidding to minimize compaction during the summer by mechanized logging. Winter logging causes less soil compaction than summer logging, but does not disturb competing vegetation as much – a factor to consider on brushy aspen sites. Shearing for aspen regeneration should always be done when soils are frozen.

Conversion to Conifers

Aspen stands to be converted to conifers should firs be harvested of all usable material. Prepare the site mechanically by shearing, roller chopping, or barre scarifying, or treating chemically between July 15 and August 15 with picloram plus 2,4-D (0.5 pounds + [illegible] pounds per acre) in 10 to 20 gallons water per acre.[illegible] Plant suitable conifers the following spring.

Release conifers from aspen suckers as needed using 2,4-D or a 50 percent mixture with 2,4,5-T when oak o other hardwoods are present. Use total rates of 3 pound per acre in 4 to 5 gallons water mixture for aeria spraying; 3 pounds per acre in 10 to 20 gallons fo ground spraying. White spruce and red pine are safe to release after July 1 but release is best after July 15. Jack pine is not safe to release until August 1. Complete the release operations by August 15. Where chemical cannot be used, hand release during the growing season (June, July, early August) to lessen regrowth of aspen

OTHER RESOURCE CONSIDERATIONS

Water

Aspen forests can have considerable impact on water yield, depending on how they are managed. Harvesting (either intermediate thinnings or regeneration clearcuts) on a sustained yield forest will have little impact on water yield, quality, or timing, because only 1/50 to 1/60 of the total acreage is cut during any 1 year. However, an individual watershed that is completely clearcut may yield 3 to 4.5 inches more water the first few years after cutting. This [illegible] after 6 to 7 years the new stand [illegible]

Smaller Birds and Mammals

Beaver populations should be controlled so they will not over-utilize riparian aspen forests by repeatedly cropping sucker stands. Repeated cropping can result in death of the stand and food scarcity for future populations.

Cavity nesting birds and mammals can be encouraged by leaving standing dead snags. These will not interfere with sucker regeneration of the new stand. Numerous songbirds, such as the Nashville warbler, a variety of sparrows, hermit thrush, and others, need all elements of food and cover — from herbaceous openings and early stages of forest succession (such as aspen) to stands of mature and old-growth timber.

Rare and Endangered Species

Three rare or endangered species using the aspen type are the bald eagle, osprey, and eastern timber wolf. All are protected by Federal and State laws. The following tabulation lists restrictions on management activities for osprey and eagle nest trees:

Distance from nest	Osprey nests	Eagle nests
Up to 350 ft.	No activity anytime	No activity anytime
350 to 650 ft.	No activity March to July	Thinning and pruning OK (no clearcutting) October to mid-February; no activity rest of year
700 and beyond	Normal activities OK	–
700 ft. to 1/4 mile	–	Normal activities October to mid-February only; no activities rest of year

If areas more than 1/4 mile away are visible from the eagle nest, the outer zone can be extended to 1/2 mile in that direction. Roads and trails within 1/4 mile of eagle nests should be closed where possible. Scattered old-growth trees, particularly the pines, should be reserved as much as possible for future nest trees.

The timber wolf generally requires no special habitat management beyond good management for deer, moose, and beaver. These are the primary prey of wolves and habitat manipulation for them will serve the wolf as well.

Landscape

Aspen is dominant and highly visible in the landscape of northern forests. Because it is abundant and predominantly maintained through clearcutting, how it is managed will have important impacts upon the landscape and recreation experiences. Aspen landscape management is needed most in stands in the foreground of scenic areas, travel corridors, use areas, and water bodies frequented by and readily visible to large numbers of forest visitors. Important factors to be considered in avoiding unsightly management practices are *viewing distance, size, shape, edge, distribution or spacing, timing, vistas,* and *operations.*

The foreground (0 to 1/2 mile) and middleground (1/2 to 3 miles) landscape zones are most important because they are most readily seen. The background zone (3 miles +) is important when it is highly visible and provides a scenic backdrop.

Foreground landscapes can be enhanced by:

1. Providing vistas that expose and frame scenic features.
2. Utilizing clearcuts to create visual variety by opening up dense stands, and breaking up straight lines of timber with curved lines and irregular openings.
3. Leaving attractive trees and snags and those of special interest.
4. Providing diversity in plant species, age class, size, and type.
5. Using transition vegetation along edges.
6. Varying the sizes and shapes of cuts.
7. Converting to other vegetative types.

An aspen regeneration cut has less impact if its *size* does not dominate and if it is varied and in scale with natural or man-made openings that may occur in the landscape. The apparent size of a cut can be reduced by restricting the amount of cut area seen from any one viewing position. Factors such as distance, shape, and screening provided by intervening ridges or other landforms and islands or clumps of vegetation help to limit the apparent size of cuts.

Irregular, free-form *shapes* that follow natural projections, indentations, soils, and topographic features expose smaller areas of clearcut to view. Avoid cutting boundaries in long straight unnatural edges or in geometric shapes which clash with natural landscape forms.

Clearcut openings whose *edges* contrast sharply with the surrounding timber can be "feathered" to soften

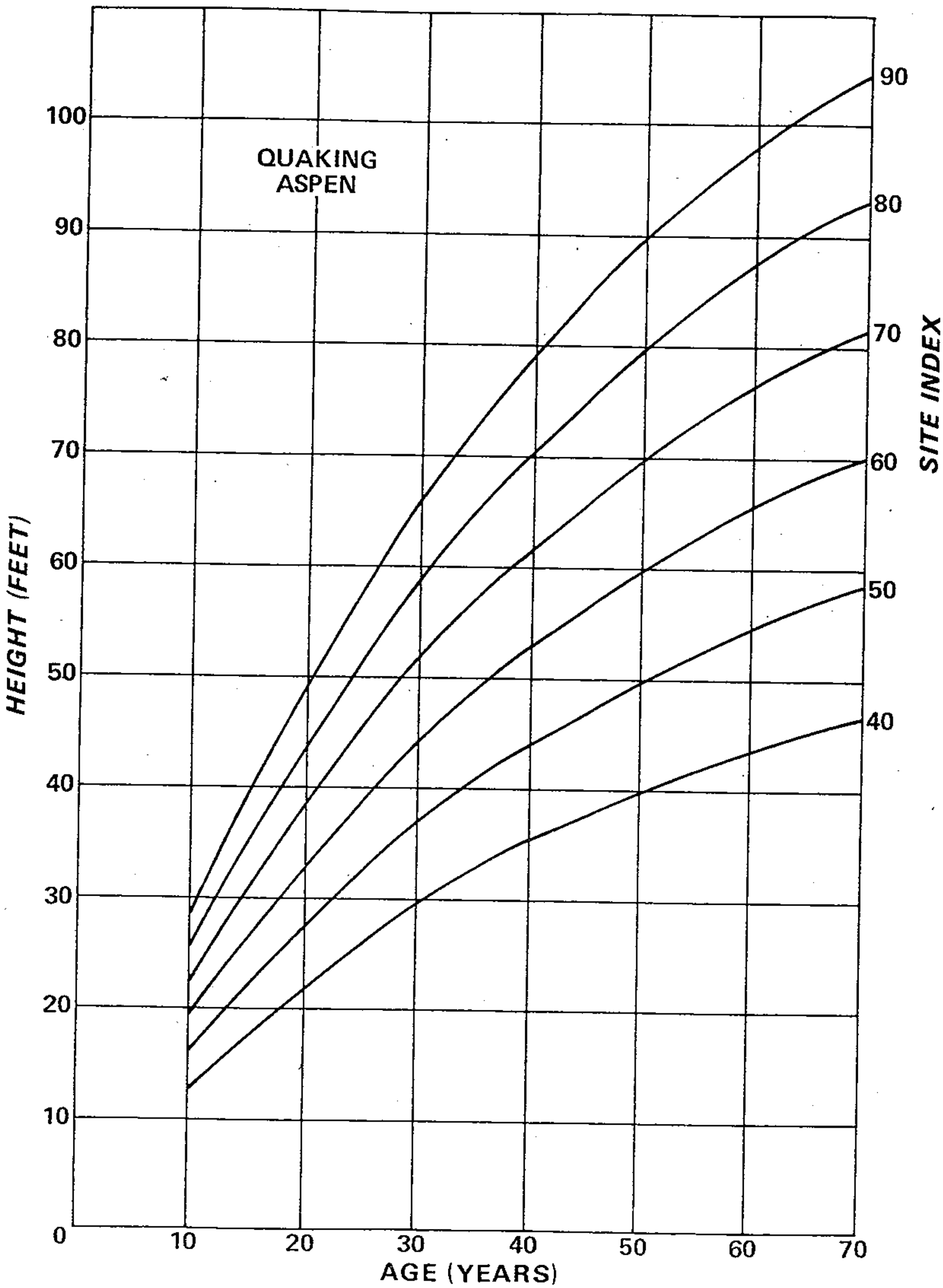


Figure 12. – *Site index curves for quaking aspen in the north-central States (Lundgren and Dolid 1970).*

Table 1. — *Estimated site index for quaking aspen in the Lake States based on soil texture and moisture regime (Stoeckeler 1960)*

Moisture regime	Percent silt-plus-clay in top 36 inches: <10	10-20	21-50	51-70	71+
	Height at 50 years, feet[1]				
Water table 2.5 to 8 feet	70	70	70	70	70
Well drained[2], with improved water holding capacity[3]	65	70	75	80	70
Well drained[2]	50	60	70	80	70
Poorly aerated[4]	60	60	60	50-60	50-60
Excessively drained[5]	40	40	55	70	70

[1]Calcareous parent material will increase site index about 5 feet. Stands exposed to wind or subject to rapid surface drainage (ridges, knolls) or on the upper half of 30 percent slopes with SE, S, SW, or W aspects will have 10 to 15 feet lower site index.

[2]No strong mottling within 1 foot of surface. Water tables deeper than 8 feet.

[3]Underlain at 2 to 3 feet with soils of greater water holding capacity (30 to 90 percent silt + clay).

[4]Strong mottling within 1 foot of surface, or water table closer than 2.5 feet.

[5]Droughty gravel is within 2 to 3 feet of surface soil and greater than 3 feet in thickness. Also includes soils where rock content exceeds 50 percent of the top 3-foot soil volume.

Table 2. — *Estimated site index for bigtooth or quaking aspen*[1] *on well-drained sandy soils, northern Lower Michigan (adapted from Graham* et al. *1963)*

Topography	Soil moisture category: Permeable subsoil, dry to 5 feet in summer	Depth to impermeable stratum[2]: 12 inches or less	13 inches to 18 inches	19 inches to 5 feet	Subsoil mottled	Water table within 5 feet
	Height at 50 years, feet[3]					
Flat uplands	30	30	40-50	50-60	60-70	70-80
Brow of slope	30-40	30-40	30-50	40-50	50-60	60-70
Upper slope: steep	30	30	30-40	40-50	50-60	60-70
Upper slope: moderate	30-40	30-40	30-50	40-50	50-60	60-70
Upper slope: gentle	30-40	30-40	30-50	40-60	50-70	70-80
Lower slope	30-40	40-50	50	60	70	80-90
Base of slope	30	40	50-60	60-70	80	90-100
Flood plain					80	80-100

[1]For quaking aspen reduce site index by 5 feet.

[2]Hardpans, clays, and fine compacted silts.

[3]Converging slopes or draws will raise site quality 10 feet above table values. Gravel (not washed layers) mixed in upper soil also will tend to raise site index. South-facing slopes will be lower than north-facing slopes. Where a range is given, the lower values are associated with coarse sands and the higher values with loamy sands; fine sands are intermediate.

Prescribed Burning

At least 10 tons (fresh weight) of slash less than 3 inches diameter are needed per acre for a burn hot enough to kill standing residuals. Generally, mature stands exceeding 60 to 80 square feet basal area will have at least 10 tons of slash after conventional harvesting. The more evenly the slash is distributed, the more overstory will be killed. Stands that have not been harvested normally will not have sufficient fuel to burn hot enough to kill much of the overstory. In these cases fire will nevertheless reduce understory competition and blacken the forest floor which will elevate spring soil temperatures to encourage suckering. Surviving trees – especially aspen – should be felled to maximize suckering.

An 8- to 12-foot wide fireline should surround the burn. Paper birches within 100 feet inside of the fireline should be felled to avoid burning birch bark being blown outside the line. After backfiring the downwind side of the burn, start headfires just upwind of the backfire in progressive strips 50 to 100 feet wide. After a safe area has burned out, a single headfire can be lit from the upwind side.

Table 4 prescribes the burning weather needed for the kinds of slash typical of harvested and unharvested aspen stands. The burning weather components must be calculated by using the reference cited.

Forecasting Future Operability

To forecast the future operability of poorly stocked stands, estimate:

(1) Site index

(2) Present age

(3) Present number of live stems per acre over 6 inches tall

(4) Number of stems that died during the last year. (These are easy to distinguish from stems that died earlier; leaf buds, fine twigs, and bark will be nearly intact compared to older mortality.)

Divide the number of dead stems by the total live *and* dead stems to estimate the present mortality rate.

Using the mortality rate and present age, use figure 15 to determine a *base number* of stems per acre.

Also, on figure 15 find a *correction factor* that corresponds to the site index.

Multiply the *base number* by the *correction factor* to determine the minimum number of stems per acre needed at present to assure a yield of 10 cunits per acre (total bolewood) at age 40.

An example: a site 70, age 10 stand has 2,000 live stems and 400 dead. The mortality rate is (400/2,000 + 400) = 0.17. Entering figure 15 we find the base number is approximately 3,500 (interpolate when necessary). Adjusting for site, 3,500 x 1.5 = 5,250 live stems are presently needed to yield 10 cunits per acre at age 40. Unless the mortality rate drops to about 0.14, 2,000 stems are inadequate. Therefore, this stand should be inspected annually to determine if the high mortality rate continues. Keep in mind that mortality can vary considerably from year to year so a several-year trend is needed to predict the probable fate of the stand.

For stands at age 20 or older, basal area is a more reliable indicator of future yields. These minimum basal areas are needed to assure 10 cunits per acre at age 40:

	Age		
	20	30	40
Site index	(minimum basal area, ft^2/acre)		
80	6	19	34
70	8	22	38
60	12	27	43
50	22	38	52

Figure 15 should be consulted also as described above to assess risk based on estimated mortality rate.

Table 4. – *Prescribed burning weather for aspen*

Observed and computed burning variables	Continuous slash (<25 percent conifer)	Continuous slash (≥25 percent conifer)	Little slash
Fuel Model[1]	D	I	F
Air temperature	>65°F	>50°F	>65°F
Relative humidity	<35 percent	<50 percent	<35 percent
Ignition component[1]	40-50	40-50	40-50
Energy release component[1]	14-17	14-17	6-8
Spread component[1]	4-7	2-6	2-4
Burning index[1]	13-21	10-21	3-4
Wind	6-12 mph	6-12 mph	6-12 mph
Number of days since rain exceeding 0.1 inch	>5	>3	>5

[1]See Deeming, *et al.* (1972) for description and calculation.

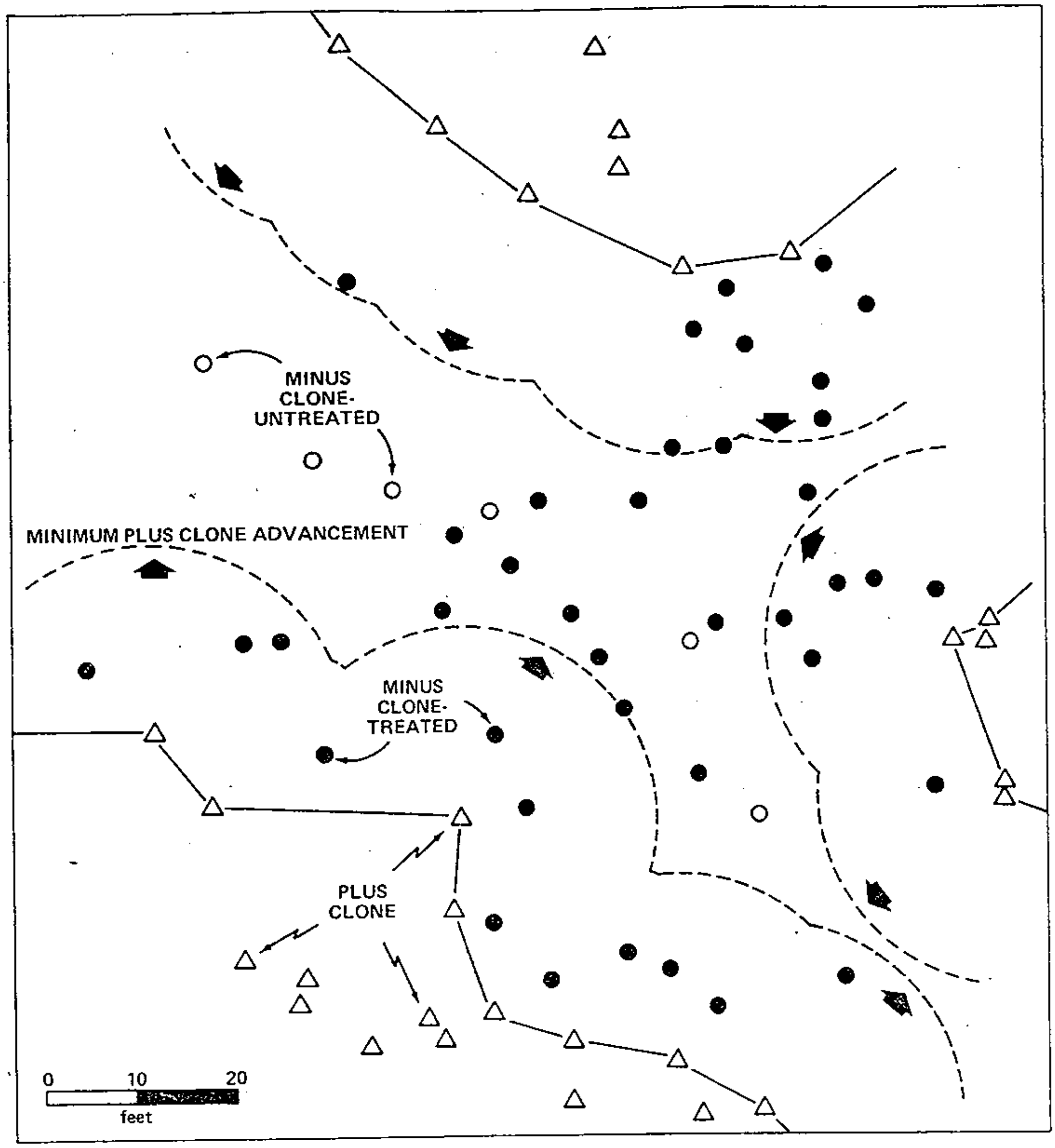


Figure 16. – *Management scheme to increase the extent of plus clones. Killing the minus trees will allow the plus clones to sucker and extend in the direction of the arrows. The untreated minus trees are needed to provide full sucker stocking outside of the minimum effective suckering range (20 feet) of the plus clones. This example is for a previously unthinned stand, age 50.*

Table 5. – *Rotation ages*[1] *for aspen in the Lake States based on culmination of mean annual increment*

Site Index	Fiber: Chips	Fiber: Bolt to 4-inch top[2]	Sawtimber 6-inch top	Veneer 8-inch top
	Without Thinning			
Feet	- - - - - *Rotation age, years* - - - - -			
50	35	NOT RECOMMENDED	NOT RECOMMENDED	NOT RECOMMENDED
60	35	60	NOT RECOMMENDED	NOT RECOMMENDED
70	35	55	60	NOT RECOMMENDED
80+	30	50	60	70
	With Thinning			
70	NOT RECOMMENDED	NOT RECOMMENDED	60	NOT RECOMMENDED
80	NOT RECOMMENDED	NOT RECOMMENDED	50	60

[1]Rotations beyond 40 or 50 years are not practical in many areas because of early stand deterioration.

[2]Top diameters are inside bark.

Table 7. — *Gross bolewood volume without bark (cunits), bolewood + bark fresh weight (tons), and complete tree fresh weight (tons); all per acre; all trees greater than 0.6-inch d.b.h. (Schlaegel 1975)*

Stand basal area	Mean stand height, ft							
	30	40	50	60	70	80	90	100
ft^2/acre								
20	2[1]	3	4	5	6	7	7	8
	7[2]	9	12	14	17	19	21	24
	9[3]	11	14	17	20	23	25	28
40	5	6	8	10	11	13	15	16
	14	19	24	28	33	38	43	47
	17	23	28	34	39	45	50	56
60	7	10	12	15	17	20	22	25
	21	28	36	43	50	57	64	71
	25	34	42	50	59	67	75	83
80	10	13	16	20	23	26	29	33
	28	38	47	57	66	75	85	94
	34	45	56	67	78	89	100	111
100	12	16	20	25	29	33	37	41
	36	47	59	71	82	94	106	118
	42	56	70	84	98	111	125	138
120	--	20	25	30	34	39	44	49
	--	57	71	85	99	114	128	142
	--	67	84	100	116	133	150	166
140	--	23	29	34	40	46	51	57
	--	66	82	99	116	132	148	165
	--	78	98	116	136	155	174	193
160	--	--	33	39	46	52	59	65
	--	--	94	113	132	151	170	188
	--	--	111	133	155	177	199	220
180	--	--	37	44	51	59	66	73
	--	--	106	128	148	170	191	212
	--	--	125	150	174	199	224	248
200	--	--	41	49	57	65	73	82
	--	--	118	142	165	188	212	236
	--	--	138	166	194	220	248	275
220	--	--	45	54	63	72	81	90
	--	--	130	156	182	208	234	259
	--	--	152	182	212	242	272	302
240	--	--	49	59	68	78	88	98
	--	--	142	170	198	226	254	282
	--	--	166	199	232	264	296	329

[1]Bolewood volume from 6-inch stump to tip of tree.

[2]Bolewood + bark fresh weight from 6-inch stump to tip of tree.

[3]Complete tree fresh weight, including branches, from 6-inch stump to tip of tree.

Note: The values in Table 7 can be estimated quite accurately from stand basal area (B) and dominant stand height (H) by rules of thumb:

(1) $\frac{4\ (B \times H)}{1000}$ = bolewood volume, cunits (without bark)

(2) $\frac{B \times H}{80}$ = bolewood + bark fresh weight, tons

(3) $\frac{B \times H}{70}$ = total tree fresh weight, tons

Equation (1) will be 2 percent low, equations (2) and (3) will be 6 and 4 percent high, respectively.

Table 10. – *Normal yield tables for quaking aspen; all trees 0.6-inch d.b.h. and larger (adapted from Brown and Gevorkiantz 1934; Schlaegel 1974, 1975)*

Age	Dominant height	Mean dbh	Number of trees per acre	Basal area per acre	Gross yield per acre: Complete tree	Gross yield per acre: 4-inch top[1]	Gross yield per acre: 6-inch top[1]	Gross yield per acre: 8-inch top[1]
Years	*Feet*	*Inches*		*Sq. Ft.*	*Tons fresh wt.*	*Cords*[2]	– *Cunits*[2] –	
SITE INDEX 80								
20	44	3.3	1490	88	53	--	--	--
30	59	4.8	880	110	89	7	--	--
40	71	6.3	600	129	125	31	5	--
50	80	8.1	400	143	160	52	25	--
60	88	10.3	265	153	191	67	44	26
70	94	12.6	185	161	212	77	58	46
SITE INDEX 70								
20	38	2.9	1800	83	46	--	--	--
30	52	4.2	1065	102	76	--	--	--
40	62	5.4	760	120	105	17	--	--
50	70	7.0	495	133	138	39	12	--
60	77	9.0	330	144	163	55	31	8
70	82	10.9	235	151	184	65	45	31
SITE INDEX 60								
20	33	2.5	2300	76	37	--	--	--
30	44	3.5	1400	94	62	--	--	--
40	53	4.5	980	110	86	2	--	--
50	60	5.9	645	122	107	23	--	--
60	66	7.6	422	133	130	40	16	--
70	70	9.3	295	139	145	49	29	10
SITE INDEX 50								
20	28	1.9	3200	60	25	--	--	--
30	37	2.7	1910	75	40	--	--	--
40	44	3.5	1300	88	56	--	--	--
50	50	4.6	856	98	75	3	--	--
60	55	5.8	580	105	88	18	--	--
70	58	7.1	400	109	95	27	9	--
SITE INDEX 40								
20	22	1.3	4100	38	12	--	--	--
30	29	1.9	2420	46	20	--	--	--
40	35	2.4	1660	54	29	--	--	--
50	40	3.2	1110	60	37	--	--	--

[1]Top diameters are inside bark.
[2]Cords and cunits are without bark.

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