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Oak Forests of the Lake States and their Management

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NOTE: Mr. Arend, now retired, was formerly Silviculturist at the Station's field office in East Lansing, Michigan, which is maintained in cooperation with Michigan State University. Mr. Scholz, also retired, was formerly Research Forester for the Station.

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Oak Forests of the Lake States and Their Management

John L. Arend and Harold F. Scholz

Oak forests occupy 6 million acres in Wisconsin, Michigan, and Minnesota, or about 10 percent of the commercial forest land (table 1). These forests, which contain a total of 10 billion board feet of sawtimber, produce about 195 thousand cords of roundwood and 190 million board feet of sawtimber annually (table 2). In addition to producing timber, the oaks are ideal multiple-use trees, providing excellent wildlife habitat and outdoor recreation opportunities.

Table 1. — Distribution of oak stands in the Lake States by area and timber volume

State	Area	Volume	
		Total growing stock	Sawtimber
	M acres	M cu. ft.	M bd. ft.
Michigan[1]			
Eastern UP	20	19,820	45,650
Western UP	73	87,280	189,240
Northern LP	1,296	864,640	1,954,800
Southern LP	1,016	585,010	1,933,450
Total	2,405	1,556,750	4,123,140
Wisconsin[2]			
Northeastern	127	126,000	239,000
Northwestern	265	144,000	191,000
Central	888	459,000	1,106,000
Southeastern	216	178,000	619,000
Southwestern	1,075	780,000	2,429,000
Total	2,573	1,687,000	4,584,000
Minnesota[3]			
Northeastern	26	19,821	30,910
Central	354	255,873	455,260
Southeastern	581	247,697	839,430
Western	79	55,063	160,510
Total	1,040	578,454	1,486,110
Total	6,018	3,822,204	10,193,250

1/Unpublished 1966 data, Michigan Forest Survey.
2/Wisconsin's forest resources (Stone and Thorne 1961).
3/A third look at Minnesota's timber (Stone 1966).

About three-fourths of the oak forest in the Lake States is located in the southern portion of the region, which also has the best oak sites. Most of these stands are scattered farm woodlands; in Wisconsin, for instance, 72 percent of the oak acreage is owned by farmers.

Poletimber stands occupy nearly half the total oak area, and seedling and sapling stands about one-fifth (table 3). Many of these are well stocked, even-aged stands that originated from clear cuts in which all sawtimber on a woodland tract was harvested and the remaining small trees were either few in number or cut for firewood. Sawtimber stands, which occupy about one-third of the oak area, are mostly 90 or more years old and are most abundant in the southern portion of the region. Some of these stands on good sites are of high quality, but many others are understocked and decadent due to repeated high-grading.

In the northern portion of the Lake States, oaks now occupy much former pine land. Clear cutting of the pine followed by recurrent fires enabled the persistent oaks, which resprout quickly after fires, to become established.

Table 2. — Annual timber cut from oak stands in the Lake States

State	Sawtimber	Poletimber	All timber
	Million bd. ft.	M cords	M cu. ft.
Michigan[1]	69.1	35	14,349
Wisconsin[2]	92.8	115	31,102
Minnesota[3]	29.0	45	8,773
Total	190.9	195	54,224

1/Unpublished 1966 data, Michigan Forest Survey.
2/Wisconsin's forest resources (Stone and Thorne 1961).
3/A third look at Minnesota's timber (Stone 1966).

Table 3. — *Distribution of oak area in the Lake States by stand-size class*
(In thousand acres)

State	Stand-size class				
	All stands	Sawtimber	Poletimber	Seedling and sapling	Nonstocked
Michigan 1/	2,405.0	725.7	1,035.1	512.4	131.8
Wisconsin 2/	2,573.0	855.0	933.0	785.0	--
Minnesota 3/	1,039.5	366.8	527.7	145.0	--

1/Unpublished 1966 data, Michigan Forest Survey.
2/Wisconsin's forest resources (Stone and Thorne 1961).
3/A third look at Minnesota's timber (Stone 1966).

PRINCIPAL OAK SPECIES OF THE LAKE STATES[1]

At least 10 species of oak are found in the Lake States: (1) northern red oak,[2] (2) black oak, (3) pin oak, (4) scarlet oak, (5) northern pin oak, (6) shingle oak, (7) white oak, (8) swamp white oak, (9) chinkapin oak, and (10) bur oak. However, only five species — northern red, black, northern pin, white, and bur oak — are commonly found over most of the region. Moreover, only northern red, white, and black oak ordinarily produce commercially valuable timber (table 4).

The Lake States are the northern limit of the range of most oaks discussed here, so the oaks are most abundant in the southern portion. The forest environment varies greatly, being most favorable for oaks in the southeast and becoming less favorable in the north and west. Because of differences in climate, growing season, and soils, the forest vegetation gradually changes from oaks and mixed hardwoods in the south to hemlock-northern hardwood forest in the north, and to prairie in western Minnesota. These environmental differences affect species distribution, physical and morphological characteristics, growth rates, and value of the oaks for timber products.

[1] *For detailed silvical characteristics see: Silvics of forest trees of the United States. U.S. Dep. Agr., Agr. Handb. 271, 762 p., illus. 1965.*

[2] *Common and scientific names of trees listed on inside back cover.*

Table 4. — *Oak volume in the Lake States by species group*

RED AND BLACK OAKS

State	Sawtimber	Total growing stock
	Million bd. ft.	Million cu. ft.
Michigan 1/	3,094.2	1,156.3
Wisconsin 2/	3,378.0	1,222.0
Minnesota 3/	885.4	373.6
Total	7,357.6	3,751.9
WHITE OAKS		
Michigan 1/	1,029.0	400.5
Wisconsin 2/	1,206.0	465.0
Minnesota 3/	600.7	4/204.9
Total	2,835.7	1,070.4

1/Unpublished 1966 data, Michigan Forest Survey
2/Wisconsin's forest resources (Stone and Thorne 1961).
3/A third look at Minnesota's timber (Stone 1966).
4/Mainly bur oak.

NATURAL ENEMIES

Although the oaks have many natural enemies, only oak wilt and the heart-rotting fungi cause major damage. Trees of the white oak group appear to be slightly more resistant to insect and disease attacks than those of the red oak group.

Late spring frosts frequently kill the lower foliage and developing acorns of all oaks; the most serious damage from frosts is periodic loss of acorn crops.

Oaks are the preferred host of many insects, but few kill or even seriously damage the living trees. Foliage-eating insects, such as the fruit-tree leaf roller (*Archips argyrospilus* (Walker)) and walkingstick (*Diapheromera femorata* (Say)) may completely defoliate an oak without killing it (Craighead 1950). A leaf roller (*Archips semiferanus*) similar to the fruit-tree leaf roller is currently causing extensive damage and some tree mortality to oaks in northeastern Lower Michigan. Gall insect attacks on the roots, bark, twigs, buds, leaves, flowers, and acorns result in numerous deformities and distorted growth, but cause little real damage (Felt 1965). Larvae of various oak borers may cause cull or grade losses, especially in the butt logs.

The acorns are seriously damaged by weevils of the genus *Curculio*. At least 60 percent and more often 90 percent of the fallen acorns are infested by insects, which greatly increases the difficulty of obtaining natural oak reproduction. No practical control has been devised to protect acorns from insects.

Most diseases of oaks are caused by fungi and result only in defects and cull. However, oaks may be killed by the oak wilt fungus (*Ceratocystis fagacearum* (Bretz) Hunt), which blocks the conductive tissues of the trees. All the oaks are susceptible to oak wilt, but the red and black oaks have less resistance than the white oaks to this disease. No practical control method has been developed for forest trees.

Butt rot often develops in pole-size and larger oaks that have been damaged by burning or logging. Decay is also common in tops of older trees, where the infection may start in large branch stubs as the tree approaches maturity.

A common heart-rot fungus that causes extensive cull in red and black oak sawtimber is *Fomes everhartii*. Another fungus causing serious damage to oak is *Armillaria mellea* Fr., which attacks the roots of oak that have been weakened by drought or soil compaction in parks and camping areas.

Phomopsis tumor of oaks forms large stem galls that often reach several feet in diameter. *Strumella* canker is found on young oaks with smooth bark. This fungus causes sunken lesions an inch to a foot or more in length (Baxter 1952).

OAK SITE-PRODUCTIVITY CLASSES

The species composition of oak stands, their growth, timber quality, and economic importance are influenced most by factors that affect soil moisture: soil depth and texture, aspect, position on the slope, and climate. The combined effect of these environmental factors on tree growth is the basis for site-productivity classification.

Available soil moisture affects stand composition on otherwise similar sites. For example, black oak usually is the predominant species on ridges in southern Michigan, but farther west where precipitation is less abundant, such sites most often support bur oak. In contrast, northern red oak often is the prevailing species on sites with optimum soil moisture.

The physical characteristics of the trees are also related to site quality; the bark of most oaks is rougher and the trees are shorter, limbier, and less valuable for timber on dry sites than on moist ones. Although oaks may be found growing over a range of sites, they produce quality timber only on good sites. Thus, proper management of oak stands requires an understanding of site potential in terms of volume and value growth for different species.

The need to correlate site productivity with the growth, yield, and occurrence of oak species for management purposes has long been recognized in the Lake States. Deters (1943) noted that the soil-moisture gradient association among the oaks in southeastern Minnesota was related to the topographic position. Bur oak occupied the driest sites and northern red oak the wettest.

More recently, Gysel and Arend (1953) reported that oak sites in southern Michigan could be classified on the basis of (1) subsoil texture, (2) slope steepness, (3) slope position, and (4) depth of the moist layers in the substrate. In southern Michigan the soils are deep and the terrain only slightly to moderately rolling, having maximum differences in elevation of only 100 to 200 feet. Consequently, soil depth and aspect (exposure) have less effect on site quality here than in the unglaciated hills of southern and southwestern Wisconsin and southeastern Minnesota.

The landforms in southwestern Wisconsin and southeastern Minnesota differ from those in southern Michigan. Soil depth varies from a thin mantle of loess or residual material underlain by limestone or sandstone bedrock to deep talus deposits on lower slopes and in valleys. The topography ranges from flat uplands to steep, sometimes precipitous slopes with local differences in elevation of as much as 500 feet. Under these conditions, soil depth, aspect, and character of the parent rock also greatly affect site productivity.

Practically all investigations of soil-site relations in other geographic areas show that the soil and topographic features that affect the quantity of available soil moisture largely determine site productivity for oak. Studies include those by Einspahr and McComb (1951) in adjacent northeastern Iowa; Gaiser (1951) and Carmean (1967) in southeastern Ohio; Trimble and Weitzman (1956), Doolittle (1957), and Trimble (1964) in the Appalachians; Smalley (1967) in northern Alabama;

and Arend and Julander (1948) in the Ozarks. Soil fertility alone has been shown to have only a slight effect on height growth of oaks in the limited studies conducted to date (Lunt 1939).

In summary, then, the investigations cited show that the soil and land features affecting available soil moisture largely determine site productivity for oak species in a given geographic area. Although the soil and land features of the Lake States vary greatly in both geologic origin and character of terrain, five factors, (1) soil texture, (2) soil depth, (3) position on slope, (4) steepness of slope, and (5) aspect or exposure, generally reflect oak site productivity (table 5).

Coarse-textured, rapid-draining sands generally are poor oak sites, whereas the finer textured loams and silt loams, with their greater water-retention capacity, favor faster growth. Lower slopes are usually more productive than upper slopes and ridges, even when soil depth and texture are similar. Oaks grow faster on north and east than on south and west exposures.

The most commonly used index of site productivity is the total height-age relation (site index). This relation is reasonably accurate for free-growing oaks 35 to 80 years old. It is not reliable for oaks that are much younger or older, or for trees that have been periodically suppressed.

OAK FOREST TYPES BY SITE-PRODUCTIVITY CLASS

The oak species or combination of species found on a site not altered by cutting or other disturbances is usually an indication of the site productivity. For example, red oak is generally found on the most productive sites, mixed oaks on medium to good sites, and black oak, bur oak, and northern pin oak on the poor to very poor sites. Only the most common and most extensive natural species associations, in which oaks should be given specific consideration in timber management, are described here.

On the most productive oak sites more shade-enduring species usually become dominant in natural succession. However, the oaks are reasonably stable ecologically on medium- and poor-quality sites (Parmelee 1953a, 1953b).

Table 5. — Soil and topographic features affecting site productivity of oak forests in the Lake States

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.

In describing the species associations of the Lake States in which oaks are important, it was not always practicable to use standard forest-type designations (Society of American Foresters 1954). When possible, however, the SAF type number or numbers most nearly applicable are shown. Because there is no satisfactory basis for estimating the total acreage of each of the major forest types, their area is given only in general terms.

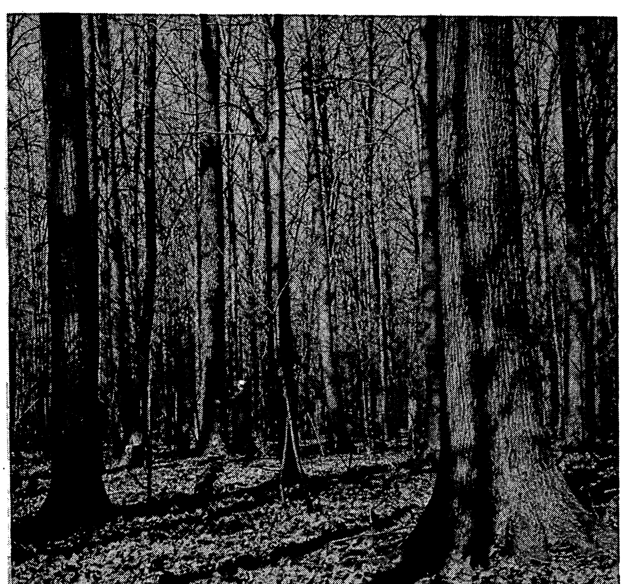
Good Sites

Northern Red Oak in Mixture With Other High-Value Hardwoods

(Includes SAF Type 54)

Northern red oak is the key overstory species in this, the most productive oak type in the Lake States. The type is usually limited to good-to-excellent sites in Lower Michigan, the southern two-thirds of Wisconsin, and the southeastern quarter of Minnesota.

The associated species in these "mixed hardwoods" forests vary somewhat across the region. In Michigan this type includes a wide mixture of hardwoods, such as northern red oak, white oak, American basswood, black cherry, white ash, rock, slippery, and American elms, black walnut, red maple, sugar maple, beech, and frequently yellow-poplar (fig. 1). In Wisconsin, northern red oak usually is found with white ash, sugar maple, red maple, slippery elm, and occasionally bigtooth aspen and butternut.



F-519092

FIGURE 1. — Northern red oak growing in mixture with other valuable hardwoods. A 26-inch d.b.h. yellow-poplar is being measured. Baker Woods near East Lansing, Michigan.

Northern Red Oak

(SAF Type 55)

This oak type is limited in the Lake States. In southwestern Wisconsin and in extreme southeastern Minnesota northern red oak forms fairly extensive stands. Equally "pure" but more limited acreages also occur on moist sites in northwestern Lower Michigan, southeastern and north-central Wisconsin, and east-central Minnesota. This forest type requires more mesic conditions for its best growth than the northern red, white, black oak and hickory mixture described for medium sites.

Northern red oak stands are typically even-aged and well stocked with high-quality timber (fig. 2) (Scholz 1946, 1952). This type is often composed of less than 10 tree species, with the bulk of the stocking in red oak (Scholz 1960).

The existing red oak stands are not very stable ecologically, because tolerant hardwoods usually become established and gradually shade out the oak in succeeding rotations. However, some ecologists feel that northern red oak forests can persist as a subclimax type for extended periods (Marks 1942). There are cases, too, where stands of sugar maple and American basswood were destroyed by fire or other catastrophes and subsequently were replaced by more xeric stands "rich" in northern red oak (Curtis 1959).

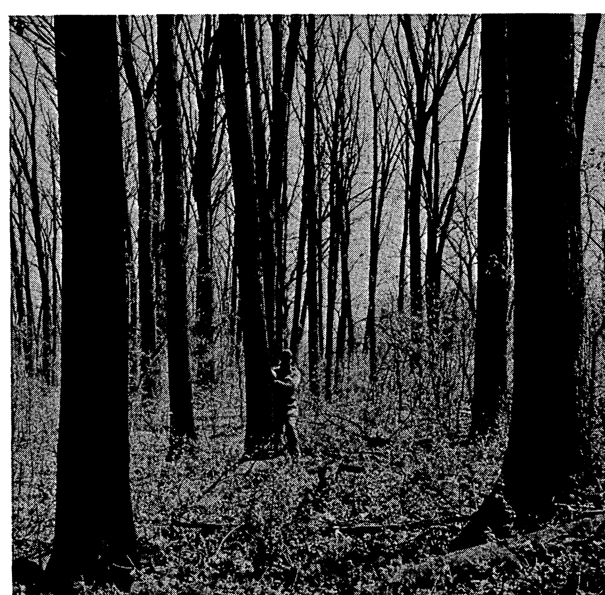


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FIGURE 2. — The growth potential of northern red oak stands is excellent. This stand near Whitehall, Wisconsin (Trempealeau County) is about 100 years old and averages 110 square feet of basal area per acre. Overstory trees are almost exclusively northern red oak up to 22 inches in diameter and 65 to 76 feet in total height.

White Oak

(SAF Type 53)

White oak grows in pure or nearly pure patches an acre or two in size on good sites in southwestern Wisconsin and southeastern Minnesota (fig. 3), but usually is found in mixture with other oaks. It is second to northern red oak in regional importance for timber, and the most valuable oak in the Lake States for high-quality sawtimber. It is considered the only satisfactory timber for the tight cooperage industry. Its heartwood is more durable than the other oaks, has a more attractive appearance, and usually is finer textured; therefore, it is in high demand for posts, piling, barrel staves, lumber, and veneer.

White oak tolerates site conditions ranging from dry sands to deep, fertile, moist-but-well-drained loams. On dry sites, it is a low-quality, small-diameter tree associated with such species as northern pin oak, black oak, and quaking aspen, but on good sites white oak produces excellent timber.

F-519091

FIGURE 3. — White oak is also an excellent quality timber tree. These white oaks are growing in southwestern (La Crosse County) Wisconsin.

Northern Red Oak in Mixture With Northern Hardwoods

(Includes Species Found in SAF Types 25, 26, 27, 60)

This highly productive type represents a near-final successional phase in the change from northern red oak to northern hardwood forest. Northern red oak is still important, but, nevertheless, secondary to sugar maple and other northern hardwoods in these stands (fig. 4).

F-519093

FIGURE 4. — Northern red oak is found as scattered, fast-growing, high-quality trees (the one shown here is 17 inches at d.b.h. and about 60 years old) in the northern hardwood-conifer complex of northeastern Wisconsin. Associated species on this site included sugar maple, red maple, yellow birch, eastern hemlock, black ash, American elm, American basswood, white pine, and balsam fir. Chilsen Timber Harvest Forest, Lincoln County, Wisconsin.

In the northern hardwood forests of Upper Michigan and the northeastern two-thirds of Wisconsin, northern red oak is present only as single, scattered trees of high quality. This has led many foresters to feel that a greater effort should be made to propagate northern red oak in northern hardwood stands, where it usually grows faster than sugar maple. However, the natural succession in such stands is toward the more shade-enduring species, especially sugar maple. Northern red oak is less tolerant and will be difficult to maintain on these sites even in its present role.

Medium to Good Sites

Northern Red Oak-White Oak-Black Oak-Hickory Type

(Includes SAF Types 52-53)

This combination of key species probably accounts for the largest acreage of oak forest in the Lake States. In general, the type occupies the drier sites of medium to good productivity (fig. 5).

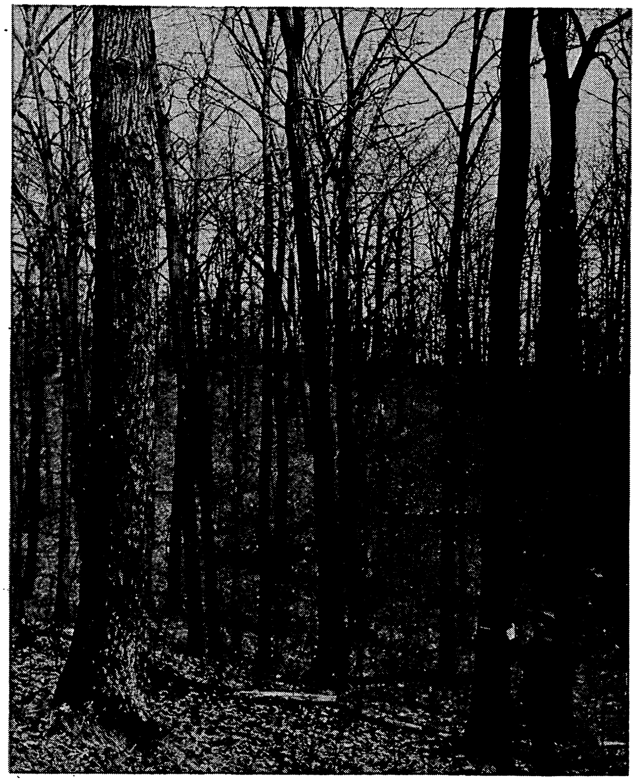

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FIGURE 5. — This mixed oak type is the most prevalent oak type in the southern portion of the Lake States.

Composition varies widely, with complex tree associations in the eastern part of the region and relatively simple ones in the west. Species (such as flowering dogwood, sassafras, and pignut and bitternut hickory) common in Michigan are rare or absent in Wisconsin and Minnesota. Bur oak is much more likely to be found in this type in Minnesota and Wisconsin than in Michigan. In southern Wisconsin large bur oaks are often found scattered among younger northern red and black oaks. In these stands the younger oaks developed after wildfires were largely curtailed by agricultural development (Marks 1942, Parmelee 1953a, Curtis 1959).

Black oak plays an interesting role in this forest complex. In Lower Michigan and southeastern Wisconsin it is one of the important species in the stand, but in southwestern Wisconsin and southeastern Minnesota it becomes secondary in importance to northern red oak and white oak. Because high-quality white oak was in such great demand during the past century, many mixed oak forests where half the original sawtimber volume was white oak now are predominantly northern red oak and black oak.

Mixed Oak-White Pine Type

(SAF Type 20)

A combination of white pine, northern red oak, white oak, and associated hardwoods occupies a limited acreage in the central third of Wisconsin and parts of south-central Michigan (fig. 6). Occasionally both red and white pines are found in these mixtures, but more commonly scattered "old-growth" white pines are found encompassed by vigorous second-growth hardwoods, especially northern red oaks. Although the hardwoods account for most of the basal area in such stands, the individual white pines often constitute a major portion of the sawtimber volume.

This forest type is of interest mainly because of the high value of the large pines. It has temporary ecological status. Few white pine saplings and poles are present because they are unable to compete successfully with the more tolerant and vigorous deciduous trees. Consequently, pines will virtually disappear from the forest association once the scattered large trees die or are cut.

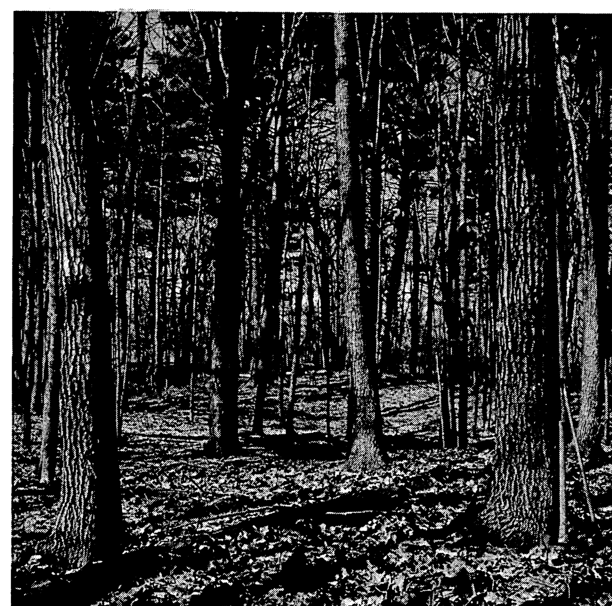

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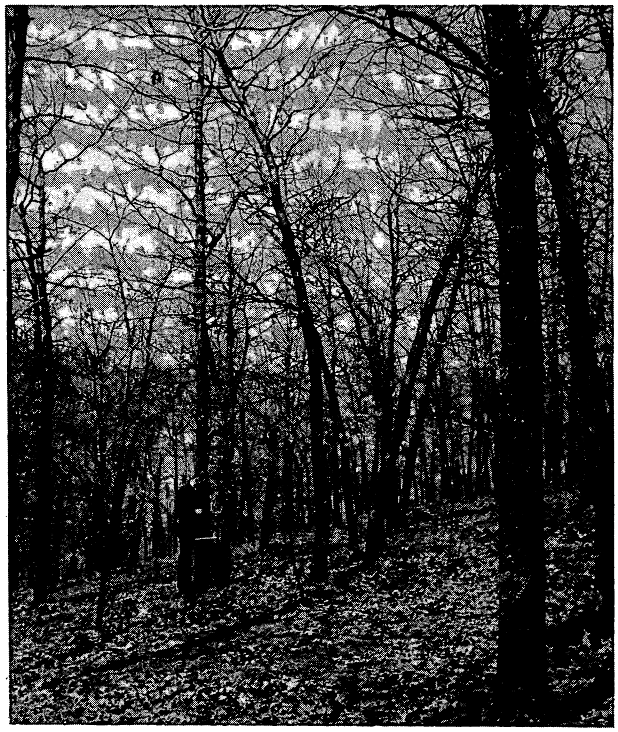
FIGURE 6. — Scattered old-growth eastern white pines in mixture with second-growth northern red oaks and other hardwoods on the Apple River Timber Harvest Forest in Polk County, Wisconsin. Note the clump of eastern white pine on the skyline in the central portion of the picture. The total basal area of the stand at this particular location was 90 to 100 square feet per acre.

Poor Sites

Black Oak-Hickory Type

(Resembles SAF Types 40 and 52)

Mixed oak stands that are predominantly black oak with scattered white oak grow on many droughty sites, such as upper slopes and narrow ridges, in southern Michigan and southeastern Wisconsin. Unlike its moist-site counterpart, this type includes very few northern red oak, white ash, sugar maple, or other mesic species. An interesting thing about this type is that the percentage of black oak in the stand increases as site quality decreases, and sometimes even form a pure subtype in patches of a few acres. The type includes most of the poorer oak lands in the southern portion of the region (fig. 7).



F-518098

FIGURE 7. — A very poor oak site near the top of a steep slope on deep sand in Ionia County, Michigan. The trees are all black oaks, averaging 8 inches in diameter, 43 feet in height, and 68 years in age. Note the limby, crooked boles.

Northern Mixed Oak Complex

(Similar to SAF Type 14)

This oak type predominates on many droughty, outwash plains that formerly supported mixed stands of pines and hardwoods, and on other dry, sandy sites in the central portion of northern Lower Michigan, central and northern Wisconsin, and east-central Minnesota (fig. 8).

F-519090

FIGURE 8. — This stand of 4- to 12-inch trees is typical of the northern pin oak complex. It occupies a droughty site of Grayling sand soil in an area where the original forests were a mixture of pines and hardwoods. The stumps are white pine.

The recurrent fires that followed cutting of the virgin pine stands built up the stocking of the oaks, because oaks, unlike pines, sprout vigorously from stumps. Thus, these second-growth forests of sprout-origin oaks have taken over a total area of about 2 million acres.

Although this forest type often has been referred to as "scrub oak," well stocked stands will average 10 cords of pulpwood per acre at 60 to 70 years (Arend 1964). However, the trees are often limby and defective from basal fire wounds.

The oaks present in this type include black oak, northern red oak, white oak, and northern pin oak. The oaks in the red and black oak group are difficult to distinguish because of overlapping physical characteristics of the leaves, acorns, buds, and bark. Other forest species may include red maple, aspen, cherry, and scattered jack pine, white pine, and red pine (table 6).

Bur Oak Type

(SAF Type 42)

Bur oak has the most extensive botanical range of the oaks in this region. As a pure type, however, it is confined mainly to the prairie-fringe soils and dry, shallow soils in the southern two-thirds of Wisconsin and Minnesota. In Wisconsin, such stands usually occupy the poorest sites and rarely are more than an acre or two in size, but in Minnesota, bur oak stands are more numerous and extensive.

Table 6. — *Species composition and stand structure of northern mixed oaks on Grayling sand in northern Lower Michigan at 60 to 70 years of age*[1]
(In number of trees per acre)

Species	D.b.h. class (inches)			
	1 to 4	5 to 9	10 to 16	All classes
White oak	197	50	6	253
Red and black oaks	86	40	12	138
Red maple	161	0	0	161
Aspen[2]	30	11	0	41
Cherry[3]	8	1	0	9
Jack pine	14	2	0	16
Serviceberry	23	0	0	23
Miscellaneous	81	0	0	81
Total	600	104	18	722

1/Based on 7 1/2-acre plots located in Wexford, Lake, Manistee, and Grand Traverse Counties, Michigan.
2/Includes both Populus tremuloides and P. grandidentata.
3/Includes Prunus serotina and P. virginiana.

In 1966 bur oak accounted for roughly one-fourth of the cubic-foot volume of all oak growing stock in Minnesota (table 4).

Bur oak, like white oak, can adapt to a variety of physical sites, both dry and moist. A pioneer species, it persisted on subclimax prairies of the Midwest in spite of wildfires (Deitschman 1958). Bur oak is usually short-boled, limby, and slow-growing in this region, but occasionally high-quality trees are sold along with white oak.

The main value of the bur oak type is to protect the land from erosion and to provide food and shelter for wildlife. Bur oak stands may have a potential value for picnic and campground sites (fig. 9).

F-519097
Figure 9. — Bur oak can provide excellent shade for picnic grounds and camping sites.

NATURAL REGENERATION OF OAKS

Most oak reproduction originates from stump sprouts and seedling sprouts. Oak seedlings grow slowly and, unless they receive adequate sunlight, the tops die back and new sprouts arise from the root system. Oak sprouts, because of their larger root system, grow much faster and can survive and grow in more subdued light than seedlings. Of course, nearly full sunlight is optimum for the best growth of either.

Seed Production

The acorns produced by species in the red and black oak group mature in about 18 months, drop to the ground in the fall of the second growing season, and germinate the following spring. Thus, these acorns are exposed to weather, insects, and animal damage longer than white oak acorns, which mature in one growing season. Both oak groups flower when the leaves come out in May, but white oak acorns mature by late September or early October, drop to the ground, and germinate during the fall.

The frequency and size of acorn crops vary somewhat by species, crown size, exposure to light and weather. Acorn production differs greatly between individual trees — some bear acorns nearly every year while others seldom yield any; thus, acorn yields are nearly impossible to predict. However, some seed is produced each year in most oak stands.

Korstian (1927) found an average of about 4,900 acorns per tree from 12 white oak and 9 black oak trees during a single season, but the remaining 16 oaks in his 37-tree sample produced no acorns. In the Missouri Ozarks, Burns, Christisen, and Nichols (1954) found that black oak produced 4,700 to 7,400 acorns, and white oak 3,400 to 4,600 per tree during the best 3 years out of 6. Gysel (1957) also found that white oaks generally produced fewer acorns than black and red oaks in Michigan. A summary of tree characteristics and environmental influences found to affect acorn production includes the following:

1. Most oaks begin to produce viable acorns at age 20 to 30 years, but optimum yields are not generally reached until age 50 to 75.
2. Acorn production generally increases with d.b.h. up to about 20 inches, but crown size is probably most important (Downs and McQuilkin 1944).
3. Dominant trees generally outproduce codominants. The south and west sides of the crown yield more acorns per unit area than the north and east sides (Gysel 1956).
4. Late spring frosts may damage the developing acorns. Warm (above normal) temperatures during the last 10 days of April followed by cool

(subnormal) temperatures the first half of May result in the best white oak acorn yields, but steadily warming spring temperatures result in poor yields (Sharp and Sprague 1967).

5. Site quality appears to affect only the weight of the acorn crops (Gysel 1957).

Insects, diseases, and animals further deplete the annual acorn crop. Korstian (1927) found that over half the total acorn crop was lost to animals, and that when all losses were totaled, less than 7 percent of the original crop was available to produce seedlings. Other studies have shown that insects and animals destroy roughly four-fifths of the annual acorn crop (Minckler 1957, Downs and McQuilkin 1944, Gysel 1957). Duvendeck (1962) found that deer will eat about 1.5 pounds of acorns per day per hundredweight in the winter.

Unfortunately, few measures can be taken to increase the number of viable acorns produced under natural forest conditions. At the present time, foliage sprays or chemicals injected into the stem to control acorn-attacking insects, and such positive control as poisoning rodents, are either impractical or unacceptable to the general public. Banding, choking, or partially girdling trees in southern Michigan did not increase acorn production. Fertilizing may increase acorn production.

The most positive cultural measure that can be used to increase acorn production is to favor trees that are good acorn producers in thinnings or improvement cuttings, thus providing more room and light for trees that regularly yield heavy seed crops.

Seedling Establishment

The failure of viable acorns that escape spoilage or destruction to become 1-year seedlings usually can be traced to one of two causes: either the seed dries out, killing the embryo, or the newly formed radicle fails to penetrate into mineral soil.

Viability decreases markedly when acorn moisture content falls below 50 percent of ovendry weight for white oak, or below 30 percent for northern red oak (Korstian 1927).

The ideal seedbed for oak acorns is moist, well-drained mineral soil protected by some litter. However, Minckler and Jensen (1959) found litter depths in excess of 1 inch to be detrimental to the establishment of oak seedlings in southern Illinois. Our observations indicate that oak seedlings are more numerous where the mineral soil has been disturbed, such as logged areas, fire lanes, and the edges of cultivated fields. Both northern red and white oak seedlings are also able to develop on sparse, grassy sites. Oak seedlings rarely are found in places where litter accumulates, such as depressions, around old logs, and in thickets of shrubs. Apparently several inches of litter prevent the radicles of germinating acorns from reaching the underlying mineral soil.

The most practical treatment to increase seedling establishment is partial cutting, because it disturbs the forest floor and lets in more light. Other practices might include prescribed burning to consume deep litter, and soil scarification to expose mineral soil a few years before the final harvest cut. Scarification would also work many of the viable acorns into the mineral soil where they are less likely to be eaten by animals and damaged by excessive drying. Of course, once oak seedlings are established, nearly full sunlight is required for their survival and growth.

Sprouts

Most of the present-day second-growth oak stands are of seedling sprout and stump sprout origin. All of the oaks indigenous to the Lake States have dormant buds along the stem that produce sprouts when the tree is cut or damaged. Although the physiological mechanism is not fully understood, sprouting is apparently controlled by hormones. Vogt (1966) showed that auxins produced by apical buds are translocated to the dormant buds, where they act as growth inhibitors. Interruption of the auxin flow, which occurs when the crown is removed or damaged, initiates sprouting.

Sprouting ability generally decreases with age, although some oak species are prolific sprouters even after the trees reach sawtimber size, especially on good sites. Sudden exposure to light following heavy cutting also appears to stimulate sprouting.

Prior to investigations by Liming and Johnston (1944) in the Missouri Ozarks, foresters had recognized only two types of oak reproduction: seedlings and stump sprouts. The term "seedling" also included seedling sprouts because it was generally assumed that the tops of such young oak were within 2 or 3 years of the age of the roots. But the Missouri study showed that more than half of the so-called seedlings actually were sprouts whose root systems (called stools) were many times as old as the tops. The amount of defect associated directly with the stools was low and the annual height growth of white oak and black oak stool sprouts was more than double that of true seedlings of the same species. This study made two important contributions to our knowledge of oak management. First, it explained how a forest gradually builds up a reproduction potential by means of standby root systems that retain their capacity to produce new tops as needed for 20 years or more. And second, it showed that properly selected sprouts provide acceptable growing stock for the next rotation of timber. Similar observations were made in southeastern Ohio by Merz and Boyce (1956).

There has been a long-standing and perhaps still unresolved question as to whether stump sprouts are as desirable as seedlings and seedling sprouts. Apparently this depends upon the size of the tree from which the sprout develops and almost certainly upon the number of times that the same root system has had to serve for successive rotations of sprouts. For example, Scholz (1931) reports that "repeated coppicing for a period of over two hundred years has reduced the vitality of the growing stock" in the Hudson River highlands of New York. Increment borings taken in conjunction with this study showed that a high percentage of outwardly sound oak sawtimber trees had heart rot. No doubt repeated coppicing on short rotations may reduce the quality and vigor of oaks. However, first-rotation oak stump sprouts are as vigorous and tall as single-stem trees at 45 years of age (Trimble 1968).

Manipulating sprout production is important in oak management. To encourage sprouting, oaks should be cut during the dormant season, leaving the stumps as low as possible. Because full sunlight on the stump also stimulates sprouting and subsequent sprout growth, cutting groups of trees is beneficial. Where oak sprouts are not desired, trees should be cut or girdled at the peak of the growing season (Clark and Liming 1953). Of course, the most feasible method of controlling oak sprouts is with herbicides, either stem-injected or sprayed on the foliage of sprouts that have developed.

HARVEST CUTTING METHODS TO REGENERATE OAK STANDS

When oak stands reach maturity, the harvest method used should ensure establishment of a new stand of trees of desirable species. The cutting method recommended will depend on the presence or absence of adequate advance reproduction of desirable species. Adequate reproduction means at least 400 well established seedlings or seedling sprouts per acre that are 1 foot or more in height (U.S.D.A. Forest Service 1962). Where advance reproduction is adequate and the main stand is mature, complete overstory removal is recommended. Where advance reproduction is inadequate, the rotation must be prolonged by a series of partial cuttings or other stand disturbances. One advance reproduction is adequate, the remaining overstory is removed.

Advance Reproduction Is Essential

Obtaining enough advance oak reproduction to regenerate the stand is a major problem on certain sites in the Lake States. Although ample reproduction is present under most mature oak stands, the percentage made up by oak varies with the productivity of the site. For example, Arend and Gysel (1952) found from 5 to 17 thousand stems per acre in trees less than 0.6 inch d.b.h. under well stocked, ungrazed oak stands in southern Michigan. However, oak constituted only 5 percent on good sites, 15 percent on poor and medium sites, and 50 percent on very poor sites. Studies in West Virginia and western Maryland also showed less oak reproduction on good sites (Weitzman and Trimble 1957, Carvell and Tryon 1961).

Even when oak reproduction is present in sufficient quantity, it is frequently not tall enough to compete with ground vegetation and seedlings of undesirable species. For example, in southern Wisconsin, a sample of the reproduction beneath two oak sawtimber stands on medium to good sites showed 4 to 10 thousand stems per acre (table 7). Although oak reproduction made up one-third to one-half of the total, it was mostly under 1 foot in height, much smaller than the competing black cherry and red maple. When the overstory trees were removed in these stands, the new stand was composed mainly of species that had a height advantage in the reproduction stage.

The same amount of shade and competition for moisture that keeps oak reproduction suppressed year after year does not prevent the development of young red maple, black cherry, and other hardwoods under mixed stands of oak in Wisconsin (Larsen 1953). Similarly, in oak forests of southern Michigan, red maple, hickory, white ash, and black cherry saplings often dominate the reproduction in oak forests, even though they usually make up only a minor portion of the overstory (Parmelee 1953a). A study of environmental factors favoring advance reproduction under oak stands in West Virginia showed that stand disturbance during the previous 20 years was most important in establishing oak reproduction, and its subsequent development was directly related to the amount of sunlight reaching the forest floor (Carvell and Tryon 1961). The vigor and shape of the crown also affect the growth of advance oak reproduction. Carvell (1967) found that oak seedlings with flat crowns grew more slowly than those with normal crown shapes.

Advance reproduction has an important role in oak management for many reasons. First, it must be present in adequate amounts before the final harvest cut if the stand is to be successfully regenerated. Second, the thrifty tree species present in the advance reproduction before the final cut will dominate the new stand. Third, advance reproduction builds up in numbers following stand disturbance (Liming and Johnston 1944, Carvell and Tryon 1961, Ward 1966). Therefore, improvement cuttings and thinnings to eliminate undesirable trees and regulate stand density, especially during the 20 years before the final harvest cut, can help improve the quantity and composition of the advance reproduction.

Table 7. — Tree reproduction in two oak sawtimber stands with brushy understories in southern Wisconsin[1]
(In stems per acre)

ALBANY WOODS (GREEN COUNTY)

Plot	Height class	Red oak	Black oak	White oak	Hickory	Black cherry	Misc. hwds.	All species
1-1	Under 1'	0	3,550	0	0	400	0	3,950
	1-5'	0	0	50	0	1,900	50	2,000
	5'+	0	0	50	0	0	0	50
	Total	0	3,550	100	0	2,300	50	6,000
2-1	Under 1'	0	1,650	100	150	2,800	300	5,000
	1-5'	0	50	150	100	6,250	200	6,750
	5'+	0	0	0	0	1,000	0	1,000
	Total	0	1,700	250	250	10,050	500	12,750
3-1	Under 1'	0	6,050	150	100	1,100	0	7,400
	1-5'	0	700	50	0	1,950	50	2,750
	5'+	0	0	0	0	800	0	800
	Total	0	6,750	200	100	3,850	50	10,950
4-1	Under 1'	1,550	1,900	850	0	2,550	0	6,850
	1-5'	800	0	350	0	700	300	2,150
	5'+	50	0	0	0	0	250	300
	Total	2,400	1,900	1,200	0	3,250	550	9,300
	Stand average	600	3,475	437	88	4,862	288	9,750
	COULEE EXPERIMENTAL FOREST (LA CROSSE COUNTY)							
1-1	Under 1'	850	0	100	25	150	1,075	2,200
	1-5'	0	0	25	25	225	2,800	3,075
	5'+	0	0	25	0	0	400	425
	Total	850	0	150	50	375	4,275	5,700
2-1	Under 1'	275	0	125	50	50	400	900
	1-5'	25	0	0	50	0	450	525
	5'+	0	0	0	0	0	200	200
	Total	300	0	125	100	50	1,050	1,625
3-1	Under 1'	175	0	0	75	25	1,025	1,300
	1-5'	0	0	0	25	0	1,175	1,200
	5'+	0	0	50	0	0	25	75
	Total	175	0	50	100	25	2,225	2,575
4-1	Under 1'	1,600	0	1,475	400	175	350	4,000
	1-5'	525	0	425	0	25	450	1,425
	5'+	25	0	25	50	25	150	275
	Total	2,150	0	1,925	450	225	950	5,700
	Stand average	869	0	562	175	169	2,125	3,900

1/ 4 randomized blocks, each containing 4 1-acre-square plots, were established in each of these 2 oak stands. Results are based on 20 milacre quadrats in the Albany Woods and 40 milacre quadrats in the Coulee Forest randomly located in each of the 4 1-acre-untreated control plots.

Brush Makes Regeneration Difficult

Some sawtimber oak stands, primarily those in southern and western Wisconsin and Minnesota, have dense, brushy understories that cause an unusual regeneration problem. The major species recorded in two such stands in southern Wisconsin were blackberry, raspberry, gray dogwood, hazelnut, gooseberry, and numerous others totaling 13 to 17 thousand stems per acre (table 8). Although tree reproduction was ample in these stands, advance oak reproduction was sparse.

Why unusually dense, brushy understories are present in some sawtimber stands in southern Wisconsin and Minnesota and not in others is not clear. These understories are found most often on medium to good oak sites where the overstory sawtimber trees are mainly first-rotation oak and scattered old-growth bur oaks. These stands developed in the prairie fringe areas after agricultural settlement had largely controlled wildfires. According to Cottom (1949), early surveyors in this area recorded the vegetation as "scattering timber," with an understory of "hazel," "prairie grasses," "red root" (*Ceanothus*), and "oak." Cottom found many present-day oak stands in Wisconsin containing bur oak, black oak, and shagbark hickory to still have a shrub understory of hazel, dogwood, and blackberry. Much of this area was initially covered with a thin mantle of loessial top soil that may also favor development of a lush ground cover under a dense, mature oak overstory.

Clear-Cut Method

Most of the ungrazed, reasonably well stocked sawtimber stands of oak in the Lake States will have ample advance reproduction when the stands are mature. The proportion of oak in these stands will depend upon such things as site, stand density, and previous disturbances. When the advance reproduction is satisfactory, removing all overstory trees at once will generally result in successful stand regeneration (fig. 10). Additional reproduction can be expected from stump sprouts after harvest cutting, but new seedlings usually fail to compete with the advance reproduction and sprouts. Even where dense, brushy understories exist, the advance tree reproduction, if knocked down in logging to promote sprouting, will normally outgrow the brush in 5 to 10 years.

Table 8. — Brush species found in two sawtimber oak stands in southern Wisconsin[1]
(In stems per acre)

ALBANY WOODS (GREEN COUNTY)

Plot	Gray dogwood	Hazel	Raspberry and blackberry	Gooseberry	Misc. species	All species
1-1	0	7,500	8,250	4,500	0	20,250
2-1	3,250	1,250	7,000	0	500	12,000
3-1	0	10,750	9,250	750	750	21,500
4-1	4,750	4,250	5,500	0	750	15,250
Stand average	2,000	5,938	7,500	1,313	500	17,250
COULEE EXPERIMENTAL FOREST (LA CROSSE COUNTY)						
1-1	5,875	3,750	4,625	3,875	5,250	23,375
2-1	5,125	500	2,125	2,250	1,375	11,375
3-1	625	0	4,000	4,875	250	9,750
4-1	2,750	500	4,500	1,375	125	9,250
Stand average	3,594	1,188	3,813	3,094	1,750	13,438

1/ 4 randomized blocks, each containing 4 1-acre-square plots, were established in each of these 2 oak stands. Results are based on 4 milacre quadrats randomly located in each 1-acre plot in the Albany Woods and 8 milacre quadrats in the Coulee Forest. These were the untreated control plots.

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FIGURE 10. — A, two-acre clear-cut area of oak saw-timber in east-central Wisconsin; B, same area 6 years later showing dense tree reproduction averaging 6 to 7 thousand stems per acre. About half of it is oak.

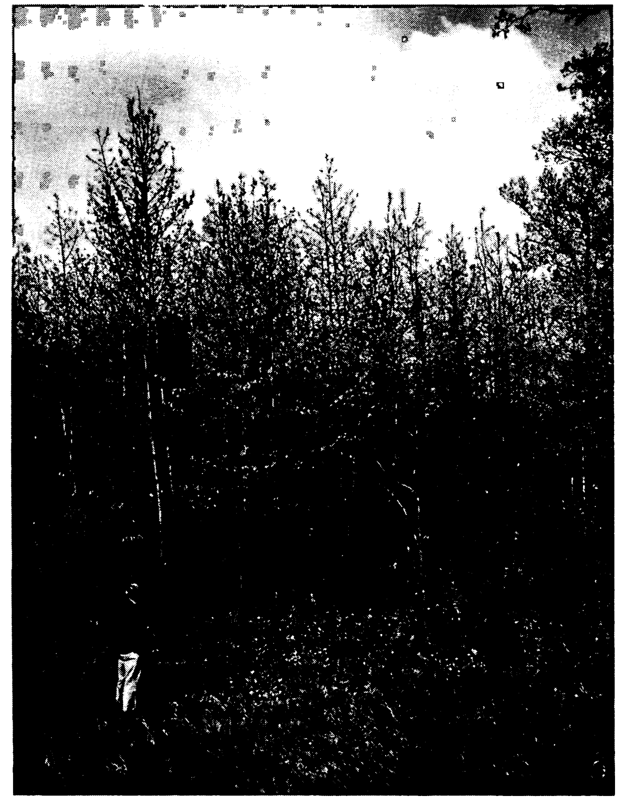

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FIGURE 11. — Dense thicket of mixed oak saplings that developed 12 to 15 years after clear cutting of the parent stand. This young growing stock is a mixture of stump coppice, seedlings, and seedling sprouts. Jackson County, Michigan.

The feasibility of the clear-cut method for regenerating small blocks of timber is frequently questioned. Yet, there are many ways of applying this method to regenerate individual oak stands to satisfy the desires of small woodland owners and to maintain esthetic values. Clear cuts can be made in groups, patches, or blocks of 1 acre or more over a period of years because all portions of the stand seldom mature at the same time; thus the total acreage cut each year can be controlled. Few oak stands, except those on poor sites and those that are overmature with few valuable trees left in the overstory, need to be harvested completely in one operation. Also, all oak stands need not be regenerated as soon as they reach merchantable size. Many owners may wish to harvest the periodic growth as long as operable cuts can be made.

Examples of the regrowth of oak following complete clear cutting are in evidence enough and the growing stock of sufficiently good quality to justify managing them for the next timber rotation (Fig. 11). It is apparent, too, that stump sprouts have been responsible for many of the present-day merchantable stands, even though they are stocked mostly with single trees in mixture with an occasional twin stem or "triplet" from a common root system (fig. 12). Multiple sprouts do not necessarily result in slow growth (Wood 1939).

Practically all studies of oak stands after various intensities of overstory cutting have reported abundant oak reproduction. However, this natural reproduction develops satisfactorily only where all the overstory trees are removed (Rudolph 1956; Scholz and DeVriend 1957; Merz and Boyce 1956; Minckler and Jensen 1959; Gammon, Rudolph, and Arend 1960; Bey 1964; Minckler and Woerheide 1965; McGee 1967).

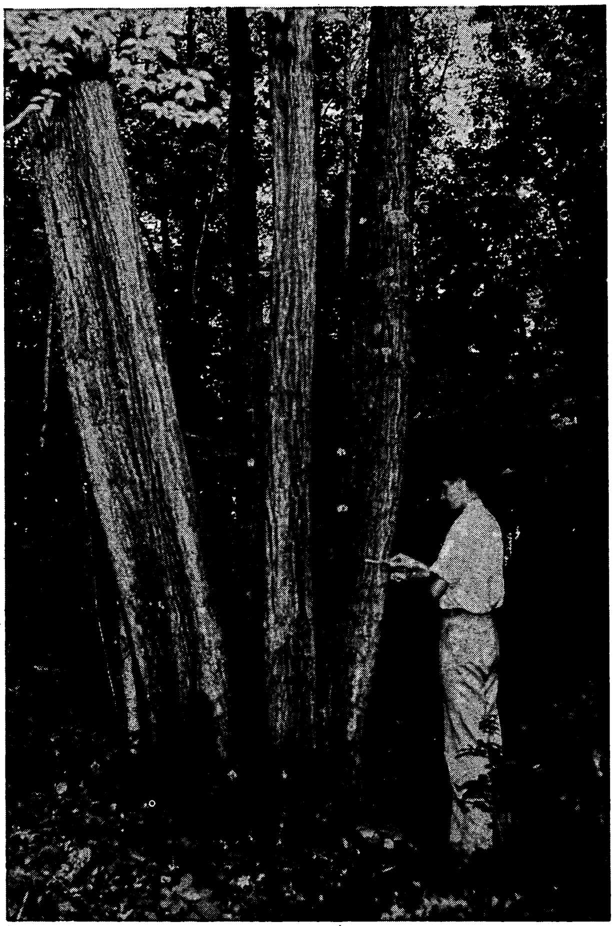

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FIGURE 12. — Six northern red oak sprouts 14 to 16 inches at d.b.h. and about 65 years in age. Normally only two or three stems would persist in a single clump for so long a period. The leaning character of the trees is typical of coppice from stumps. Clinton County, Michigan.

Complete clear cutting favored the best development of hardwood reproduction on more than 200 experimental plots in the central upland hardwoods of southern Illinois, southern Indiana, southeastern Ohio, and eastern Kentucky.[3] Six years after advance reproduction was knocked down by logging, new sprouts were more than twice as tall as stems of advance reproduction not killed back. New seedlings developed in the clear-cut areas after 2 years, but failed to compete successfully with the new sprouts. One acre was recommended as the minimum size for clear cutting; the maximum size will depend on local conditions, area of oak ready for harvesting, and desires of the owner.

[3] *Sander, I. L., and Clark, F. B. Reproduction of Upland hardwood forests in the Central States. (In preparation for publication, Northeast. Forest Exp. Sta., U.S.D.A. Forest Serv., Upper Darby, Penn.)*

Removing all the unmerchantable trees in clear cutting presents a costly and challenging problem (fig. 13). Any trees not knocked down or felled during logging should be cut or stem-injected with herbicides (table 9). In general, all trees over 2 inches d.b.h. should be removed.

Also, time and patience are needed in oak regeneration. For example, in the south central hardwoods, Sander and Clark[3] reported that all species, desirable and undesirable grow at about the same rate for the first 5 years after clear cutting. However, by the time the young stands reach 12 to 15 years of age, more desirable trees reach the dominant and codominant crown classes. Although no similar study of cutover oak stands has been conducted in the Lake States, general observations indicate that most of them are reasonably well stocked with desirable tree reproduction after 10 to 15 years.

Shelterwood Method

The shelterwood system, which is a series of partial cuts (normally three) to remove mature overstory trees, is usually recommended where desirable advance reproduction is inadequate to form a new stand. This condition may exist (1) where the overstory casts such a dense shade that seedlings and seedling sprouts of preferred species cannot survive, or (2) where they are present but are submerged in a brush understory.

In two shelterwood cutting studies in Wisconsin, we obtained adequate tree reproduction over a 14-year period by removing the overstory trees in three cuts. However, the results also indicated that removal of the overstory in two cuts would be even more practical. Not only was adequate oak reproduction obtained within 4 years after the first cut (nearly 3 thousand seedlings and seedling sprouts per acre), but high mortality and poor growth resulted from continuing the partial shade from a second partial cut. Also, the three cuts prolonged the rotation, resulting in increased cull and degrade losses to overmature overstory trees.

The first cut should remove one-third to one-half the basal area, leaving the best seed trees. The actual amount of overstory to remove will depend on the stand density and the abundance of the understory brush. When brush is scattered, the stand can be opened up to about 50 percent uniformly distributed crown cover. When brush is abundant, the forest floor should be left about 75 percent shaded by overstory trees, unless brush is first controlled by herbiciding or mowing. Trees left in the overstory should be dominants of desirable species that show evidence (old acorns on the ground) of being good seed producers. The cutting should be mainly from below. The principal oaks to favor for seed trees are northern red oak and white oak. If other valuable hardwoods such as white ash, basswood, and sugar maple are present

F-470320
FIGURE 13. — Sawtimber stand of oak on very good site (Miami silt loam) commercially clear cut for logs and veneer. Note number of unmerchantable trees left.

Table 9. — General herbicide prescription guides for killing pole-size hardwoods in the Lake States by spaced stem injections[1]
(In milliliters per injection)

Interval between injections (edge to edge) (inches)	Picloram mixture 2/ (diluted 50/50 with water)	Undiluted amine salt 2,4,5-T or 2,4-D 3/ (4 lb. a.e. gal.)	
	All seasons	Growing season	Dormant season
2	0.5-1.0	0.5	2.0
4	1.0-2.0	1.0	(4/)
6	2.0-4.0	4.0	(4/)

1/Large-crown dominant hardwoods, particularly sugar maple and white ash, are difficult to kill by spaced stem injections. These trees should be completely frill girdled by overlapping injections.

2/Contains 0.54 acid equivalent of 4 amine-3,5,6-trichloropicolinic acid and 2 pounds a.e. of 2,4-dichlorophenoxyacetic acid as the triisopropanolamine salt.

3/2,4-D amine is more effective than 2,4,5-T on most hardwoods except red maple.

4/Not recommended in dormant season.

and desired over oak on good sites, they too can be selected for seed trees. Red maple may qualify too, depending upon local soil and moisture conditions. Less commonly, yellow-poplar and black walnut may be left for the second (and final) harvest. When a choice must be made between seed trees, dominants and codominants with balanced crowns and apparent windfirmness should be reserved.

Special efforts should be made to knock down all ground cover and stir up the mineral soil. Litter over 1 inch in depth should be burned off or otherwise disturbed to expose the mineral soil. Herbicide treatments, disking, or rotary mowing might be needed to destroy the brush and encourage oak sprouts.

The final cut should be made immediately after the desired reproduction is obtained. Again, no attempt should be made to protect the advance reproduction in the final logging operation. The trampled and cut reproduction will sprout vigorously. Also, trees over 2 inches d.b.h. should be cut or killed.

Selection Method

The single-tree selection method of harvesting mature timber, which works so well for perpetuating certain tolerant hardwoods, is not feasible for regenerating mixed oak stands because the oak seedlings need full sunlight for best development. Selection cuttings periodically remove the mature trees at intervals ranging from 1 to 20 years. This stimulates the establishment of new seedlings, but the stand is not opened up enough for oak reproduction to develop successfully.

The disadvantages of the selection system for managing mixed oak were demonstrated on the Kaskaskia Experimental Forest in southern Illinois (Minckler, Plass, and Ryker 1961). Nine years of annual selective cutting reduced a 24-acre merchantable stand to one consisting mainly of saplings, poles, and small sawtimber. Annual cutting had to be discontinued because the small remaining trees did not grow fast enough to maintain periodic harvests.

Regeneration cutting experiments in southern Michigan also demonstrated that single tree selection was inferior to small-block clear cutting, group selection, and shelterwood cuttings that removed about 50 percent of the oak stand (Rudolph and Arnold 1956). Sander and Clark[3] reported that even 35 years after selection cutting, none of the reproduction had grown into pole-size trees, and that the stand looked the same as it did 5 years after cutting.

In previously unmanaged stands of oak, it is advisable to harvest the older or larger scattered trees of poor form, quality, or vigor that are crowding better trees at least 10 or more years prior to the final harvest cut (fig. 14). This, however, is an improvement cutting and thinning and should not be confused with a harvest cutting to regenerate the stand. Yet, such intermediate cuts in oak stimulate the establishment of advance reproduction that is needed when the final harvest cut is made 10 to 20 years later (Carvell and Tryon 1961, Ward 1966).

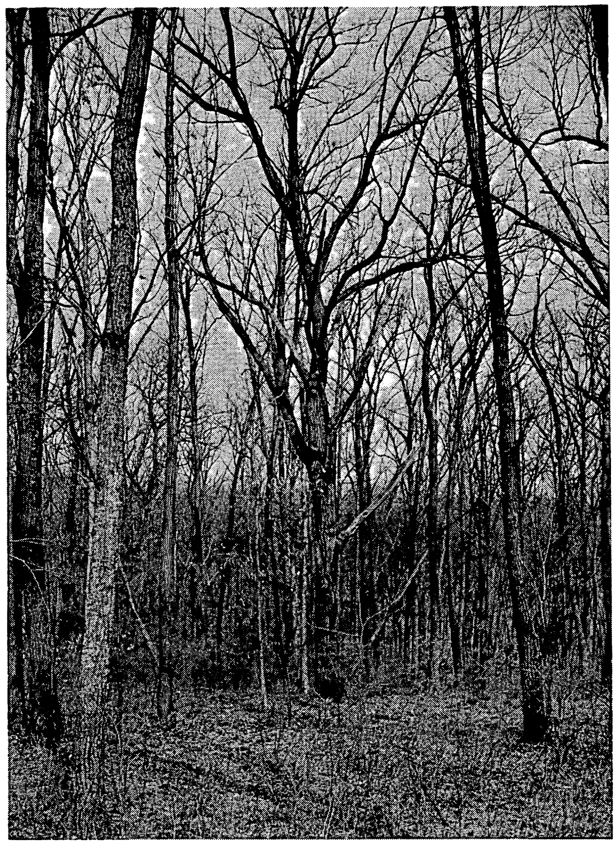

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FIGURE 14. — Unmanaged oak stands have many poor-quality trees that need to be removed by timber stand improvement and thinning operations. Note the large, limby northern red oak in the middle of this photo that is nearly worthless for timber, and is retarding the growth of many trees. Also note advance reproduction that is common in most oak stands.

Other Cultural Treatments

Questions are frequently asked about ground cover and soil treatments that might be tried to hasten oak regeneration and control brush. Many such treatments have been tried, with both positive and negative results.

Soil scarification. — Disking has been shown to increase the initial establishment of oak seedlings. Scholz (1955, 1959) found that disking and other soil disturbances greatly increased the number of red oak seedlings per acre in Wisconsin. He concluded that it was impractical from a cost standpoint because nearly the same quantity of oak reproduction was present after 10 or more years on both disked and undisked plots. However, disking to control brush and break up sod and deep litter to expose the mineral soil needs to be further explored, especially in open, understocked stands.

Burning. — Prescribed burning before regeneration cutting will consume deep litter and may provide a more favorable seedbed. However, our spring and fall burning trials before regeneration cutting on two experimental oak stands in Wisconsin failed to reduce brush. Burning immediately after clear cutting encourages oak to sprout from the base of stumps, reduces butt rot (Roth and Sleeth 1939), and also kills back the tops of advance reproduction and pole-size trees causing them to sprout vigorously. Prescribed burning techniques have not been perfected for the oak types; the elaborate precautions taken to prevent fires from escaping and causing extensive damage have kept costs high, but these can be reduced with experience. Of course, as soon as the quantity of oak reproduction is adequate, fire must be controlled.

Herbiciding. — Brush can be controlled by herbicide sprays. Before clear cutting two Wisconsin oak stands, we foliage-sprayed the brush with 2,4,5-T ester (about 1 lb. per acre) in mid-growing season using a portable mist blower. This killed back the ground cover temporarily, but a new crop developed in 2 years. If this treatment is used, however, we recommend foliage spraying as soon as the understory brush leafs out in May, just before the overstory leafs out. Most herbicides kill the desirable hardwoods as well as undesirable brush, and treatments cost $5 to $10 per acre.

Mowing. — Heavy rotary mowers also have possibilities for cutting back brush before regeneration cuts, especially where partial shelterwood cuttings are made to establish reproduction. Sprouts from the tree reproduction might outgrow the new brush crop. Mowing northern hardwood reproduction increased sprouting in New England (Jensen and Wilson 1951), but was considered impractical for this forest type.

ARTIFICIAL REGENERATION OF OAKS

Most of the oaks can be established artificially by planting either acorns or seedlings. Such plantings are normally made only to supplement natural reproduction in recent cutover oak stands on medium to good sites. A major reason why artificial regeneration of oak in the Lake States is seldom practiced is that for the same costs, hardwoods of greater value, such as black walnut, yellow-poplar, basswood, sugar maple, and white ash, can be planted. Nevertheless, there will be some medium to good quality sites where oaks, particularly red or white, may be desired.

Because oak seedlings require full sunlight for successful development does not mean that abandoned agricultural fields and old pastures are the best oak planting sites. Rather, the ideal sites will be recently logged sawtimber stands where all the trees have been taken off and open areas prevail (fig. 15).

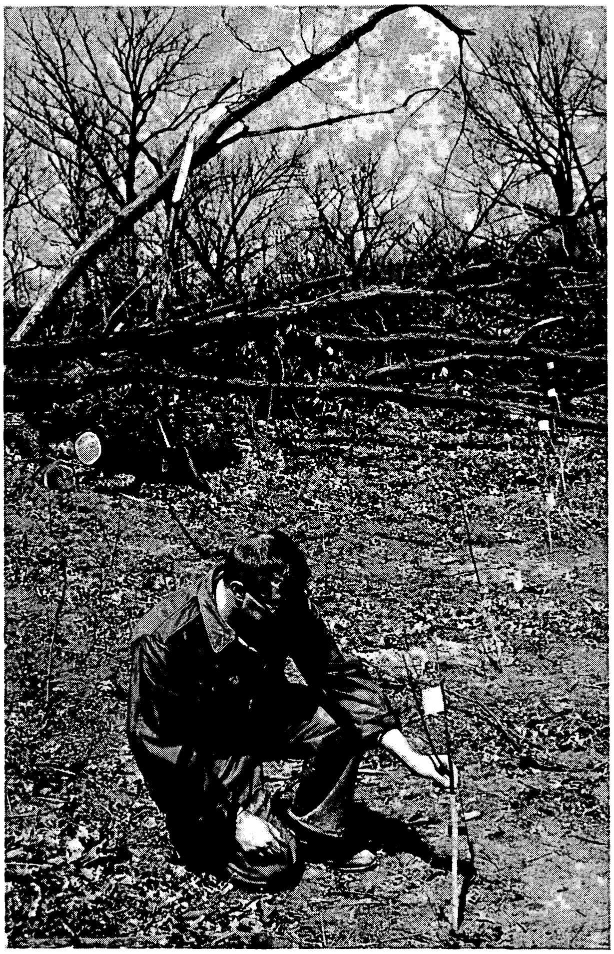

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FIGURE 15. — Planting valuable hardwoods in bare openings of cutover oak stands.

Direct Seeding

The usual method of direct seeding is to plant the acorns an inch or two deep in mineral soil that has been exposed by scalping spots 1½ to 2 feet in diameter or by furrowing with a special plow (Sluder, Olson, and Jarrett 1961; Scholz 1964).

Species in the red and black oak group are somewhat easier to establish by planting acorns than those in the white oak group.

One of the problems in direct seeding white oaks is that the acorns must be collected and planted soon after they fall, because germination takes place in the autumn, often the driest season of the year in the Lake States region.

Rodents are the chief obstacle to reproducing oak by direct seeding (Bramble and Sharp 1949, Krajicek 1955). Various methods of control have been used to prevent or discourage pilfering of the seed. The most positive one is to cover the spots where the acorns are planted with protective screens of hardware cloth or some other material (Stoeckler and Scholz 1956). This procedure has proven effective throughout the eastern United States (Krajicek 1960; Sluder, Olson, and Jarrett 1961; Scholz 1964), but the costs are relatively high.

Damage may also be reduced by fall planting to get the acorns underground and out of sight of mice, chipmunks, and squirrels. This practice, in conjunction with screens, gave excellent results in the semihumid climate of North Carolina (Sluder 1964). In southeastern Ohio, fall-planted seed, including northern red oak acorns, also made the best showing (Plass 1952). Losses of acorns to rodents were lower with fall than with spring seeding in the Missouri Ozarks, but none of the various controls (season of planting, screening spots, or use of repellents) were good enough to be recommended for general use (Nichols 1954). Until satisfactory rodent control methods are developed, direct seeding of the oaks cannot be recommended as a standard practice.

Planting

Oak seedlings may be grown in a nursery and field planted as 1-0 or 2-0 stock. This method is more expensive than direct seeding but it assures better initial establishment of the seedlings. The trees should be planted where they will receive nearly full sunlight and on sites of at least medium quality.

Rabbits and other rodents often girdle or clip off the tops of the young trees. This damage can be curtailed by reducing the rodent population, planting when it is naturally low, or by wrapping the stems with a protective cover.

We hand-planted northern red oak, yellow-poplar, white ash, black walnut, basswood, sugar maple, and red maple seedlings in two locations after complete clear cutting in southern Wisconsin. The initial survival after 2 years was about 90 percent. Height growth averaged nearly 20 inches per year for all species except northern red oak, which averaged only about 5 inches per year.

INTERMEDIATE CUTTINGS

Even after oak regeneration is established, additional treatments will be needed to ensure that enough young trees of desirable species and quality are free to grow. Such treatments may include weeding and cleaning, liberation cutting, thinning, and pruning of selected trees. Because the cost of these treatments is incurred long before harvest cuttings are made, prudent management requires that the potential investment costs (plus interest) be weighed against the expected returns. Intensive management will seldom be profitable on poor sites, so costly cultural practices should be limited to those oak sites where faster growth rates and higher quality trees can be expected.

Fortunately, few young stands will need all the above treatments. The basic objective in oak management on good sites is to produce about 100 high-quality sawtimber trees per acre in the shortest possible time. Since it is nearly impossible to select final sawtimber crop trees 60 to 80 years in advance of maturity, additional trees must be carried through the rotation as insurance against loss or damage.

Weeding and Cleaning

Weeding and cleaning are carried out in stands not past sapling size to remove stems that are competing with potential crop trees. Eliminating undesirable species and poorly formed stems would be most desirable when the trees are 3 to 4 feet tall. However, releasing about 200 to 300 selected saplings per acre when they are 16 to 20 feet tall is more practical. At this time the main job is to weed out undesirable species or poorly formed trees that are crowding or suppressing potential crop trees.

The initial dominance of oak regeneration has an important effect on its future growth rate. In a 5-year period beginning 4 years after clear cutting of the parent stand, released dominant oaks made double the height growth of unreleased ones, but intermediate and suppressed trees failed to respond to this treatment (Walters 1963).

Do not attempt to eliminate all undesirable stems in sapling stands. It is too costly and will do more harm than good, because the released trees will develop excessively branchy crowns. Instead, select potential crop trees on about a 15-foot spacing, and release them by killing adjacent stems within a radius equal to half the tree's height. This spacing of crop trees and degree of release should provide acceptable stocking by the time the trees average 4 to 5 inches d.b.h. Also, do not select trees that have suppressed or intermediate crowns for crop trees just to maintain adequate spacing, because such trees grow slowly even after release. The 15-foot spacing figure is only a guide; some crop trees may be closer and others farther apart.

Species to be favored in weeding and cleaning include high-quality oaks, white ash, American basswood, black cherry, yellow-poplar, butternut, and black walnut. Trees to be removed include poorly formed trees of all species, and so-called "weed species" such as eastern hophornbeam (ironwood) and American hornbeam (blue beech). Also, any species found on a site too poor for its best development could be considered a weed species, although it might be acceptable when grown on a suitable site. Red maple is a classic example of such a tree, and to a lesser degree, so is sugar maple.

Trees eliminated in cleaning may be cut or killed by herbicide injections. Basal sprouts that may develop later will create no problem because the released trees are tall enough to maintain their height advantage over any new shoots. The principal disadvantage of cutting and felling medium-to-large saplings (trees 20 or more feet tall) is the labor required; use of a tree injector usually is cheaper. The number of trees that must be treated per acre seldom requires more than 1 man-day to complete the job.

Cleaning can be done faster by using herbicides in tree injectors. Several makes of tree injectors are on the market, and the particular one used will be a matter of personal choice. A hypohatchet, which applies the herbicide at a convenient chopping height, is faster and less tiring than an injector. An ordinary hatchet can also be used to make cuts through the bark, and a plastic squeeze bottle or a small oil can to apply the herbicide. Several herbicides can be used effectively in tree injectors; their prescriptions vary by species and tree size (table 9).

Liberation Cutting

Liberation cuttings are made to free young trees not past the sapling stage from the competition of older, overtopping trees (Smith 1962). This type of cutting will be required in many oak stands where successful hardwood reproduction has developed in the openings created by heavy cutting (fig. 16). The scattered older trees are usually not numerous enough or of sufficient value to justify leaving them for another harvest cut. Where these stand conditions exist, the liberation cutting should be made promptly to release the reproduction and minimize damage caused by felling or girdling of the large overstory trees.

Whenever possible, such overstory trees should be cut and utilized. Even when they cannot be utilized, it may be desirable to cut them for esthetic or safety purposes along roads and around forest recreation areas. Where esthetic values are not a consideration, unmerchantable overstory trees can be girdled injected with herbicides and allowed to slowly deteriorate.

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FIGURE 16. — This stand was commercially clear cut leaving many unmerchantable trees. Abundant reproduction has developed, but it will be retarded unless a liberation cut is made.

Improvement Cutting and Thinning

Improvement cuttings are made in stands past the sapling stage for the purpose of improving species composition and stem quality by removing trees of undesirable form and species from the main canopy (Smith 1962). Thinnings, on the other hand, are made in immature stands for the purpose of stimulating growth of the remaining trees, to shorten the rotation, and to increase the total yield of useful timber products from the stand. Surplus trees are removed to concentrate potential wood production on a limited number of selected crop trees (Smith 1962). Although the specific objectives of improvement cuttings and thinnings are different, few unmanaged oak stands contain surplus high-quality trees. The principal job will be removing less valuable trees until a desired stand density is reached. This can be accomplished by a combined improvement cutting and thinning operation.

Several studies have shown the growth response of crop trees following improvement cutting and thinning in oak stands. In southern Illinois, growth of pole-size white oak trees the year after release was 41 percent greater than average growth for the previous 10 years (Minckler 1967). And their growth was 46 percent greater than that of unreleased trees in the stand. The growth response of individual trees was not influenced by age for trees 35 to 100 years old. The smaller crown class trees (codominant and less in size) continued to accelerate in growth the second year after release.

In two southern Michigan oak stands, the board-foot growth in the 10 years following an improvement cut was 20 percent greater than on the control plots (Arend and Monroe 1950). In West Virginia, Carvell (1964) made a series of three improvement cuts over an 11-year period in immature mixed hardwoods, favoring the 100 trees per acre most promising for quality saw logs. After three improvement cuts, 354 trees per acre totaling 7.8 cords had been cut and sold. The remaining volume was still equal to that in the control area where no improvement cuts were made. In addition, the remaining thinned trees were about 1 inch larger in diameter.

Most improvement cuttings and thinnings are made periodically to maintain rapid growth of the most desirable trees. For oaks, the "stop thinning" age is about 60 to 70 years on medium sites and less on better sites (U.S.D.A. Forest Service 1962), provided the stand has been properly managed. In unmanaged stands, improvement cuttings and thinnings may be useful even at later ages on good sites.

All trees left for sawtimber in oak stands should have straight, clear, nearly defect-free stems for at least 10 feet and preferably 16 to 20 or more feet in height, and well balanced crowns that make up 30 to 50 percent of the total tree height. Species to favor in addition to northern red and white oak include black walnut, butternut, red maple, yellow-poplar, sugar maple, basswood, white ash, and black cherry. Hickories have had a lower value in the past than most hardwoods, but this is changing. In addition, hickories have some excellent multiple-use qualities, such as producing nuts for animal and human consumption and improving soil by virtue of the high calcium content of their foliage (Lutz and Chandler 1946).

One of the problems apparently related to thinnings and improvement cuttings in oak is epicormic branching. In a study of old-growth Appalachian hardwoods, Jemison and Schumacher (1948) found that many trees develped new sprouts after the stands were partially cut. Dense stands that were heavily cut showed the highest incidence of postlogging sprouting.

In southeastern Iowa, examination of the butt logs of 600 white and black oaks after thinning in 25-to 50-year-old stands showed a higher incidence of epicormic branching to be associated with these factors: low residual stocking, sprout clumps, and suppressed, intermediate, and codominant crown classes (Brinkman 1955). White oaks that became dominant due to thinning developed epicormic sprouts on the butt log more frequently than those that were dominant prior to cutting. The lowest residual stocking gave the best diameter growth, but at the cost of more epicormic branches and potentially lower quality.

Another study in south-central Iowa confirmed that dominant white oaks have fewer epicormic branches than those in other crown classes (Krajicek 1959). Examination of 400 trees (100 each for suppressed, intermediate, codominant, and dominant crown classes) showed that dominant trees had the fewest epicormic branches, the highest number of clear log-faces, and other quality advantages. Thus, it seems advisable to favor dominant trees when making intermediate cuttings in white oak stands.

Little information on epicormic branching of northern red oak can be found in the forestry literature. However, we have observed "feathering out" of this species in heavily thinned stands that are slow in closing the crown canopy. Black oak is probably worse in this respect than northern red oak, which has excellent natural pruning tendencies.

The problem of epicormic sprouting is more critical in younger stands because the trees are smaller and the branches will have a longer period to develop into major defects before a final harvest is made. In general, thinnings should favor single-stemmed dominant trees and maintain stocking levels as high as possible without adversely affecting the volume growth of these trees.

Pruning

The pruning of deciduous trees is still in an experimental stage in the United States. This is understandable because there has been an exploitable supply of good hardwoods in natural stands throughout most of the eastern half of the country during the past 30 to 40 years. Consequently, most foresters and interested landowners have doubted that pruning was a sound economic investment. However, the future outlook in unmanaged stands is for declining timber quality, and this prospect may justify future financial investment in pruning.

Several hardwood pruning studies have been made. In West Virginia, selected trees in a stand of mixed oak 6 to 12 inches d.b.h. were pruned during the months of January, April, July, and August to a height of 17 feet. Ten years later these oaks were cut, and the pruning wounds were dissected and analyzed. One conclusion was that the vigor of the pruned trees, rather than the season when the work was done, seemed to be the important factor in healing (Roth 1948). Also, pruning scars wider than 1.5 inches at the time of treatment were more likely to develop decay than smaller scars. Sprouting was so profuse on the boles of pruned white oak that a question was raised as to the advisability of pruning this species.

However, in another white oak pruning study in southern Illionois, Minckler (1967) reported that a combination of release and pruning of crop trees can fulfill the need for high-quality white oak in the near future. He found that 72 percent of the pole-size white oaks with one to three branches pruned in the first 17 feet were still clear after 10 years. Trees with an average of eight live branches pruned in this zone had an average of two new sprouts 10 years later. Therefore, dominant white oaks with only a few branches might be successfully pruned to maintain clear logs.

In another white oak pruning study made by Boyce and Neebe (1963), trees 3⅓ to 5 inches d.b.h. were pruned to a height of 17 feet. The stems were coated with a variety of sprout-inhibitors during both the dormant and growing seasons. The most effective control for stem sprouts on white oak was SAE 20W oil applied with a brush. On trees given this treatment, an average of only 2.5 sprouts per 17 feet of pruned bole developed by the end of 4 years compared to 10.5 sprouts for untreated trees. When the oil was applied during the dormant season, damage to white oak was slight; black oaks, however, were injured by this treatment regardless of season.

A pruning study on pin oak in southeastern Missouri provided some additional information on bole sprouts (Minckler and Krajicek 1964). A total of 150 dominant and codominant trees 6 to 10 inches d.b.h. were pruned to a height of 17 feet in March, June, and October 1957. Cuts were made flush with the bole with a pole pruning saw. No effort was made to cut into the branch callus, although this often happened. Half of all sample trees, including controls, were exposed to direct sunlight on the south and southwest sides by cutting adjacent trees. Prior to pruning there was an average of 20 small (less than ½ inch in diameter) branches per tree, 13 medium (½ to 1 inch), and 2.4 large (more than 1 inch). Season of pruning had little effect on the number of new branches. The average butt log had 36 bole branches initially, and 4 years after pruning there were only 7. Of these, five were less than 12 inches in length and two were already dead. New branches were concentrated on the exposed faces, and they were twice as long as those on the shaded faces. Trees with the most branches initially developed the most new branches. After 4 years, 96 percent of the pruning wounds were healed over.

In summary, it appears that limited artificial pruning may have practical application in oak stands. Recommendations are as follows:

1. Prune only well formed, vigorous, dominant trees 5 to 8 inches d.b.h. where removal of a few branches can produce a clear log. (Stems that support numerous branches along the bole can seldom be successfully pruned artificially.)
2. Saw off the branches flush with the stem. The low ridge of callus around the branches may be cut through, but no special effort need be made to do this as in pine. Branches up to 3 inches have been reported completely healed over in 4 years (with little risk of rot).
3. Avoid pruning branchy oaks.
4. Provide adequate crown growing space for pruned trees, but avoid excessive exposure of the stems to direct sunlight.

The removal of a few branches from vigorous, dominant oaks may upgrade many future saw logs. When done in this way, artificial pruning of oaks and associated valuable hardwoods may be profitable.

GROWTH AND YIELD

Growth of individual trees and stands, and yield of well stocked oak forests in the Lake States, have been studied by several investigators over the past 40 years (Kittredge and Chittenden 1929, Schnur 1937, Gevorkiantz and Scholz 1948, Gysel and Arend 1953). Periodic growth has also been measured in several sawtimber stands. Considerable growth and yield data are available for evaluating the productivity of unmanaged oak stands on various sites, but only scant information is available for evaluating the growth potential of oak stands under intensive management.

Periodic Annual Growth

Medium to Good Sites

In the Lake States, well stocked, unmanaged stands of mixed oak sawtimber on medium to good sites will produce an average net periodic annual growth of about 200 board feet per acre. This amount will vary considerably because of differences in individual tree vigor, tree age and size, stand structure, and site.

In southern Michigan (Livingston County), the 10-year periodic net annual growth in four mixed oak farm woodlands ranged from 128 to 268 board feet per acre, averaging 205 board feet (table 10). These stands were fairly well stocked (86 square feet of basal area per acre) and growing on medium to good sites. Cutting and grazing were excluded during the 10-year period.

In Wisconsin, maximum volume growth rates for well stocked mixed oak stands were reached between 60 and 80 years of age (Gevorkiantz and Scholz 1948). Average annual growth was 275 board feet per acre on medium sites and 290 feet on good sites. In the ensuing 20-year period, however, volume growth on these sites dropped to 170 and 190 board feet per acre, respectively.

Poor Sites

Few studies have been made of the growth of oak stands on poor sites that once supported pine. Kittredge and Chittenden (1929) reported periodic annual growth for average stands 40 to 60 years old to be about 18 cubic feet per acre. In well stocked stands of the same age it averaged 30 cubic feet per acre.

More recently, Arend (1964) measured the 11-year growth of mixed oak stands on former pine sites in northern Lower Michigan. On Grayling sand the periodic annual growth averaged 29.8 cubic feet per acre (0.38 cord) in six 40- to 60-year-old stands with stocking about 55 square feet basal area. On Rubicon sand, which is a somewhat more productive soil, the periodic annual growth was about 42 cubic feet or nearly 0.6 cord per acre for stands 60 to 70 years old. These data indicate that unmanaged oak stands on poor sites in Lower Michigan are producing from 30 to 40 cubic feet or 0.4 to 0.6 cord of merchantable pulpwood per acre each year.

Table 10. — Volume and growth per acre of mixed oak stands, Livingston, County, Michigan[1]

Farm woodlot	Average stand age 1949	Estimated net volume[2/] 1939	Estimated net volume[2/] 1949	Mean periodic annual growth: Ingrowth	Mean periodic annual growth: Saw log trees 1939	Mean periodic annual growth: Total
	Years	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
Robinson	70	4,432	6,268	23	161	184
Kerber	80	4,636	7,020	49	189	238
Salmon	70	4,576	7,256	47	221	268
Miller	85	7,608	8,888	15	113	128
Average	76	5,313	7,358	34	171	205

1/From Lake States Forest Exp. Sta. Tech. Note 327 (Arend, Gunderson, and Monroe 1950).
2/International 1/4-inch log rule.

Yield

Projected oak yields for various ages, stocking, and sites have been made in Wisconsin by Gevorkiantz and Scholz (1948) and in the eastern oak region by Schnur (1937). The expected yields from such oak stands for normal or full stocking are presented in table 11.

The average yields of the best unmanaged stands at age 80 in southern Michigan ranged from 900 to 2,500 board feet per acre on poor sites, and from 11,000 to nearly 20,000 board feet on good sites (table 12). Two oak sawtimber stands, which are remnants of the presettlement forests in southern Michigan, contained 25,000 board feet per acre in 1952. However, few such stands remain.

Effect of Stocking or Stand Density

Total growth and yield per acre on a given site are similar over a fairly broad range of stand density. This is the stocking range where the trees are able to effectively utilize the available growing space. However, the stocking within this range does affect the stem taper and the diameter growth of individual trees, and these characteristics have an important effect on the final products. Therefore, it is difficult to define "optimum" stocking without knowing the management objectives. If the objective is oak sawtimber, table 13 can be used as a guide for determining the number of trees and basal area that well stocked stands of different sizes should contain.

Importance of Tree Vigor and Quality

The expected growth and yield from unmanaged oak stands have been presented without reference to the growth performance of individual trees. Species has some effect on individual tree growth; for example, northern red oak is generally the fastest growing oak in the Lake States. However, when the net growth rates of different oak species are compared on the same site for trees having similar crowns, stems, age, and position in the stand canopy, species differences are not too important (table 14). Oak species also vary greatly in their longevity and adaptability to different site conditions, and in their value for different wood products. All of these factors must be considered in deciding which tree to favor in timber managment.

A 12-year study in southern Michigan (Washtenaw County) showed the effects of crown and stem characteristics on the net growth of individual trees. When this study was started, the stand was about 90 years old, had a total net volume of 6,886 board feet per acre (International ¼-Inch Log Rule), and 90 square feet of basal area in trees 5 inches d.b.h. and larger. The stand was fully stocked, and the site was medium to good. The species composition was 33 percent black oak, 31 percent white oak, 18 percent northern red oak, 16 percent hickory, and 2 percent other species, such as red maple.

The individual trees were classified by management potential both at the beginning and the end of the study as follows:

Good. —

a. Straight stems with less than 10 percent sweep.

b. Clear bole or other having a No. 1 or better log potential for 16 or more feet.

c. Merchantable species.

d. Balanced crown occupying one-third to one-half the total height.

e. Less than 10 percent cull defect in the main stem.

Poor. —

a. Crook or forking in the main stem to restrict potential log length to less than 16 feet.

b. Species difficult to sell.

c. Crown less than one-third height or otherwise limited in size.

d. Cull and defect in main stem exceeding 25 percent.

Fair. — Trees not meeting the obvious "good" and "poor" management potential requirements were classed as "fair."

The individual tree class ratings changed very little during the 12 years. The "poor" tree class suffered the most mortality. Average stand growth during the study was 247 board feet per acre per year.

Table 11. — Comparison of reported yields for upland oaks

Site designation		Average stand age	Volume per acre[1]					
Wisconsin	Eastern Region		Wisconsin[2]			Eastern Region[3]		
		Years	Cu. ft.	Cords	Bd. ft.	Cu. ft.	Cords	Bd. ft.
Very poor site	Very poor site (SI 40)	20	480	--	--	485	--	--
		40	1,050	10	--	1,030	8.0	50
		60	1,555	19	550	1,540	16.7	400
		80	2,000	25	2,500	1,975	24.1	1,450
		100	2,350	29	4,550	2,375	30.5	3,350
Poor site	Poor site (SI 50)	20	650	1	--	635	.8	--
		40	1,350	15	--	1,360	12.8	150
		60	1,950	25	2,300	2,050	24.5	1,100
		80	2,550	32	6,400	2,635	34.1	4,000
		100	3,050	38	9,600	3,140	41.4	7,750
Medium site	Average site (SI 60)	20	850	2	--	805	2.0	--
		40	1,750	21	300	1,725	18.6	500
		60	2,550	33	4,700	2,590	32.9	3,150
		80	3,300	41	10,200	3,325	43.9	8,350
		100	3,900	49	13,600	3,970	52.7	13,700
Good site	Good site (SI 70)	20	1,000	3	--	975	4.2	--
		40	2,050	25	1,600	2,075	24.6	1,100
		60	3,050	39	7,600	3,115	40.9	6,700
		80	3,950	50	13,400	4,000	53.1	14,100
		100	4,700	59	17,200	4,780	63.5	19,900
Very good site	Excellent site (SI 80)	20	1,150	4	--	1,145	7.3	--
		40	2,400	30	2,800	2,440	30.7	2,500
		60	3,600	46	10,500	3,690	48.9	11,350
		80	4,600	59	16,800	4,725	62.8	19,700
		100	5,500	69	21,100	5,650	75.1	26,100

1/ Cubic foot volume based on entire stem inside bark; cord volume based on all merchantable stemwood to a 4-inch top outside bark; board foot volume based on Scribner Rule to a minimum top diameter of 8.0 inches inside bark.

2/ From Wis. Conserv. Dep. Public. 521 (Gevorkiantz and Scholz 1948).

3/ From U.S. Dep. Agr. Tech. Bull. 560 (Schnur 1937).

Table 12. — Yields of well-stocked unmanaged mixed oak stands in southern Michigan at 80 years[1]

VERY POOR SITES

D.b.h. class (inches)	Total trees of all species	Basal area	Per acre volume[2/]		
	Number per acre	Sq. ft. per acre	Cu. ft.	Cords	Bd. ft.
5-10	194	59.7	838	10.5	900
11-13	36	27.9	432	5.4	
Total	200	87.6	1,270	15.9	
POOR SITES					
5-10	174	53.9	765	9.6	2,535
11-15	59	47.3	1,003	12.5	
Total	233	101.2	1,768	22.1	
MEDIUM SITES					
5-10	89	29.4	475	5.9	
11-22	81	86.5	1,944	24.3	5,650
Total	170	115.9	2,419	30.2	
GOOD SITES					
5-10	81	21.7	414	5.2	
11-25	88	107.7	3,080	38.5	11,440
Total	169	129.4	3,494	43.7	
VERY GOOD SITES					
5-10	55	17.4	378	4.7	
11-24	95	125.4	5,130	64.1	19,950
Total	150	142.8	5,508	68.8	

[1/]Adapted from Mich. Agr. Exp. Sta. Tech. Bull. 236 (Gysel and Arend 1953).

[2/]Cubic foot volume based on main stem, less bark; cord volume based on all merchantable wood to a 4-inch top, outside bark; board foot volume by International 1/4-inch log rule.

How did the individual trees perform over the 12-year period? The trees classed as having "good" management potential, representing only one-third of the stocking, produced 168 board feet on the average or over two-thirds of the total annual growth. Trees in the "poor" management potential class, representing nearly one-half the total growing stock, produced less than 10 per cent of the growth. On a per-tree basis, the weighted average growth was 5.6 board feet per year for "good" trees versus 1.0 board foot per year for "poor" trees (table 14).

If the "poor" management potential trees could have been removed 10 to 15 years prior to this growth study, leaving a basal area of about 60 square feet per acre, the subsequent growth would have been concentrated on the taller, straighter trees, which are capable of producing the greatest volume of usable timber.

This emphasizes the importance of improvement cuttings in our presently unmanaged oak stands. By favoring the "good" and "fair" potential trees, it seems reasonable that the prevailing 200 board feet per acre per year now being produced by fully stocked stands on medium to good sites could be at least doubled (fig. 17).

Table 13. — Acceptable range in stocking for managed mixed oak stands in the Lake States Region[1]

Average tree diameter[2] (inches d.b.h.)	Trees per acre[3]	Basal area per acre
	Number	Sq. ft.
3	775-1430	38- 70
4	530- 930	46- 81
5	380- 655	52- 89
6	285- 495	56- 97
7	220- 385	59-103
8	180- 305	63-107
9	145- 255	65-112
10	125- 210	67-115
11	105- 180	69-118
12	90- 155	71-122
13	80- 135	73-124
14	70- 120	74-126
15	60- 105	75-128

1/ Adapted from Forest Sci. 13: 38-53 (S. F. Gingrich 1967). These figures appear high for saplings--200 to 300 per acre are normally adequate. The minimum ranges could be considered adequate after thinning and maximum ranges would indicate need for thinning.

2/ Includes all trees 2 inches d.b.h. and larger.

3/ The maximum values correspond closely to what Schnur (1937) considered necessary for 100-percent stocking, and the minimum values correspond closely to what he considered 50-percent stocking.

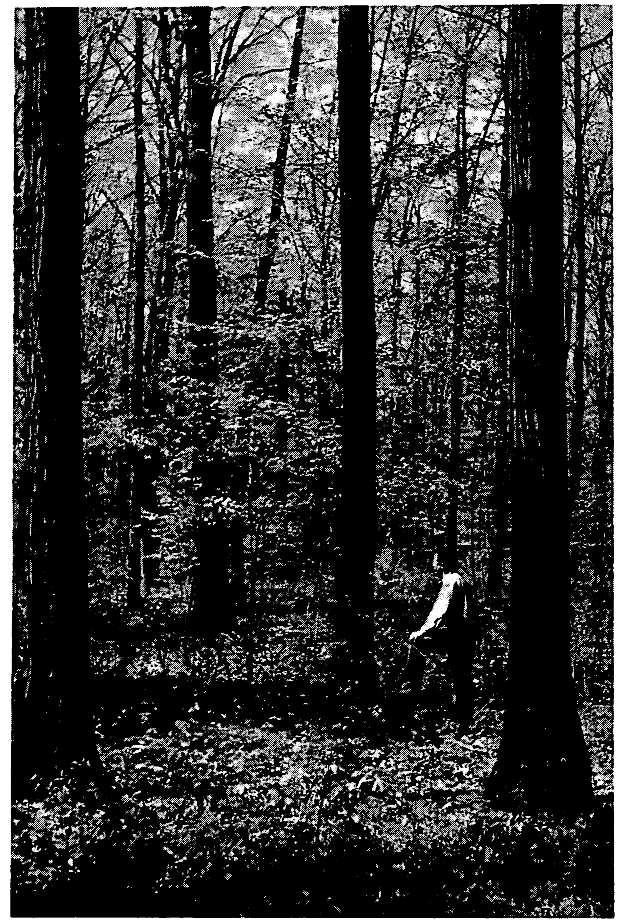

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FIGURE 17. — Well-managed oak stand in southern Michigan. Periodic improvement cuts and thinnings have been made for previous 20 years.

MANAGING OAK LAND FOR MAXIMUM RETURNS

Forest land is not always owned or acquired solely for timber production. Some people have forest land for outdoor recreation, pride of ownership, or for investment purposes.

Although much of the oak in the northern Lake States is publicly owned, most of the oak in the southern portion (where the greater share of the oak area is found) is privately owned. Whatever the owner's objectives, he might still like to know what the potential revenues from managing and harvesting this timber would be. The following discussion presents guidelines for the forest owner who is interested in managing his oak lands for timber production.

Table 14. — Effect of species and potential stem quality on periodic annual growth rate in a southern Michigan mixed oak stand[1]

Management potential class	Net periodic annual growth per tree[2]						Net periodic annual growth per acre, all species
	Northern red oak	Black oak	White oak	Hickory	All species		
	---- Bd. ft.	----			Bd. ft.	Cu. ft.	Bd. ft.
Good	6.3	5.2	5.8	5.4	5.6	0.9	168
Fair	4.7	4.0	2.3	2.9	3.4	.5	60
Poor	-2.5	1.7	1.2	-.1	1.0	.3	19

1/Based on growth of trees 5.0 inches d.b.h. and larger over a 12-year period after the stand reached 90 years of age.

2/International 1/4-inch log rule.

Although silvicultural practices can maximize timber yields for any particular stand, the profitability of management is limited by site productivity and present stand condition. Because site influences species composition, growth rate, tree quality, and regeneration potential, site productivity is the key to oak management decisions (figs. 18, 19). For example, growing oak on poor sites over a full rotation cannot be justified solely for the timber value. Yields are not high enough at present prices to offset accumulated costs of ownership plus interest. Although harder to regenerate, the best oak sites can produce high-quality sawtimber and veneer logs, which bring the highest stumpage prices.

F-470321

FIGURE 18. — White oak veneer logs cut from mixed oak on good site in Ionia County, Michigan. Note bare condition of soil. Dense reproduction developed after the clear cutting.

The other factor limiting profitability — present stand condition — is determined largely by age of the main stand and stocking. Stand age largely determines tree size, value, vigor, and response to thinnings and release. It is also important in evaluating net financial return from a specific stand treatment. Stocking is important because yields in understocked stands will be low regardless of the productivity of the site, and tree quality may be poorer.

F-519102

FIGURE 19. — Clear cutting oak for pulpwood on poor sites in northern Lower Michigan (Grayling sand). This stand averaged about 10 cords per acre at age 65 years. Note the number of small trees left after commercial pulpwood cutting.

Medium to Good Oak Sites

(Sites Where the Largest Oaks Are 65 to 80 Feet Tall at 50 Years)

On the more productive oak sites (table 5), oaks and associated hardwoods can be managed for high-quality sawtimber. High-quality saw logs and veneer are the most profitable oak timber products; Grade 1 logs sell for twice as much as Grade 2 logs, and Grade 3 logs can seldom be harvested at a profit. Seldom will it be advisable to convert oaks to conifers on good sites, because conifers cannot compete successfully with hardwoods on highly productive sites.

Well Stocked Stands

Sawtimber stands. — Young, well stocked sawtimber stands, especially those having no previous management, will require improvement cuttings and thinnings to remove the many poorly formed, low-value trees and to provide adequate growing space for the best potential crop trees (table 13). This practice will also stimulate establishment of the oak reproduction essential for regenerating the stand. These stands will rank highest in work priority on the basis of return on the investment in silvicultural work (Herrick and Morse 1968). Generally, the trees that need to be removed can be sold. This will include some of the larger mature trees that are common in unmanaged stands of sawtimber size. Large culls and other unmerchantable trees that are occupying valuable growing space can be killed with herbicides (table 9). These improvement and partial harvest cuttings can be carried out periodically as long as operable cuts can be made, depending on the specific condition of each stand and the desires of the owner. All trees should be removed in the final harvest cut in order to regenerate the stand, provided adequate advance reproduction is present. Normally this will be no problem in managed stands.

Poletimber stands. — These stands will require timber stand improvement to remove poor-quality trees and to release about 100 potential crop trees per acre to keep them growing rapidly. Where a market exists for pulpwood, most trees removed from pole-size stands can be sold. When no such market exists, about 100 potential crop trees per acre should be maintained in a free-growing condition by poisoning the competitors. Also, pruning some of the potential crop trees is desirable if they have a few scattered branches in the first 16-foot log.

Seedling and sapling stands. — Weeding and cleaning are desirable to keep the best 200 to 300 trees per acre from being suppressed and to shorten the rotation. However, costs need to be kept low because of the long waiting period before the released trees can be harvested. Compared to poletimber and sawtimber stands, these stands will rate low in work priority based on return on silvicultural investment.

Poorly Stocked Stands

These are stands that are considered 50 percent or less stocked for their age.

Sawtimber and poletimber stands. — When oak stands of this size are poorly stocked, about all that can be done is to wait until the trees can be harvested and a new stand established. Some timber stand improvement work may be undertaken to control large culls or other undesirable trees that are suppressing valuable trees. Also, where removing a few limbs will produce Grade 1 logs, trees should be pruned.

Seedling and sapling size stands. — The way these stands should be handled depends on their stocking. If the stocking will eventually produce an operable crop of poletimber or sawtimber trees, no immediate attention is required. However, thinning and pruning can be considered as the stand develops.

If the stand is too poorly stocked to produce an operable crop of timber, planting may be needed to increase the stocking. On suitable sites, stocking can be increased by planting fast-growing, high-value species such as black walnut, yellow-poplar, white ash, basswood, and maple. Planting oak will seldom be advisable because sprouts are normally scattered throughout the stand and planted oak seedlings grow slowly.

Good oak sites are seldom understocked for long in the seedling and sapling stages. Light-seeded tree species quickly invade the openings. Burning will kill back existing reproduction to a common age, stimulating more vigorous sprouting and providing a favorable seedbed for light-seeded species. Thus, on sites where adequate natural reproduction can be expected in a reasonable time period, few costs can be justified to improve the stocking.

Poor to Medium Sites

(Sites Where the Largest Oaks Are 40 to 60 Feet Tall at 50 Years)

These oak stands should either be managed for oak pulpwood or converted to pine, because high-quality sawtimber is difficult to produce on such sites. The choice depends on many factors, such as existing oak stocking, site productivity, desires of the owner, available capital, annual costs, rate of return expected on the capital investment, oak and pine stumpage prices, and possible returns from hunting and other outdoor recreation.

Managing for oak timber production alone on poor and medium sites is not profitable. In fact, even if annual costs total as little as 50 cents per acre over the rotation, fully stocked oak stands at

40 years would show a minus net worth (table 15). Even with no annual costs (and this is unrealistic) these oak stands would yield only a few dollars per acre. Therefore, supplemental income from hunting rights or other outdoor recreational uses of the land is needed to meet costs of ownership. With such an additional source of income, producing oak timber on these sites can be made profitable.

Table 15. — Present worth of oak stands managed for oak timber on poor and medium sites at 4 percent interest[1]
(In dollars per acre)

POOR SITES (SI 50)

Rotation length (years)	Stocking percent	Present worth of timber when annual costs are			
		$ 0.00 per acre		$ 0.50 per acre	
		Pulp	Logs	Pulp	Logs
40	100	4.08	--	-12.01	--
	75	3.05	--	-13.04	--
	50	2.03	--	-14.07	--
	25	1.00	--	-15.09	--
60	100	3.39	1.36	-13.76	-15.79
	75	2.54	1.01	-14.61	-16.13
	50	1.68	.67	-15.47	-16.48
	25	.83	.32	-16.32	-16.62
80	100	2.07	2.42	-15.75	-15.39
	75	1.55	1.81	-16.27	-16.01
	50	1.02	1.20	-16.80	-16.83
	25	.50	.59	-17.32	-17.23
MEDIUM SITES (SI 60)					
40	100	6.29	--	-9.81	--
	75	4.71	--	-11.38	--
	50	3.13	--	-12.96	--
	25	1.55	--	-14.54	--
60	100	4.48	3.95	-12.67	-13.20
	75	3.35	2.95	-13.79	-14.20
	50	2.23	1.96	-14.92	-15.19
	25	1.10	.97	-16.05	-16.18
80	100	2.77	5.09	-15.05	-12.73
	75	2.07	3.81	-15.75	-14.01
	50	1.37	2.53	-16.45	-15.29
	25	.67	1.25	-17.14	-16.56

1/Oak yields from U.S. Dep. Agr. Tech. Bull. 560 (see table 11). Stumpage prices used were $1.00 per cord for pulpwood and $7.50 per M for sawtimber. These were increased annually by 0.5 percent for pulpwood and 1 percent for sawtimber.

Small Sawtimber and Poletimber Stands — All Stockings

In oak stands where trees are approaching pole size (5 inches and larger at d.b.h.), the best policy is to wait until the existing trees can be harvested. Thinning costs cannot be justified with present costs and stumpage values. As soon as a harvest cut can be made, the stand should be clear cut. On poor sites, pulpwood yields of 25 to 30 cords per acre can be expected in fully stocked stands at age 60 to 80 years. On medium sites, 30 to 40 cords per acre can be expected for stands of similar age and stocking (table 11). Medium sites may also produce some board foot volume at age 60 to 80 years.

Seedling and Sapling Stands — All Stockings

When the stand consists of reproduction on poor and medium sites, the owner has several management alternatives to consider. These alternatives are nearly the same ones that exist immediately after clear cutting. The choice will depend on the age and stocking of the oak stand. If the stand is well stocked with saplings, the owner may decide to wait until it can be harvested for pulpwood. On the other hand, if the sapling stand is sparsely stocked, the owner may consider converting to pine.

Management Alternatives on Poor and Medium Oak Sites

For stands that have been commercially clear cut and for poorly stocked seedling and sapling stands, the forest manager will have several timber production alternatives. These alternatives are as follows:

1. Wait 40 to 80 years and eventually harvest oak pulpwood and some sawtimber. The yield that can be expected will depend on the present stand stocking. Yields from commercially clear-cut stands will be reduced 25 to 50 percent if no further work is done, because the many cull trees left standing will suppress new sprout growth. This "do nothing" alternative will produce a few dollars worth of timber if annual expenses are not charged to the timber production (table 15).

2. Kill back the tops of all remaining trees that are more than 2 inches in diameter; a fully stocked stand can be expected from this treatment. A spring or fall burn immediately after the clear cut will not only kill back most of the small suppressed trees and promote sprouting, but it will also char the stumps, and retard high stump sprouts that often develop heart rot. A 25-percent increase in stocking will increase pulpwood yield about $1 or less per acre (table 15); therefore treatment costs need to be kept low.

3. Convert to red pine. A better financial return can be obtained by investing $40 to $50 per acre to convert to pine. This will be true even with annual costs up to $1 per acre (table 16). However, this is assuming the investor will be satisfied with a 4-percent return on his long-term investment. If 6-percent interest or higher is desired, conversion at present costs with the expected future yield does not appear profitable. Nearly full stocking of pine is required with periodic thinnings for pulpwood and a harvest cut for sawtimber. The most profitable rotation is 60 years for pine. Managing for pine pulpwood alone would not be profitable with the proposed conversion costs and stumpage prices. In other words, if the forest manager attempts to convert oak on poor and medium sites to pine, he must manage intensively to make a profit on the investment.

Converting Oak on Poor and Medium Sites to Pine

Many stands of mixed oak on poor and medium sites have been successfully converted to pine — mainly red pine — in the northern Lake States. Although converting to pine can, under certain conditions, produce a profitable return on the investment, this alternative may not always be the most profitable or best use of the land. For example, when a limited amount of capital is available for managing a wide range of oak lands, the highest return can be obtained by investing in improvement cutting and thinning in overstocked pole and small sawtimber stands on medium-high and good sites (Herrick and Morse 1968). However, if sufficient capital is left over to manage poor and medium oak sites, converting to pine can be more profitable than growing oak, if the owner is willing to accept 4 percent interest on his investment. In any forest management plan, the potential return from land uses other than timber production must also be considered. If converting to pine will create extensive blocks of conifers that decrease wildlife production and increase fire, insect, and disease protection costs, it may not be the best management alternative. Other potential land uses are discussed in the last section of this publication.

Converting oak to pine is more profitable on medium than on poor sites. Conversion costs will be similar on both sites, but medium sites give nearly twice the return (table 16). Also, a larger oak volume will be harvested on medium sites preparatory to conversion, thus more capital is available for reinvestment.

Table 16. — Present worth of red pine on poor and medium oak sites where the pine is managed for sawtimber with pulpwood thinnings[1]
(In dollars per acre)

POOR SITES (SI 50)

Thinning and harvesting schedules	Stocking percent	Conversion costs	Present worth of timber at 4 percent interest when annual costs are: $ 0.00 per acre	$ 0.50 per acre	$ 1.00 per acre
Thin at 40 years and clearcut sawtimber at 60 years[2/]	100	50	41.35	24.20	7.02
		40	51.47	34.32	17.15
	75	50	16.71	-.44	-17.61
		40	26.84	9.69	-7.49
	50	50	-7.92	-25.07	-42.24
		40	2.20	-14.95	-32.12
Thin at 40 and 60 years and clearcut sawtimber at 80 years[3/]	100	50	11.30	-6.52	-24.36
		40	20.87	3.05	-14.79
	75	50	-5.05	-22.87	-40.71
		40	4.52	-13.30	-31.14
	50	50	-21.40	-39.22	-57.06
		40	-11.83	-29.65	-47.49
MEDIUM SITES (SI 60)					
Thin at 40 years and clearcut sawtimber at 60 years[2/]	100	50	71.39	54.24	37.07
		40	81.51	64.36	47.19
	75	50	39.25	22.10	4.92
		40	49.37	32.22	15.04
	50	50	7.10	-10.05	-27.22
		40	17.22	.07	-17.10
Thin at 40 and 60 years and clearcut sawtimber at 80 years[3/]	100	50	32.64	14.82	-3.03
		40	42.21	24.39	6.55
	75	50	10.95	-6.87	-24.71
		40	20.53	2.71	-15.14
	50	50	-10.73	-28.55	-46.39
		40	-1.16	-18.98	-36.82

1/ Stumpage prices used were $3.50 per cord for pulpwood and $25 per M for sawtimber. These prices were increased annually by 0.5 percent for pulpwood and 1 percent for sawtimber. Annual costs were increased 3 percent annually for expected inflation. Conversion costs assumed were (1) $50 for preplanting release and planting approximately 800 3-0 red pine per acre, plus $5 for release in 8 years, and (2) $40 per acre for planting approximately 800 3-0 red pine per acre, plus $5 per acre for release in 5 years. Red pine pulpwood and sawtimber yields at 40, 60, and 80 years were interpreted from U.S. Dep. Agr. Tech. Bull. 1272 (Buckman 1962) for site indexes 50 and 60, with thinning schedules maintained at 90 square feet of basal area. These natural stand yields appear conservative compared to red pine plantation yields measured on comparable sites in northern Lower Michigan.

2/ Thinning and harvesting schedules assumed at 60 years were: thin 15 and 20 cords at 40 and 60 years, respectively; harvest 11.2 and 13.6 M board feet per acre on SI 50 and 60 sites, respectively.

3/ Thinning and harvesting schedules assumed at 80 years were: thin 15 cords per acre at 40 and 60 years; harvest 13.3 M board feet at 80 years on SI 50 sites. On site index 60 sites, thin 20 cords at 40 and 60 years; harvest 15.9 M board feet at 80 years.

Hand planting has been most widely used for converting oak to pine, especially under reasonably well stocked stands of oak. After logging, slash is generally too abundant for machine planting, and it also hinders hand planting. However, in some understocked stands it is possible to machine plant 400 to 600 pines per acre before the oaks are cut. Direct seeding techniques have not been perfected.

Burning the stand with a hot summer fire after commercial clear cutting is currently being tested in Lower Michigan. This practice increases oak sprouting if the fire is not exceptionally hot, but it reduces slash and makes machine planting possible.

When sprouts and competing vegetation start to suppress the pine, an aerial spray applied in early August (1 pound of 2,4,5-T ester diluted in 2 to 3 gallons of oil-water mixture per acre) will release the pine. This can generally be done for about $6 per acre. Where drift from this type of herbicide application may damage adjacent hardwood timber, a helicopter may be used at slightly higher cost. A second release may be needed. Release should not be delayed too long because red pine that is suppressed for several years will not resume normal height growth for about 3 years following release. On the other hand, releasing too early kills back the competing hardwood competition before the pine can utilize the extra growing space.

Poor and medium site oak lands in the agricultural areas in the southern Lake States are mostly narrow ridges, upper slopes, steep south and west slopes, and shallow soil areas. These sites are not often found in large blocks under one ownership, but usually occur in small, scattered tracts. Converting to pine on small tracts can be accomplished by hand planting, and release by herbicides applied with a portable mist blower. Such conversion adds beauty to the landscape and improves the habitat for wildlife, as well as increases timber production.

Oaks Growing in Mixture With Pines

Very Poor Sites

On very poor sites, the main conifer growing in mixture with oak is jack pine. The oaks are nearly worthless for timber and the jack pine will also be of poor quality. About all the timber management that can be justified is fire protection until the trees can be harvested for pulp (both the oak and pine).

Poor and Medium Sites

The northern pines — jack, white, and red — can all be found growing in mixture with oaks on poor and medium sites. On these sites the pines will produce more and higher quality timber than oak. The pines, especially white pine, will also seed in under the oak.

The oaks should be removed when they start to suppress the pine. This release can be accomplished by logging if the trees are merchantable, or by aerial sprays of 2,4,5-T if they are unmerchantable.

Good Sites

Both red and white pines, but most commonly white pine, may be found growing with oak on good sites. The pines cannot compete with hardwoods on good oak sites. Therefore, it is advisable to harvest the mature pine and manage the stand for high-quality hardwood sawtimber.

Multiple Use for Oak Land

The long-term rate of return from young oak stands will be low in most cases. On poor and medium sites the projected return from oak timber at age 40 or more is not even expected to pay the minimum annual expenses of owning the land, not to mention silvicultural costs to increase timber values (table 15). The highest return can be expected from young, well stocked sawtimber stands growing on good sites. These oak stands should receive the highest priority when investing in silvicultural practices (table 17).

The oaks are ideal multiple-use trees. They provide large quantities of food for deer, squirrels, grouse, turkeys, and many nongame species, and make excellent shade trees. White oak is especially durable and long-lasting. Bur oak is well suited for picnic areas and camping sites because it tolerates dry sites. Of course the oaks, like most trees, succumb where the soil is severely compacted by automobiles and campers, but they withstand this type of use better than most tree species.

On poor and medium oak sites, the highest monetary returns from timber production can be expected by converting to red pine (table 16). However, in the northern Lake States, where large acreages of conifers already exist, the forest manager is often challenged with growing a timber crop that will help pay ownership expenses and at the same time enhance the value of the forest for other outdoor uses. This is especially important on publicly owned lands. Since, in this case, annual expenses need not be met by timber sales alone, managing for oak may well return a greater benefit in the long run than conversion to pine.

Converting to pine may yield the greatest total return in the agricultural lands of the southern part of the region. Here, poor and medium oak sites are intermingled with good and highly productive sites, and land values are high. Because most of the forests in this area are hardwood, scattered pine stands would increase timber yields, beautify the landscape, provide additional wildlife habitat, and increase outdoor recreation potential.

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Table 17. — Summary of silvicultural prescriptions and investment priorities

MEDIUM-HIGH TO VERY GOOD SITES (SI 65 TO 80)

Stand size and stocking[1/]	Silvicultural prescription	Investment priority
Small sawtimber		
Fully stocked	TSI and thin	Very high
Understocked	TSI and prune	Low
Poles		
Fully stocked	TSI and thin	High
Understocked	None or limited TSI	Low
Seedlings and saplings		
Fully stocked	Cleaning	Low
Understocked	None, burn or plant	Very low
MEDIUM-LOW TO POOR SITES (SI 40 TO 60)		
Small sawtimber and poles		
All stockings	None	--
Saplings		
Fully stocked	None	--
Understocked	None or convert to pine	Low
Seedlings		
All stocking	None or convert to pine	Low

1/ See range of full stocking in table 13. Understocked would be less than the minimum values listed for full stocking.

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COMMON AND SCIENTIFIC NAMES OF TREES, SHRUBS, AND PLANTS MENTIONED

Ash, white	*Fraxinus americana* L.
Aspen, bigtooth	*Populus grandidentata* Michx.
Aspen, quaking	*Populus tremuloides* Michx.
Basswood, American	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Birch, paper	*Betula papyrifera* Marsh.
Blackberry	*Rubus* spp.
Boxelder	*Acer negundo* L.
Butternut	*Juglans cinerea* L.
Cherry, black	*Prunus serotina* Ehrh.
Cherry, pin	*Prunus pensylvanica* L. f.
Chokecherry, common	*Prunus virginiana* L.
Cottonwood, eastern	*Populus deltoides* Bartr.
Dogwood, flowering	*Cornus florida* L.
Dogwood, gray	*Cornus racemosa* Lam.
Elm, American	*Ulmus americana* L.
Elm, rock	*Ulmus thomasii* Sarg.
Elm, slippery	*Ulmus rubra* Muhl.
Gooseberry	*Ribes* spp.
Hawthorn	*Crataegus* spp.
Hazel, American	*Corylus americana* Walt.
Hemlock, eastern	*Tsuga canadensis* (L.) Carr
Hickory, bitternut	*Carya cordiformis* (Wangenh.) K. Koch
Hickory, pignut	*Carya glabra* (Mill.) Sweet
Hickory, shagbark	*Carya ovata* (Mill.) K. Koch
Hophornbeam, eastern	*Ostrya virginiana* (Mill.) K. Koch
Hornbeam, American	*Carpinus caroliniana* Walt.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, blackjack	*Quercus marilandica* Muenchh.
Oak, bur	*Quercus macrocarpa* Michx.
Oak, chestnut	*Quercus prinus* L.
Oak, chinkapin	*Quercus muehlenbergii* Engelm.
Oak, northern pin	*Quercus ellipsoidalis* E. J. Hill
Oak, northern red	*Quercus rubra* L.
Oak, pin	*Quercus palustris* Muenchh.
Oak, scarlet	*Quercus coccinea* Muenchh.
Oak, shingle	*Quercus imbricaria* Michx.
Oak, swamp white	*Quercus bicolor* Willd.
Oak, white	*Quercus alba* L.
Pine, jack	*Pinus banksiana* Lamb.
Pine, red	*Pinus resinosa* Ait.
Pine, white	*Pinus strobus* L.
Raspberry	*Rubus* spp.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Serviceberry	*Amelanchier* spp.
Walnut, black	*Juglans nigra* L.
Yellow-poplar	*Liriodendron tulipifera* L.

ABOUT THE FOREST SERVICE . . .

As our Nation grows, people expect and need more from their forests — more wood; more water, fish, and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U.S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forests and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continuous benefits from the Country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.