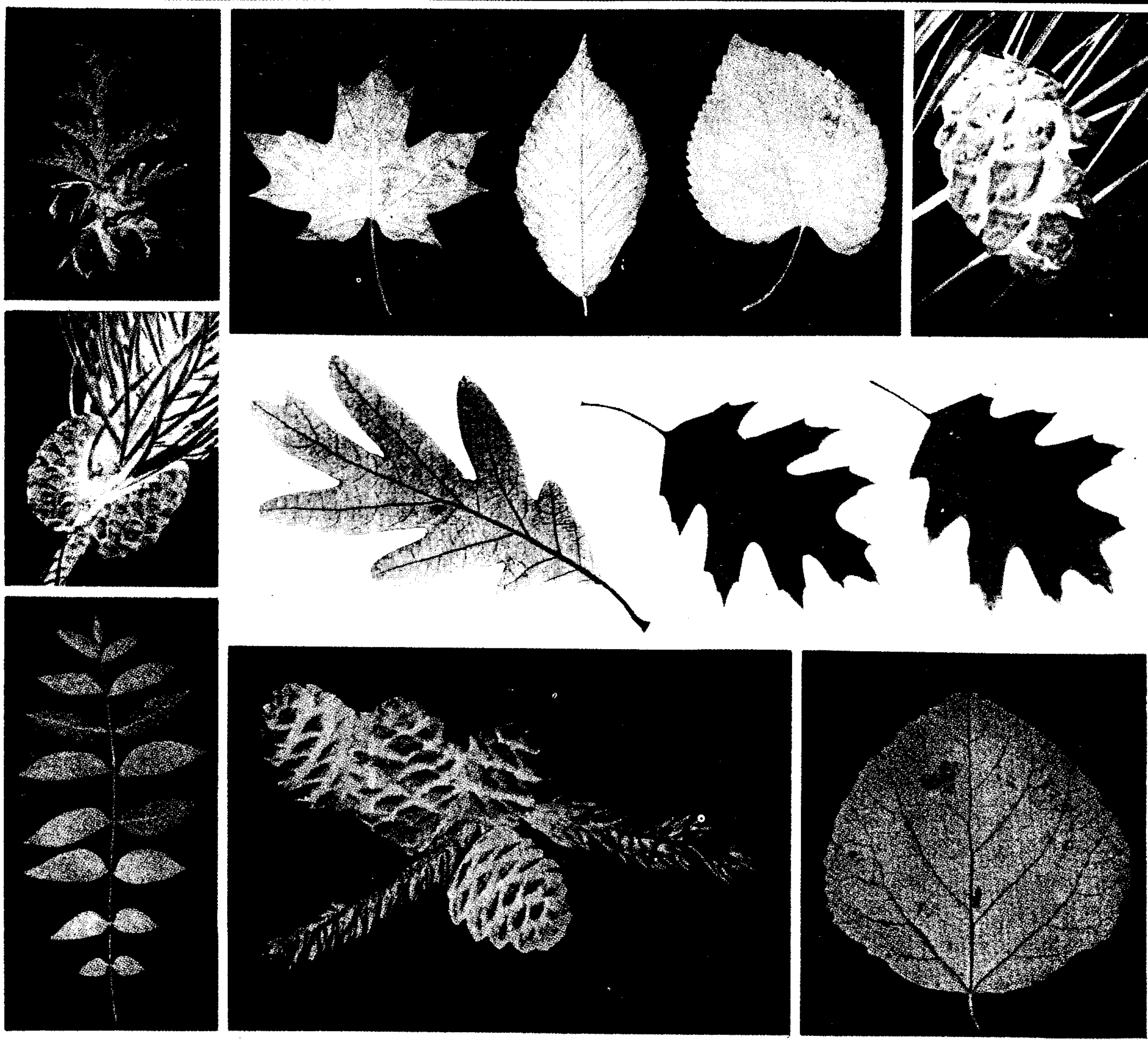

manager's handbook for

OAKS IN THE NORTH CENTRAL STATES

GENERAL TECHNICAL REPORT NC-37

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

Other Manager's Handbooks are:

- Jack pine – GTR-NC-32
- Red pine – GTR-NC-33
- Black spruce – GTR-NC-34
- Northern white-cedar – GTR-NC-35
- Aspen – GTR-NC-36
- Black walnut – GTR-NC-38
- Northern hardwoods – GTR-NC-39

North Central Forest Experiment Station
John H. Ohman, Director
Forest Service – U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108

Manuscript approved for publication August 16, 1976

1977

Bertsch

FOREWORD

This is one of a series of manager's handbooks for important forest types in the north central States. The purpose of this series is to present the resource manager with the latest and best information available on handling these types. Timber production is dealt with more than other forest values because it is usually a major management objective and more is generally known about it. However, ways to modify management practices to maintain or enhance other values are included where sound information is available.

The author has, in certain instances, drawn freely on unpublished information provided by scientists and managers outside his specialty. He is also grateful to the several technical reviewers in the region who made many helpful comments.

The handbooks have a similar format, highlighted by a "Key to Recommendations". Here the manager can find in logical sequence the management practices recommended for various stand conditions. These practices are based on research, experience, and a general silvical knowledge of the predominant tree species.

All stand conditions, of course, cannot be included in the handbook. Therefore, the manager must use technical skill and sound judgment in selecting the appropriate practice to achieve the desired objective. The manager should also apply new research findings as they become available so that the culture of these important forest types can be continually improved.

CONTENTS

OAKS
IN THE NORTH CENTRAL STATES

Ivan L. Sander, *Principal Silviculturist*
Columbia, Missouri

INTRODUCTION

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

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

SILVICAL HIGHLIGHTS

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

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

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

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

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

The frequency of sprouting from stumps varies somewhat among oaks. Black and white oaks generally sprout less frequently than northern red, scarlet, or chestnut oaks; small stumps sprout more frequently than large ones. Sprouts that originate at or below ground level and from small stumps are less likely to develop heartwood decay.

The juvenile height growth of new oak sprouts is related to the size of the old stem from which they originate. Sprouts from large stems grow faster than sprouts from small stems. Oaks respond well to release unless they are overtopped or have grown in dense stands for long periods of time. Sapling and pole-size trees that are dominant or codominant respond best and grow rapidly when given enough space.

Epicormic sprouting may be heavy on oaks that have grown in fully stocked stands for 20 years or more and then given sudden and heavy release. Dominant and codominant trees are less likely to produce as many epicormic sprouts as intermediate or suppressed trees.

MANAGEMENT OBJECTIVES AND NEEDS

Growing full yields of the highest value products the site can produce in a relatively short time is the management objective considered in this handbook. Most of the product volume will be in high quality sawtimber and some veneer quality trees, but pulpwood and other small roundwood products will be harvested from thinnings or as the final crop, especially on poor sites. Where the objective is to manage for a resource other than timber, or for any combinations of timber, water, wildlife, recreation, and range, the recommendations in this handbook should be modified as needed.

To achieve the objective of producing high quality sawtimber and veneer trees, even-aged silviculture and management are recommended. Prompt regeneration is needed and our present knowledge suggests that this is best attained through clearcutting or some form of shelterwood. But silvicultural knowledge for intensive management is not complete. Techniques need to be further developed to ensure adequate regeneration, and yield tables for managed stands need much refinement.

KEY TO RECOMMENDATIONS

The following key describes some of the management options and silvicultural alternatives that will lead to efficient timber production. Every possible situation cannot be presented in detail, so the silviculturist must choose the alternative that best fits the situation. The key does not consider uses other than timber. However, where necessary, the silvicultural recommendations can be modified according to the information in the section on other resource considerations.

Starting with the first pair of numbered statements, select the statement that better describes the stand in question. Each statement will give either a number, a partial recommendation and a number, or a final recommendation. If a number is given, repeat the selection process until a final recommendation is reached. The overall recommendation is the sum of the partial recommendations arrived at while going through the key. Turn to the page and letter references in the "Timber Management Considerations" section for more detail on management options and silvicultural treatments.

1. **Oak site index 75 or greater** 2
1. **Oak site index less than 75** 9

   2. **Stand in "Driftless Area" of Wisconsin, Minnesota, and northeastern Iowa, or northern Lower Michigan** (See p. 4, A) 3
   2. **Stand not in above areas** 6

3. **Stand mature (more than 50 percent of basal area in trees that have reached the desired size for the site)** . . . . CONVERT TO OTHER HARDWOODS . . 4
3. **Stand immature (less than 50 percent of basal area in trees that have reached the desired size for the site)** 5

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

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

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

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

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

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

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

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

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

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

9. Oak site index 65 through 74 10

9. Oak site index less than 65 11

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

TIMBER MANAGEMENT CONSIDERATIONS

Stand Size

A number of factors must be considered when choosing the size of a stand and delineating its boundaries. There is no silvicultural reason to set an upper limit for stand size, but *there are* silvicultural reasons to limit the minimum size. When an old stand is completely removed, the new stand develops in the opening. In every opening there is a zone around the edge in which growth of the new stand is retarded by the surrounding stands. For best development of the new reproduction the proportion of the stand area in this zone should be kept as low as possible. As stand size is reduced below about 2 acres the percent of area in this zone increases rapidly. Thus, for silvicultural reasons the minimum stand size should be 2 acres (for metric equivalents, see p. 33, Appendix V).

Silvicultural prescriptions are easier when a stand is relatively uniform and occupies relatively uniform site conditions. The stand should be large enough so it can be readily mapped and entered into records, and so it can be accurately located for future silvicultural operations. Stand size can be smaller for small forest properties than for larger properties because on small properties small stands are easier to keep track of.

Site Quality

For the purpose of this handbook three broad site classes have been recognized. Good sites are those with a site index for oak of 75 or more, average sites have an oak site index of 55 to 74, and the oak site index for poor sites is 40 to 54.

In determining site index, local site index curves should be used if available. In areas where local curves are not available, regional curves or tables can be used (see Appendix I, tables 4 and 5, figs. 1-6). Site index should be estimated directly from height-age measurements if suitable trees are present. Trees selected should be single-stemmed, dominant or codominant, and show no signs of past suppression.

If suitable trees for direct estimation of site index are not available, site index may be estimated from soil and topographic features in areas where soil-site relations have been studied and correlations made (Appendix I, tables 6-10).

Site-Species Relations

Oaks occur in varying mixtures over the entire range of upland sites in the north central States. Other hardwood species may occur in mixture with the oaks, especially on the good sites, and on average to poor sites pines may be present. The preferred species for timber production are listed in table 1.

A. On good sites (oak site index 75+), the opportunities to manage for oak will vary according to geographic location. It will often be difficult and probably impractical to perpetuate essentially pure oak stands in many areas on these sites.

In the "Driftless Area"[1] of southwestern Wisconsin southeastern Minnesota, and northeastern Iowa and in northwestern Lower Michigan, existing northern red oak stands and the northern red oak-white oak mixture are ecologically unstable. The trend is toward species other than oaks. Sugar maple, American elm, American basswood, white ash, and black cherry usually become established under present oak stands, while oak advance reproduction is scarce to nonexistent. In these areas managing for oaks beyond the life of presently existing stands may not be practical. Establishing adequate oak advance reproduction will be extremely difficult and costly because of the severe competition from other species. Future stands will contain some northern red and white oaks of stump sprout origin, but the eventual domination of these sites by more mesic species is inevitable. Consider managing succeeding stands as mixtures of oaks and other hardwoods (see P, p. 9), or to converting these sites to other hardwoods (see R, p. 10).

In southern Illinois, southern Indiana, and in parts of Lower Michigan, yellow-poplar and other intolerant species will increase as the present oak stands are harvested. Future stands will probably always contain some oaks; the proportion will depend on the amount and size of the oak advance reproduction present when the harvest cut is made. These stands should be managed as mixtures. It may be possible to manage for essentially pure yellow-poplar on these sites, but weedings by age 10 will probably be necessary.

In the Ozarks region of Missouri, desirable nonoak timber species are limited and oaks will continue to be the species to manage for on good sites. Even so, special measures may be necessary to ensure establishment and development of adequate oak advance reproduction.

B. The average sites (site index 55 to 74) are well suited to oak management, and the perpetuation of oaks anywhere in the region should not be too difficult except for sites near the upper limit of the class. As oak site index increases from about 65 to 74, yellow-poplar and other intolerant or more mesic species will increase in southern Illinois and Indiana. In the Driftless Area and in Lower Michigan species such as American elm, sugar maple, white ash, and American basswood will increase where adequate seed sources exist because of their ability to become established and persist in the understory. Oaks will probably be present in the stands that follow harvest cutting because of their ability to sprout. In these situations consider managing mixtures of oaks and other hardwoods.

[1] *The hilly, unglaciated portions of these States.*

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

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

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

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

C. The poor sites (site index 40 to 54) are almost exclusively occupied by oaks. Stands are often of poor quality, and dominated by the less desirable oaks such as post and blackjack oak in Missouri, and bur oak in southern Minnesota and Wisconsin. Mixtures of pine and oak also occur on these sites in Missouri and Lower Michigan.

These poor sites should probably be managed for pulpwood or other small products if markets exist. The best management for oak stands on the poorest sites may be no management. When they provide a commercial harvest, they should be harvested, but cultural work should be limited to that necessary to provide for adequate regeneration. Thinnings may be feasible in stands on sites in the upper part of the range. However, trees should be of merchantable size and the thinning operation should pay for itself.

Conversion of these sites to pine or managing them for pine-oak mixtures is often feasible, and should be done if the cost of conversion is not prohibitive (see "Conversion To Other Species", p. 10).

Rotation Length

D. Oaks are relatively long-lived trees and rotation can be long. In unthinned stands, individual tree growth is slow and dominant trees on site 55, at age 80, will average about 12 inches in diameter, while those on site 75 at age 80 will average about 18 inches in diameter.

Rotation lengths can be shortened if stands are thinned early and regularly. The rotation lengths and tree sizes recommended in table 2 assume thinnings will be started early and continued on a regular cycle over the rotation.

Table 2. – *Recommended rotation lengths and diameter for oak sawtimber*[1]

Site index class	Rotation length	Rotation diameter[2]
Feet	*Years*	*Inches*
75+	60-75	24-28
55-74	75-90	20-24
40-54	90-120	16-18

[1]Rotation lengths for pulpwood are about 1/2 to 2/3 of those for sawtimber.

[2]Average diameter of crop trees.

Controlling Stand Establishment

E. Two basic principles of reproducing oaks must be understood by silviculturists managing this type.

1. The newly reproduced stand will contain oaks in proportion to the advance oak reproduction on the area before the overstory is removed.
2. Advance oak reproduction must be relatively large, with a well established root system, in order to compete successfully with other woody vegetation in the new stand.

Before a final harvest cut is made, the oak advance reproduction should be inventoried to determine if it is adequate to ensure a dominant oak component in the new stand. (See Appendix IV, "Evaluating the Adequacy of Oak Advance Reproduction".) If the minimum standards of this guide are met, the old stand can be removed. Clearcutting is the recommended silvicultural system. After the merchantable timber is harvested, any remaining trees larger than about 2 inches d.b.h. (or about 20 to 25 feet tall) should be removed. Desirable oaks should be cut and allowed to sprout. Species not wanted in the next stand should be killed. This is important because if left, many of these trees will become wolf trees.

F. If the oak advance reproduction does not meet the standards in the guide, harvest cutting should be delayed. If oak advance reproduction is scarce or absent, new seedlings will have to be established. There are no known cultural techniques that result in new seedlings being established. Some reduction of overstory density should help to stimulate seed production, but because of the periodicity of seed crops the time required to establish enough new seedlings for adequate stocking is likely to be relatively long.

Site preparation by soil scarification has not proven beneficial in establishing new oak seedlings. Even where many new seedlings are initially found on scarified areas, after a few years there are just as many present on unscarified as on scarified areas.

In areas of known heavy deer populations and severe browsing, or high populations of acorn-consuming wildlife, it will be impossible to establish natural oak regeneration unless measures are taken to control the consuming animals. If control is not feasible, oak seedlings can be planted, but they will have to be protected from deer.

Where advance reproduction is scarce or absent, oak seedlings can be planted under an overstory and allowed to develop as advance reproduction. This practice has not been tried and proven and its ultimate success or failure is unknown. The overstory should be maintained at about 60 percent stocking and if competition from an existing understory will impair the growth of the planted seedlings, its density should be reduced. Seedlings should be planted at the rate of 500 to 600 per acre. Spacing can be irregular and seedlings should not be planted close to large overstory trees. As with natural reproduction, the planted seedlings must be allowed to reach the minimum size necessary before the overstory is finally removed.

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

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

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

Controlling Composition

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

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

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

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

Controlling Growth

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

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

Table 3. – *A comparison of yields per acre at age 60 when thinning is begun at different ages; thinning interval 10 years (Gingrich 1971)*

Yields at age 60	Age of stand at time of first thinning (years) 10	20	30	40	50	60
			SITE 55			
Cubic feet	3,900	2,940	2,910	2,580	2,550	2,520
Cords	37.8	28.8	27.6	23.7	23.4	22.9
Board feet	8,340	4,680	3,360	2,700	1,500	900
			SITE 65			
Cubic feet	4,860	4,040	3,750	3,270	3,270	3,300
Cords	44.1	35.4	34.5	30.6	31.2	30.8
Board feet	12,000	7,680	5,220	4,680	4,600 (7,000)*	5,160 (6,580)*
			SITE 75			
Cubic feet	6,360	5,400	4,770	4,290	4,080	4,140
Cords	56.7	49.2	44.7	39.3	37.7	37.7
Board feet	18,840	14,100	10,080	9,000	7,800 (11,800)*	9,288 (10,850)*

*Board-foot yields at age 70.

about to die and the overall vigor and health of the remaining trees will improve.

Poor sites are the only exception to this. On poor sites the cost of precommercial thinnings probably cannot be recovered because of the long period of time these costs will have to be carried at compound interest.

In young stands of sapling or small pole (15 to 20 years old) size, the first thinning can be a crop tree release. For crop trees select only dominant or codominant trees on a 15- to 20-foot spacing, and release only those that need it. This spacing should provide acceptable stocking of crop trees by the time the trees average large enough for commercial thinnings.

Thinnings cannot be continued indefinitely. Maintaining good growth on the trees left in the stand requires that they be spaced so the site is fully occupied and that the effect of a thinning is distributed throughout the stand. When the trees become large, removal of only a few trees does not benefit the entire stand, and may leave large holes in the canopy – a situation that should be avoided. In general, if a stand has been thinned regularly, stop thinning oaks at 60 to 70 years on average sites, and 50 to 60 years on good sites, or about three-fourths of rotation age.

Twenty to 30 years prior to the contemplated harvest age, managers should be establishing and developing oak advance reproduction to replace the current stand. Thus, some cultural measures may be required beyond the age when thinnings to maintain growth are stopped.

Stocking percent should be used as the measure of stand density to control thinning intensity (see Appendix III, "Evaluating Stand Density and Growing Stock Quality"). Generally oak stands should be thinned to leave residual stands at about 60 percent stocking. There are two exceptions to this general rule: in young stands less than 20 years old, and in stands 30 years and older.

In stands 20 years old or less, the first thinning may reduce stocking to 50 percent. These young stands grow rapidly and in 10 years they will again be approaching maximum stocking. In stands 30 years and older, the first thinning should reduce stocking to only 70 percent. Trees that have grown in stands near maximum stocking for 30 years or longer have relatively small crowns that cannot quickly expand and occupy the available growing space if thinned too heavily. Moreover, the residual trees will develop excessive bole sprouts which reduce quality. A more gradual opening of these older stands will allow the crowns to expand gradually, utilize the increased growing space more efficiently, and reduce bole sprouting. The second and subsequent thinnings should then reduce stocking to about 60 percent.

Thinning should generally be from below for a good biological reason. Intermediate and suppressed trees have very small crowns, are of low vigor, and respond very slowly to release. However, dominant and codominant trees are usually of high vigor, are the best quality trees and respond to release with rapid growth. To thin oak stands from above only lengthens rotations and lowers the quality of the growing stock.

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

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

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

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

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

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

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

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

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

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

MIXTURES OF OAKS AND OTHER SPECIES

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

Regulating stocking in mixed stands will depend primarily on the proportion of oaks in them. In the northern part of the north-central region, when oaks comprise two-thirds or more of the stand basal area at about age 20, the recommendations in this handbook should be followed. If oaks account for one-third or less of the basal area, use the recommendations in the handbook for northern hardwoods (Tubbs 1977). For those stands composed about equally of oaks and other hardwoods, there is no good information on which to base stocking. Thinnings in such stands should favor the best quality, fastest growing trees. Stocking levels should probably be intermediate between those for oaks and those for northern hardwoods.

In the southern part of the region, except in the Ozarks area, stocking in stands containing 50 percent or more of the basal area in oaks at about age 30 can probably be regulated according to the guidelines in this handbook. If stands contain more than 50 percent yellow-poplar or other intolerants, a somewhat higher stocking percent than shown in figure 7 (Appendix III) will be required, but how much higher is not accurately known. However, at a given average stand diameter, increasing the figure values by 20 percent appears to be a reasonable compromise.

Q. In mixed oak and pine stands there is no information available to guide regulation of stocking. When thinnings are made in such stands, they should provide adequate growing space for the best trees while maintaining adequate stocking to fully utilize the site. The pines will generally produce more and higher quality timber than oaks and should be favored as much as possible.

Conversion to Other Species

Consider converting existing oak stands to other species in the following three situations.

R. The first is where the ecological trends clearly indicate the replacement of oaks with more mesic species on good sites. This occurs in parts of Lower Michigan, Minnesota, Wisconsin, and northeastern Iowa where species such as white ash, American basswood, and sugar maple grow well.

These stands may be converted immediately if a seed source of desirable nonoak species is present. There will usually be an understory composed primarily of these species. Removal of the oak overstory may be by shelterwood (Tubbs 1977), or by clearcutting if the understory is well developed.

If a seed source of desirable nonoak species is limited or lacking, planting will be required; simply removing the oak overstory will lead to the development of a stand composed of undesirable nonoak species. White ash, sugar maple, or other suitable species should be interplanted. The seedlings planted should be large and competing vegetation may need to be controlled. Herbicides should be applied as broadcast foliage spray before harvest cutting and planting, or as selective stem treatments at the time of planting (see Pesticide Precautionary Statement, Appendix V).

S. The second is in southern Illinois, southern Indiana, and parts of Lower Michigan, where oaks will be largely replaced by yellow-poplar, white ash, and other more mesic species as existing oak stands on good sites are harvested. These species are generally minor components of existing stands and can be converted simply by clearcutting the mature stand. There may also be enough oaks present in new stands to form a manageable mixed oak-other hardwood stand.

T. The third situation where conversion should be considered is on poor sites in locations where shortleaf, red, eastern white, and jack pines occur naturally. These sites will produce higher timber yields if converted to pine, and unless there is reason to retain oaks on them for purposes other than timber production, they should be converted as soon as possible.

In the southern part of the region, conversion should be to shortleaf pine. Site preparation is required for seedbeds and to control hardwood competition. Prescribed burning or bulldozing results in satisfactory seedbeds. Bulldozing results in better hardwood control than prescribed burning, but should be restricted to level areas or to gentle slopes where excessive erosion will not be a problem. Shortleaf pine can be either direct seeded using 1/2 to 3/4 pound of repellent-treated seed per acre, or planting 1-0 seedlings at a rate of 500 to 700 trees per acre.

To maintain pure seeded or planted shortleaf pine stands, they may have to be released from hardwood competition 2 to 4 years after establishment. However, if the competing hardwoods are desirable oaks, consider managing the stands as mixtures.

In the northern part of the north central States, many oak stands are growing on low sites that were formerly in pine; these sites should be relatively easy to convert back to pine. Red pine is the first choice. If blister rust is not a factor, eastern white pine is also satisfactory. Jack pine can also be used, particularly for pulpwood, and on very poor sites. To establish these northern pines use the guidelines in the jack pine and red pine handbooks (Benzie 1977a, 1977b).

Damaging Agents

Fire

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

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

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

Drought

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

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

Disease

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

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

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

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

Insects

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

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

OTHER RESOURCE CONSIDERATIONS

Water

Silvicultural activities in oak forests will have little impact on water yields. Although an area that is clearcut for regeneration will yield more water for a few years, this yield gradually diminishes. Vegetation grows rapidly following clearcutting and after 5 to 10 years the water yield will be essentially the same as from a mature stand. Peak flows may be increased somewhat from clearcut areas, but this increase is usually of no practical significance and will not contribute to flooding. Thinnings will have a negligible effect on water yield so long as stands are maintained at least at B-level stocking.

Sedimentation resulting from cuttings will be minimal if proper precautions are taken. Water will not flow overland in clearcuts unless the forest floor has been scraped off or destroyed. Thus, disturbance of the forest floor should be kept as low as possible. Careful location, construction, and proper maintenance of roads and skid trails is necessary. Where site preparation for regeneration includes scarifying or burning for seedbeds, take extreme care in planning and executing these measures to avoid excessive overland water flow and erosion.

Where water yield is of primary importance such as on municipal watersheds, established principles of good watershed management must be followed. Timber yields will be of secondary importance.

Wildlife

Oak forests provide habitat for numerous wildlife species. The principal game species include white-tailed deer, turkey, fox, and gray squirrels, and in some areas ruffed grouse. Other important species include raccoon, opossum, red fox, bobcat, skunk, and a host of birds.

Creating and maintaining diverse vegetation is the key to providing a large variety of wildlife with suitable habitat. Regeneration clearcuts should be planned for a whole rotation and dispersed throughout a compartment or group of compartments to provide a well regulated range of age classes. This will result in several vegetation stages ranging from open, recently clearcut regeneration areas, through areas of saplings, poles, immature sawtimber, and mature sawtimber. Each of these stages contributes to the habitat requirements of different groups of wildlife species.

Even so, special measures to enhance the habitat for species with specific requirements may sometimes be needed. Many of these measures will result in lower timber yields, but to what extent is unknown. During thinning operations, a few defective trees can be left to provide cavities or potential cavities for hole-nesting wildlife species. About 30 cavity-nesting bird species inhabit oak forests. In addition to cavities, some of these birds need an open overstory and a well developed mid-story – conditions often found in old-growth or overmature stands. Retaining selected stands beyond the normal rotation age will provide these conditions.

Leave dead snags standing in clearcut areas and kill unmerchantable trees during thinning operations instead of cutting them, so as to provide sites for hole-nesting species. This should have little or no effect on timber production.

One of the most important contributions to wildlife from oak stands is mast, or acorns. Acorns are, of course, vital for regenerating oak, and any measures that will increase or optimize acorn production in a particular stand will benefit both wildlife and timber production. In general, thinnings that increase tree growth will also stimulate acorn production. Maintaining 40 to 60 percent of the area of each compartment in stands of mast-bearing age will be optimum for wildlife. In compartments that contain a relatively high proportion of poor sites that would produce more timber if converted to pine, this may mean foregoing conversion and the higher yields it would bring.

High populations of acorn-consuming wildlife can be detrimental to establishing oak reproduction. Even in good acorn years, essentially the entire crop may be lost in such areas. Acorns not damaged by insects will be eaten by squirrels, turkey, deer, or other acorn consumers, and thus not be available for reproducing the oaks.

Esthetics

Oak-hickory forests can be managed with a minimum of visual impact if operations are planned and executed carefully. Primarily, the cutover areas should appear neat and orderly. In travel zones stumps should be low and slash should be lopped. Logging roads and skid trails should be located and constructed to cause the least landscape disruption possible. Trash should not be allowed to accumulate.

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

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

APPENDIX I

SITE INDEX CURVES AND TABLES

Table 4. – *Black and scarlet oak site index estimates by 2-foot height and 2-year age intervals*[1] *(McQuilkin 1974)*

Age (years)	Height (feet) 8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
10		55	57	59	61	63	64	66	68	70	72																																
12			54	56	58	60	62	63	65	67	69	71																															
14				53	55	57	59	61	62	64	66	68	70	72	74																												
16					52	54	56	58	60	62	63	65	67	69	71	73	75																										
18						51	53	55	57	59	60	62	64	66	68	70	72	74	76	78																							
20							50	52	54	56	58	60	61	63	65	67	69	71	73	75	77	79																					
22								49	51	53	55	57	59	61	63	65	67	69	71	73	75	77																					
24									48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78																			
26										48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78																		
28										45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	76																		
30											45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77																
32												45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77															
34													45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77														
36													42	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	78													
38														42	44	47	49	51	53	55	57	59	61	63	65	67	69	71	74	76	78												
40															42	44	47	49	51	53	55	57	59	61	63	65	67	70	72	74	76	78											
42																43	45	47	49	51	54	56	58	60	62	64	66	68	70	72	74	76	78	80									
44																	44	46	48	50	52	54	56	58	60	62	64	67	69	71	73	75	77	79	81								
46																	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81							
48																		43	45	47	49	51	53	55	57	59	61	64	66	68	70	72	74	76	78	80	82						
50																			44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82					
52																				45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81					
54																				44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	75	77	79	81				
56																				43	45	47	49	51	53	55	57	59	61	63	65	67	68	70	72	74	76	78	80				
58																					44	46	48	50	52	54	56	58	60	62	63	65	67	69	71	73	75	77	79	81			
60																					44	45	47	49	51	53	55	57	59	60	62	64	66	68	70	72	74	75	77	79			
62																					43	45	47	48	50	52	54	56	58	60	61	63	65	67	69	71	73	74	76	78	80		
64																					42	44	46	48	50	51	53	55	57	59	61	62	64	66	68	70	71	73	75	77	79		
66																						43	45	47	49	51	52	54	56	58	60	61	63	65	67	69	70	72	74	76	78	79	
68																						43	45	46	48	50	52	53	55	57	59	61	62	64	66	68	69	71	73	75	76	78	
70																						42	44	46	47	49	51	53	54	56	58	60	61	63	65	67	68	70	72	74	75	77	78
72																						42	44	46	47	49	51	52	54	56	57	59	61	62	64	66	68	69	71	73	74	76	78
74																							44	45	47	49	50	52	54	55	57	59	60	62	64	65	67	68	70	72	73	75	77
76																							43	45	47	48	50	52	53	55	56	58	60	61	63	64	66	68	69	71	73	74	76
78																								45	46	48	50	51	53	54	56	58	59	61	62	64	65	67	69	70	72	73	75
80																								45	46	48	49	51	52	54	55	57	59	60	62	63	65	66	68	69	71	72	74

[1]All height and age combinations in this table are within the range of the original black oak data; height and age combinations within the lines indicate the range of the original scarlet oak data.

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

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

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

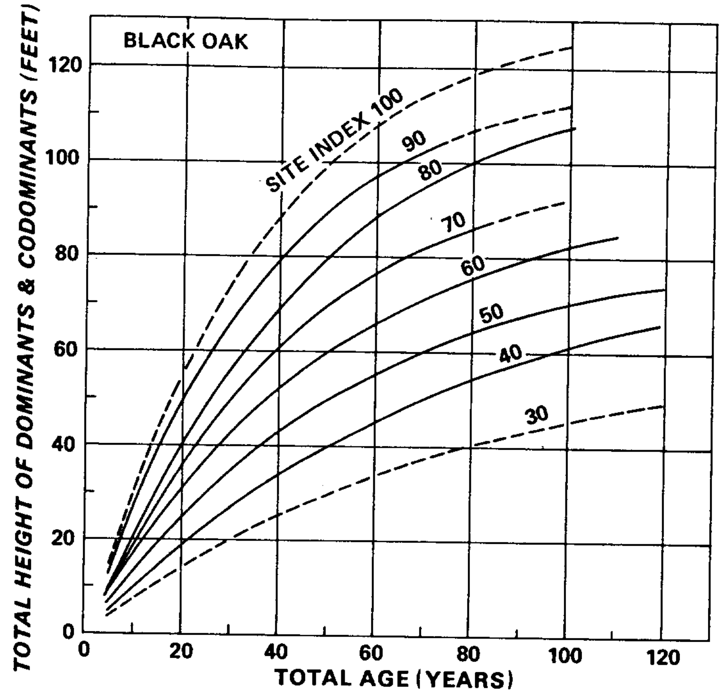

Figure 1. – *Site index curves for black oak in the Central States. These curves are based on stem analyses of 300 dominant and codominant black oaks growing on 120 plots located in the unglaciated portions of southeastern Ohio, eastern Kentucky, southern Indiana, southern Illinois, and southern Missouri (Carmean 1971).*

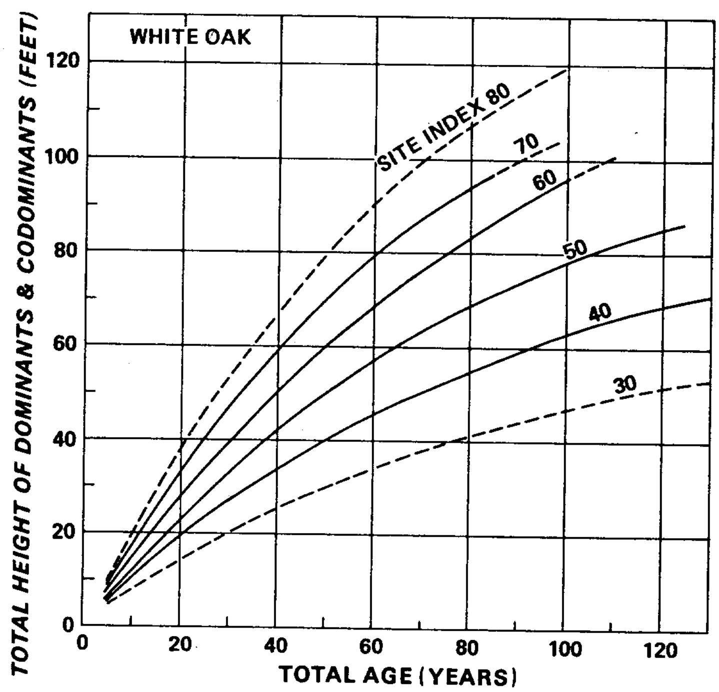

Figure 2. – *Site index curves for white oak in the Central States. These curves are based on stem analyses of 112 dominant and codominant white oaks growing on 41 plots located in the unglaciated portions of southeastern Ohio, eastern Kentucky, southern Indiana, southern Illinois, and southern Missouri (Carmean 1971).*

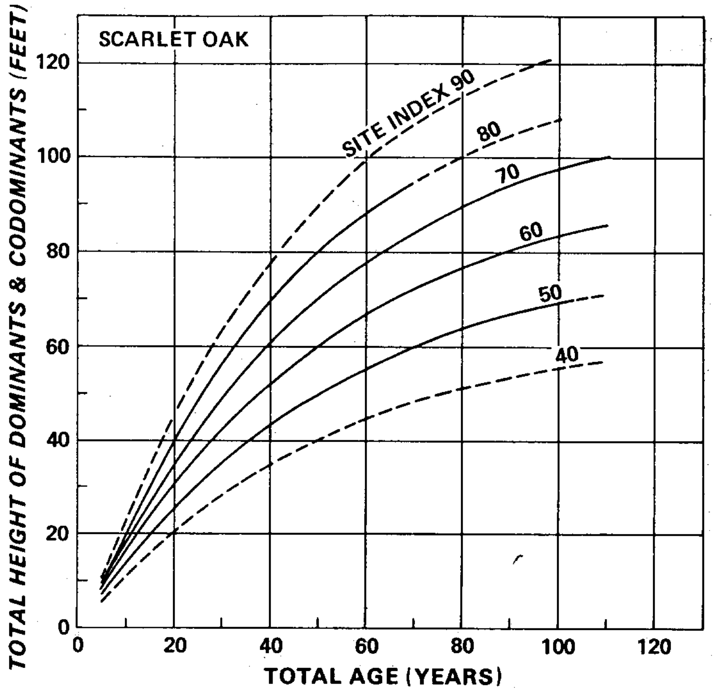

Figure 3. – *Site index curves for scarlet oak in the Central States. These curves are based on stem analyses of 88 dominant and codominant scarlet oaks growing on 25 plots located in the unglaciated portions of southeastern Ohio, eastern Kentucky, southern Illinois, and southern Missouri (Carmean 1971).*

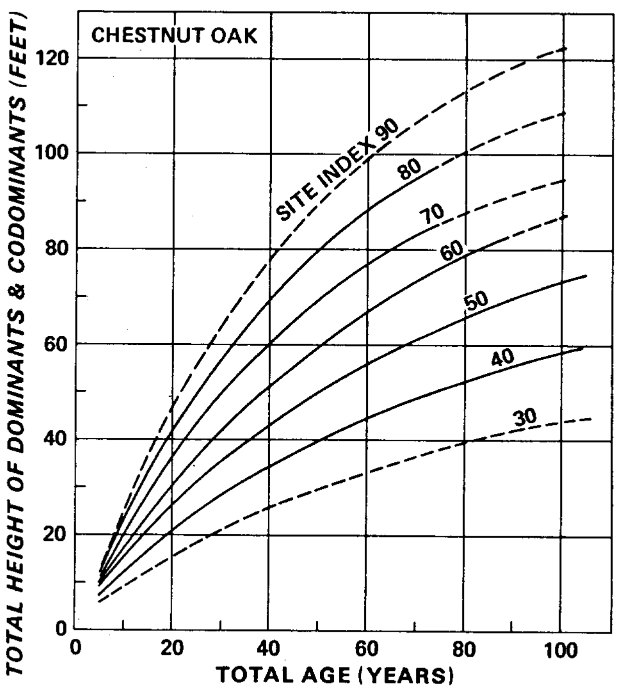

Figure 4. – *Site index curves for chestnut oak in the Central States. These curves are based on stem analyses of 59 dominant and codominant chestnut oaks growing on 18 plots located in the unglaciated portions of southeastern Ohio, eastern Kentucky, and southern Indiana (Carmean 1971).*

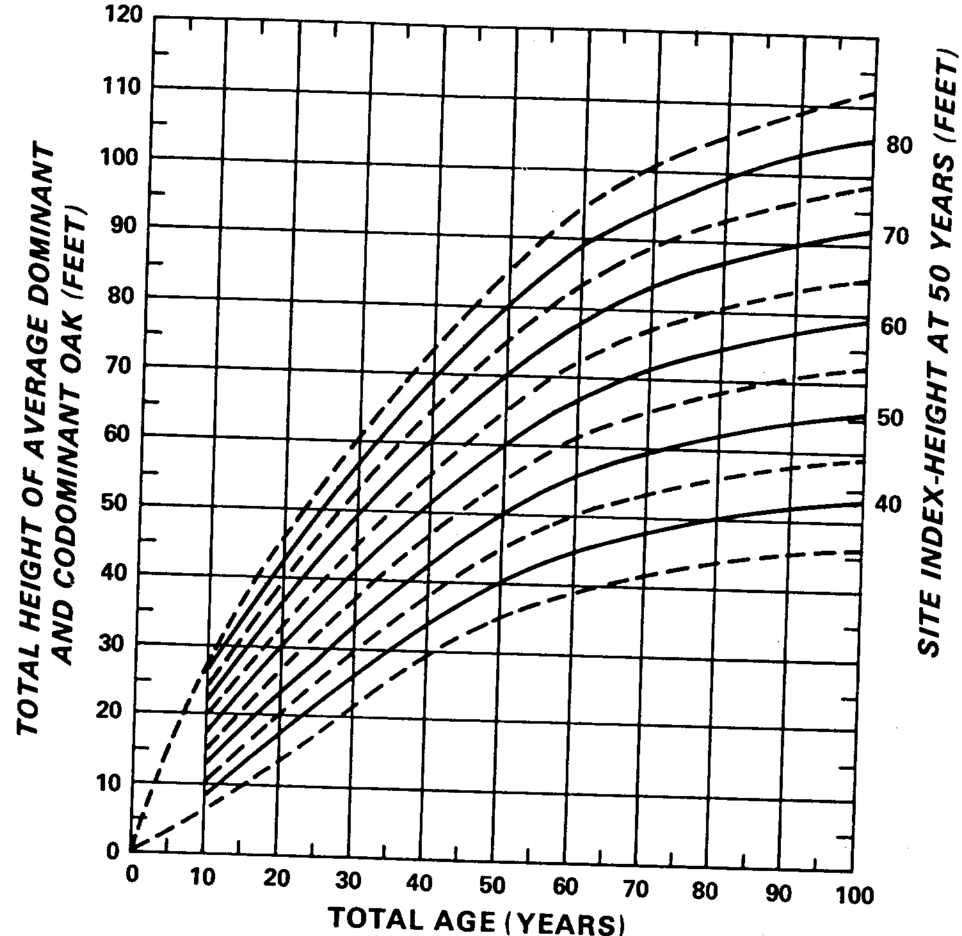

Figure 5. – *Site index curves for upland oak (Schnur 1937).*

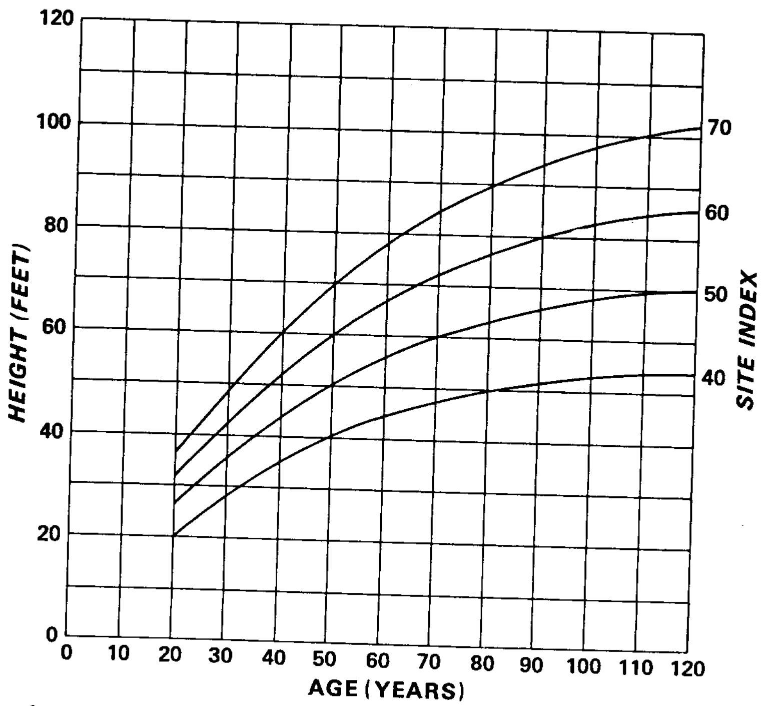

Figure 6. – *Site index curves for red oak in the Lake States (Gevorkiantz 1957).*

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

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

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

Table 7. – *Site characteristics to be considered in classifying the productivity of upland sites in southern Michigan for black and red oaks* (Gysel and Arend 1952)*

Texture of subsoil	Position of the moist layers in the substrata	General topography	Position on slope	Site class
Fine	High†	Flat		VERY GOOD
	High†	Rolling	Upper	GOOD
			Middle	GOOD
			Lower	GOOD
			Bottom	VERY GOOD
	High†	Hilly	Upper	MEDIUM
			Middle	GOOD
			Lower	GOOD
Medium	Low	Flat		MEDIUM
	Low	Rolling	Upper	MEDIUM
			Middle	MEDIUM
			Lower	GOOD
			Bottom	VERY GOOD
	Low	Hilly	Upper	POOR
			Middle	MEDIUM
			Lower	GOOD
	High	Flat		GOOD
	High	Rolling	Middle	GOOD
Coarse	Low	Flat		VERY POOR
	Low	Rolling	Upper	VERY POOR
			Middle	POOR
			Lower	MEDIUM
			Bottom	GOOD
	Low	Hilly	Upper	VERY POOR
			Middle	POOR
			Lower	GOOD
	High	Flat		GOOD
	High	Rolling	Middle	GOOD

*The combinations of site characteristics listed describe the most common sites on which oak was found in southern Michigan during this study.

†"High" for the fine-textured subsoil class refers to varying amounts of clay.

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

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

[1]Greater than 36 inches.

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

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

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

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

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

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

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

Table 10. – *Predicted site index for black oak in southern Indiana (Hannah 1968)*

Position	Depth of surface soil ($A_1 + A_2$ horizons--inches): Less than 4.0	4.1-5.0	5.1-6.0	6.1-7.0	7.1-8.0	8.1-9.0	More than 9.0
Ridges	48	54	60	66	72	79	87
Upper slopes 1-25 percent of distance from ridge	51	56	62	68	74	80	87
Upper midslopes 26-50 percent of distance from ridge	56	62	66	72	77	82	88
Lower midslopes 51-75 percent of distance from ridge	62	67	72	76	80	84	89
Lower slopes 76-99 percent of distance from ridge	69	74	78	80	84	87	90
Bottoms	73	77	80	83	86	88	91

Stone content: All site-index values are for relatively stone-free soils (0 to 30 percent stone in B_2 horizon); for stony soils (31 to 60 percent stone in B_2), and very stony soils (more than 60 percent stone in B_2), the following substractions should be made:

Site index	Stony soil
<60	-2
61-90	-3
>90	-4

Site index	Very stony soils
<60	-4
61-75	-5
76-87	-6
>87	-7

Subsoil texture: All site-index values are for soils having less than 40 percent clay in the subsoil (loams, clay loams, silty or sandy clay loams, and silt loams). For soils with heavier subsoil textures (more than 40 percent clay), the following substractions are needed:

Site index	Upper subsoil (B_2 horizon) has less than 40 percent clay; lower subsoil (B_3, B_x, or C horizon) has more than 40 percent clay (Reduction)
<52	-2
53-73	-3
>74	-4

Site index	All subsoil horizons have more than 40 percent clay (Reduction)
<57	-4
58-69	-5
70-80	-6
>80	-7

Texture of the B_3 horizon: Site-index values are for conditions where the B_2 horizon and those underlying it have the same general texture. Subtract 4 feet if a B_2 horizon with less than 40 percent clay is underlain by a B_3, B_x, or C horizon with 40 to 60 percent clay. Subtract 4 feet if a B_2 horizon with 40 to 60 percent clay is underlain by a B_3, B_x, or C horizon with more than 60 percent clay.

APPENDIX II
YIELD TABLES

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

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

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

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

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

Table 13. – *Yields per acre for upland oak; first thinning at age 20 (Gingrich 1971)*

Age	Residual stand: Basal area	Residual stand: Average tree diameter	Residual stand: Yield			Cut stand: Basal area	Cut stand: Yield			Cumulative total yields (cut stand plus residual stand)		
Years	*Square feet*	*Inches*	*Cubic feet*	*Cords*	*Board feet*	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*
					SITE INDEX 55							
20	34	2.3	60	0.6	--	--	--	--	--	60	0.6	--
30	49	4.2	600	5.1	--	15	--	0.9	--	600	6.0	--
40	58	6.1	1,220	12.2	880	16	300	2.9	--	1,520	16.0	880
50	66	8.6	1,750	16.0	2,350	15	300	3.2	150	2,350	23.0	2,500
60	71	10.6	1,980	18.6	3,960	15	360	3.2	570	2,940	28.8	4,680
70	74	12.1	2,170	20.0	5,810	14	370	3.8	820	3,500	34.0	7,350
					SITE INDEX 65							
20	37	2.8	160	1.6	--	--	18	--	--	178	1.6	--
30	50	4.6	750	7.4	--	20	132	1.2	--	900	8.6	--
40	63	7.7	1,760	16.0	1,320	15	290	3.2	--	2,200	20.4	1,320
50	69	9.8	2,150	19.7	3,500	19	625	4.1	400	3,215	28.2	3,900
60	73	12.0	2,460	22.5	6,120	18	515	4.4	1,160	4,040	35.4	7,680
70	77	14.6	2,730	24.2	9,030	16	520	4.9	2,010	4,830	42.0	12,600
					SITE INDEX 75							
20	46	3.6	476	4.4	--	--	218	2.0	--	694	6.4	--
30	57	5.6	1,275	13.0	--	26	307	3.6	--	1,800	18.6	--
40	66	8.4	2,140	19.8	2,160	21	535	4.8	240	3,200	30.2	2,400
50	71	10.8	2,600	24.7	6,450	21	665	5.4	1,160	4,325	40.5	7,850
60	76	13.4	3,060	28.5	10,680	19	615	4.9	2,020	5,400	49.2	14,100
70	79	16.3	3,465	31.5	13,720	19	635	5.2	2,740	6,440	57.4	19,880

Table 14. – *Yields per acre for upland oak; first thinning at age 30 (Gingrich 1971)*

Age	Residual stand: Basal area	Residual stand: Average tree diameter	Residual stand: Yield			Cut stand: Basal area	Cut stand: Yield			Cumulative total yields (cut stand plus residual stand)		
Years	*Square feet*	*Inches*	*Cubic feet*	*Cords*	*Board feet*	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*
					SITE INDEX 55							
30	58	4.3	528	4.8	--	17	55	0.5	--	583	5.3	--
40	55	5.7	1,120	9.4	200	27	265	3.1	--	1,440	13.0	200
50	62	7.8	1,600	14.2	1,500	15	330	3.4	--	2,250	21.2	1,500
60	67	10.2	1,950	17.4	3,000	15	310	3.2	360	2,910	27.6	3,360
70	72	11.7	2,135	19.6	5,040	12	335	3.1	550	3,430	32.9	5,950
80	75	13.0	2,280	20.6	8,000	12	345	3.7	1,010	3,920	37.6	9,920
					SITE INDEX 65							
30	62	4.9	1,120	9.6	--	20	80	1.0	--	1,200	10.6	--
40	60	6.6	1,520	13.6	640	29	400	3.8	--	2,000	18.4	640
50	67	9.0	2,000	18.5	2,450	18	470	4.2	--	2,950	27.5	2,450
60	72	11.2	2,370	21.5	4,620	17	430	3.9	600	3,750	34.5	5,220
70	76	13.7	2,660	23.8	8,320	16	440	3.9	1,510	4,480	40.6	10,430
80	78	16.1	2,880	24.8	10,900	16	460	4.0	2,510	5,160	45.6	15,520
					SITE INDEX 75							
30	66	5.5	1,450	14.0	--	23	220	2.7	--	1,670	16.7	--
40	62	7.1	1,840	17.0	1,400	34	600	5.5	--	2,660	25.2	1,400
50	68	9.7	2,400	22.8	4,200	20	555	5.0	650	3,775	36.0	4,850
60	73	12.4	2,880	26.7	7,980	19	515	4.8	1,450	4,770	44.7	10,080
70	77	15.2	3,325	29.8	13,020	17	490	4.4	2,100	5,705	52.2	17,220
80	80	17.7	3,760	31.6	15,440	16	500	4.8	3,400	6,640	58.8	23,040

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

Age	Residual stand: Basal area	Residual stand: Average tree diameter	Residual stand: Yield			Cut stand: Basal area	Cut stand: Yield			Cumulative total yields (cut stand plus residual stand)		
Years	*Square feet*	*Inches*	*Cubic feet*	*Cords*	*Board feet*	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*
SITE INDEX 55												
40	63	5.0	1,140	10.5	--	24	180	1.6	--	1,320	12.1	--
50	62	7.4	1,538	13.0	900	23	282	3.4	--	2,000	18.0	900
60	67	9.1	1,830	15.6	2,430	15	288	3.1	270	2,580	23.7	2,700
70	72	11.0	2,065	18.6	4,445	12	300	2.7	465	3,115	29.4	5,180
80	74	12.7	2,240	21.6	6,880	12	350	2.8	865	3,640	35.2	8,480
90	76	13.8	2,430	24.8	9,180	9	355	3.0	1,100	4,185	41.4	11,880
SITE INDEX 65												
40	69	6.5	1,600	15.9	440	27	240	2.3	--	1,840	18.2	440
50	66	8.5	1,910	17.7	1,800	28	410	4.0	200	2,560	24.0	2,000
60	70	10.4	2,200	20.7	4,200	18	400	3.6	280	3,270	30.6	4,680
70	74	12.4	2,485	23.1	7,210	16	420	3.7	710	3,955	36.7	8,400
80	77	14.5	2,720	24.8	8,960	15	410	4.0	1,050	4,600	42.4	11,200
90	79	16.5	2,925	26.6	10,710	13	460	4.0	1,630	5,265	48.2	14,580
SITE INDEX 75												
40	73	7.4	2,130	20.2	1,380	28	300	3.0	--	2,440	23.2	1,380
50	68	9.6	2,390	21.8	3,450	31	635	6.2	300	3,325	31.0	3,750
60	73	11.6	2,730	24.9	7,680	19	625	5.2	1,020	4,290	39.3	9,000
70	76	13.8	3,115	28.0	11,200	19	610	4.8	1,620	5,285	47.2	14,140
80	79	16.5	3,480	30.8	14,080	17	590	5.2	2,340	6,240	55.2	19,360
90	81	18.7	3,735	33.7	15,810	15	660	5.3	3,000	7,155	63.4	24,120

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

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

Table 17. – *Yields per acre for upland oak; first thinning at age 60 (Gingrich 1971)*

Age	Residual stand: Basal area	Residual stand: Average tree diameter	Residual stand: Yield			Cut stand: Basal area	Cut stand: Yield			Cumulative total yields (cut stand plus residual stand)		
Years	*Square feet*	*Inches*	*Cubic feet*	*Cords*	*Board feet*	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*
SITE INDEX 55												
60	76	8.2	1,860	17.1	780	28	660	5.8	120	2,520	22.9	900
70	73	9.3	1,960	17.5	2,345	19	285	4.0	685	2,905	27.3	3,150
80	70	10.3	2,000	18.4	4,320	16	335	3.0	555	3,280	31.2	5,680
90	72	11.3	2,115	19.3	5,850	10	250	2.5	530	3,645	34.6	7,740
100	74	12.3	2,200	20.8	7,300	8	270	1.9	510	4,000	38.0	9,700
110	75	13.2	2,310	22.6	8,580	7	235	2.0	570	4,345	41.8	11,550
SITE INDEX 65												
60	78	9.4	2,400	22.2	3,900	33	900	8.6	1,260	3,300	30.8	5,160
70	75	10.2	2,450	22.1	4,550	23	360	3.6	770	3,710	34.3	6,580
80	73	12.0	2,520	23.0	5,920	20	400	3.6	810	4,180	38.8	8,760
90	77	14.1	2,610	23.8	7,785	13	365	3.6	895	4,635	43.2	11,520
100	78	15.5	2,650	25.5	9,850	12	325	3.1	915	5,000	48.0	14,500
110	80	17.2	2,750	26.6	11,770	9	345	3.1	960	5,445	52.2	17,380
SITE INDEX 75												
60	82	10.2	3,060	27.0	7,848	32	1,080	10.7	1,440	4,140	37.7	9,288
70	78	11.5	3,150	27.3	8,540	21	460	4.7	870	4,690	42.7	10,850
80	76	13.5	3,320	28.4	9,760	21	420	4.2	1,290	5,280	48.0	13,360
90	78	15.6	3,510	29.9	10,935	16	425	3.6	1,665	5,895	53.1	16,200
100	80	17.2	3,725	31.5	12,200	13	415	3.3	1,835	6,525	58.0	19,300
110	82	19.1	3,795	33.0	13,530	9	445	3.2	1,920	7,040	62.7	22,550

Table 18. – *Yields of well-stocked unmanaged mixed oak stands in southern Michigan at 80 years*[1] *(Arend and Scholz 1969)*

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.*
VERY POOR SITES					
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 Michigan Agricultural Experiment Station 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.

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

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

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

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

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

APPENDIX III

EVALUATING STAND DENSITY AND GROWING STOCK QUALITY

The basic data needed to evaluate stand stocking and quality are *basal area* and *number of trees per acre* (by size class and growing stock quality class). Stocking percent and average stand diameter are determined from figure 7 using these two data items. The charts in figure 7 show how well a particular stand is utilizing its growing space, and how much of the stand can be removed in an intermediate cut. The inventory to obtain these data is left to the discretion of the user, but should be intense enough to provide reliable estimates of stand parameters.[2] Four size classes are defined as follows:

Mature Timber – trees that have reached the rotation diameter desired for the site.

Sawtimber – trees over 11 inches d.b.h. but less than the rotation diameter desired for the site.

Poletimber – trees 6 to 11 inches d.b.h.

Small Trees – trees 2 to 6 inches d.b.h.

The class limits were selected to conform to commonly accepted usage, but may be changed to meet the needs of the user.

Two growing stock quality classes are suggested within three of the above size classes. (They are not needed in the mature timber class because these trees are ready for harvest.) These quality classes are good or "acceptable growing stock" (AGS) and "undesirable growing stock" (UGS). AGS trees are trees of good form, quality, and species that would be satisfactory crop trees in the final stand on the site, or have the potential of yielding products in a future intermediate cutting within 20 to 40 years. UGS trees are trees that are salable for products or that might eventually be salable if left to grow, but because of form, defect, vigor, or species, are not wanted in the stand.

Cull trees are trees that are not and never will be merchantable for products and should be tallied without regard for size class.

[2] *The method suggested by Roach and Gingrich (1968) is recommended. Tree size classes and quality classes are the same as they suggest.*

When the stand inventory has been completed, the stocking chart can be used to determine present stocking and the amount of basal area that can be removed in a cut. Assume the following information has been obtained from the inventory:

Site class 55 to 74
Rotation diameter objective 20 to 24 inches
Number of trees per acre - 220
Basal area per acre

	AGS	UGS	Cull	Total
Mature timber	–	–	–	–
Sawtimber	32	2	3	37
Poletimber	18	2	1	21
Small trees	10	20	0	30
Total	60	24	4	88

Referring to the stocking chart (fig. 7), locate the point where total basal area and number of trees intersect to find the current stocking percent (80) and average stand diameter (8.6 inches). Then project a line parallel to the line denoting 8 inches average diameter to the B and C curves to find the basal area needed for B-level (64), and C-level (50) stocking. Now, compare the basal area of acceptable growing stock from the tally with that required for B and C levels determined from the chart.

In the example, there are 60 square feet of basal area in acceptable growing stock, not quite enough for B level but well above C level. Inspection of the data shows the stand is immature but no single size class contains more than 50 percent of the basal area. The sawtimber and pole classes must be combined to form the main stand or stand to manage. Twenty-four square feet of basal area can be removed from this stand in an intermediate cut without falling below B-level stocking (88-24=64). Note that not all culls and undesirable growing stock (24+4=28) can be removed and retain B-level stocking (64-24=40). The cut should be designed to remove the cull trees and as much undesirable growing stock as possible and still retain uniform spacing.

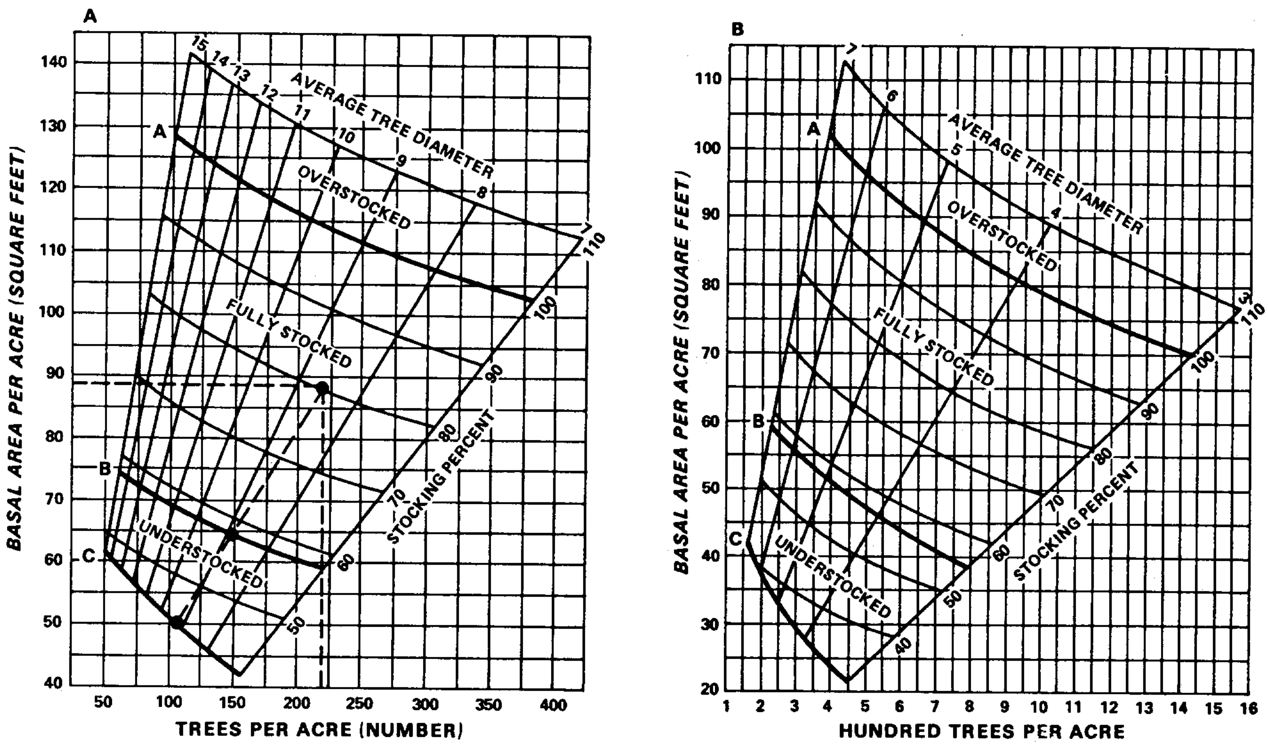

Figure 7. – *Relation of basal area, number of trees, and average tree diameter to stocking percent for upland central hardwoods. For average tree diameters 7 to 15, use the chart at left; for diameters 3 to 7, use the chart at right. (Average tree diameter is the tree of average basal area.) On both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

APPENDIX IV

EVALUATING THE ADEQUACY OF OAK ADVANCE REPRODUCTION

To evaluate whether the oak advance reproduction can adequately reproduce the stand a survey must be made. This survey can be made at the same time that the inventory to determine stand stocking and quality is made. In fact, the *number of overstory trees per acre* from the stand stocking inventory is needed to estimate the *number of stump sprouts per acre* necessary to compensate for oak advance reproduction deficiencies. The sample form (fig. 8) can be used to record the tree count needed for estimating number of overstory trees per acre.

Use the following procedure developed by Sander *et al.* (1976) for evaluating oak advance reproduction:

1. Take 10 or more 10-factor angle gauge sample points in the stand being examined. At each sample point tally the trees on a 1/20-acre plot by species and size class (overstory inventory, see sample form, figure 8).

2. Select the number of 1/735-acre plots (4.3 feet in radius) to use in the advance reproduction inventory from the following tabulation according to the acreage of the stand being examined:

For stand size (acres)	Use this number of 1/735-acre plots
<10	25
10 to 30	40
30 to 50	60

3. Distribute these 1/735-acre plots uniformly throughout the stand.

4. On each 1/735-acre plot look for oak reproduction stems 4.5 feet tall or taller and less than 2.0 inches in diameter at the ground line or not over 1.5 inches d.b.h. (stems larger than this should be considered part of the overstory and tallied as such, even if below the main canopy). If at least one such stem is present, record the plot as stocked. If no such stem is present, record the plot as not stocked (see right margin of sample form, figure 8).

5. Compute the percent of plots stocked. If 59 percent or more are stocked, there is adequate oak advance reproduction present; no further calculations are necessary and the stand may be harvested.

6. If fewer than 59 percent of the plots are stocked, oak advance reproduction is inadequate to reproduce the stand if it is cut. But the stand could still be reproduced if enough stumps of the overstory oaks will sprout after they are cut. An example of how to compute the expected number of stump sprouts follows:

a. Assume that the inventory of plots provides the data on the sample worksheet (fig. 8).

b. Note that there are 26 black oaks 2 to 5 inches in diameter per acre. Multiply 26 by 0.85 (from table 20) to find how many of the 26 stumps would be expected to sprout. 26 x 0.85 = 22. Note that 22, number of expected stump sprouts per acre for 2- to 5-inch black oaks, is listed at the bottom of figure 8.

c. Similarly, compute the expected number of stump sprouts for the other size classes of black oak (5 for the 6- to 11-inch class, 4 for the 12- to 16-inch class) and note that all these classes sum to 31. Do the same for all oak species.

d. Summing size classes for all oaks gives a total of 124 expected oak stump sprouts per acre (fig. 8).

7. Note that the sample data from figure 2 gave 17 plots stocked of a total of 40, or 43 percent of plots stocked (determined under point 4 above). Go to the tabulation below and find the number of stump sprouts required in combination with

Table 20. – *Expected percentage of oak stumps that will sprout after cutting*[1]

Size class[2] (inches)	Black oak	Scarlet oak	Northern red oak	White oak	Chestnut oak
2-5	85	100	100	80	100
6-11	65	85	60	50	90
12-16	20	50	45	15	75
17+	5	20	30	0	50

[1] Adapted from Roth and Hepting (1943), Wendel (1975), Johnson (1975), and unpublished data at Columbia, Missouri.

[2] D.b.h. class of parent tree.

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

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

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

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

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

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

Sample point number	Dbh class	Black oak	White oak	Scarlet oak	Northern red oak	Chestnut oak	Other species	Total
1	2-5	••	⁖	•			••	
	6-11		•				•	
	12-16						•	
	17+				•			
2	2-5	••	∷‾					
	6-11	•	•				••	
	12-16		•					
	17+							
3	2-5	•	•	••			•	
	6-11			•				
	12-16		•				•	
	17+							
4	2-5		••				⁖	
	6-11							
	12-16	••		•			••	
	17+							
5	2-5		∷‾	••				
	6-11	•	••					
	12-16							
	17+		•					
6	2-5	•	••	⁖			••	
	6-11						•	
	12-16	••	•				•	
	17+							
7	2-5	⁖	⁖	••				
	6-11		•				••	
	12-16						•	
	17+	•						
8	2-5	••	•	•	••		⁖	
	6-11	•						
	12-16	•			•			
	17+							
9	2-5		⁖				••	
	6-11	•			•		•	
	12-16	••	•	•			•	
	17+							
10	2-5	••	∷‾	•				
	6-11		•		•		•	
	12-16	••						
	17+							
Total No. per acre	2-5	26	60	24	4		26	140
	6-11	8	12	2	4		22	48
	12-16	18	8	4	2		14	46
	17+	2	2	0	2		0	6
	Total	54	82	30	12		62	240
No. of stump sprouts per acre	2-5	22	48	24	4		✕	Total per acre
	6-11	5	6	2	2		✕	
	12-16	4	4	2	1		✕	
	17+	0	0	0	0		✕	
	Total	31	58	28	7		✕	124

Date
Compartment 1
Stand 1

1/735-acre plots
Total No. 40
Stocked █ ⊓
Not Stocked ⊠ ⊠ ⁖
Percent Stocked 43

Adv. Repro. Adequate No

Adv. Repro. + stump sprouts Adequate **Yes**

Figure 8. – *Example tally form for recording on 1/20-acre plots and number of 1/735-acre plots stocked with advance oak reproduction.*

APPENDIX V

MISCELLANEOUS

Metric Conversion Factors

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

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

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

Common and Scientific Names of Plants and Animals

Plants

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

Animals

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

PESTICIDE PRECAUTIONARY STATEMENT

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

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

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

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

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

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

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

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

LITERATURE CITED AND OTHER REFERENCES

Arend, J. L., and H. F. Scholz. 1969. Oak forests of the Lake States and their management. USDA For. Serv. Res. Pap. NC-31, 36 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Benzie, John W. 1977a. Manager's handbook for jack pine in the north central States. USDA For. Serv. Gen. Tech. Rep. NC-32, 18 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Benzie, John W. 1977b. Manager's handbook for red pine in the north central States. USDA For. Serv. Gen. Tech. Rep. NC-33, 23 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Carmean, W. H. 1971. Site index curves for black, white, scarlet, and chestnut oaks in the Central States. USDA For. Serv. Res. Pap. NC-62, 8 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Einspahr, D., and A. L. McComb. 1951. Site index of oaks in relation to soil and topography in northeastern Iowa. J. For. 49:719-723.

Fowells, H. A., Compiler. 1965. Silvics of forest trees of the United States. U.S. Dep. Agric., Agric. Handb. 271, 762 p.

Gevorkiantz, S. R. 1957. Site index curves for red oak in the Lake States. USDA For. Serv. Tech. Note 485, 2 p., Lake States For. Exp. Stn., St. Paul, Minnesota.

Gevorkiantz, S. R., and H. F. Scholz. 1948. Timber yields and possible returns from the mixed-oak farmwoods of southwestern Wisconsin. Wisconsin Dep. Conserv. Publ. 521, 72 p.

Gingrich, S. F. 1971. Management of young and intermediate stands of upland hardwoods. USDA For. Serv. Res. Pap. NE-195, 26 p., Northeast. For. Exp. Stn., Upper Darby, Pennsylvania.

Gysel, L. W., and J. L. Arend. 1953. Oak sites in southern Michigan: their classification and evaluation. Michigan State Coll. Agric. Exp. Stn., Tech. Bull. 236, 57 p.

Hannah, P. R. 1968. Estimating site index for white and black oak in Indiana from soil and topographical factors. J. For. 66:412-417.

Haussman, R. F. 1960. Permanent logging roads for better woodlot management. USDA For. Serv. State & Private For., 38 p.

Johnson, Paul S. 1976. Eight-year performance of interplanted hardwoods in southern Wisconsin oak clearcuts. USDA For. Serv. Res. Pap. NC-126, 9 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Lull, H. W., and K. G. Reinhart. 1967. Increasing water yield in the northeast by management of forested watersheds. USDA For. Serv. Res. Pap. NE-66, 45 p. Northeast. For. Exp. Stn., Upper Darby, Pennsylvania.

McQuilkin, R. A. 1974. Site index prediction table for black, scarlet, and white oaks in southeastern Missouri. USDA For. Serv. Res. Pap. NC-108, 8 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Roach, B. A., and S. F. Gingrich. 1968. Even-aged silviculture for upland central hardwoods. U.S. Dep. Agric., Agric. Handb. 355, 39 p.

Sander, I. L. 1972. Size of oak advance reproduction: key to growth following harvest cutting. USDA For. Serv. Res. Pap. NC-79, 6 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Sander, I. L., and F. B. Clark. 1971. Reproduction of upland hardwood forests in the central states. U.S. Dep. Agric., Agric. Handb. 405, 25 p.

Sander, I. L., P. S. Johnson, and R. F. Watt. 1976. A guide for evaluating the adequacy of oak advance reproduction. USDA For. Serv. Gen. Tech. Rep. NC-23, 7 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Schnur, G. L. 1937. Yield, stand, and volume tables for even-aged upland oak forests. U.S. Dep. Agric. Tech. Bull. 560, 88 p.

Tubbs, C. H. 1977. Manager's handbook for northern hardwoods in the north central States. USDA For. Serv. Gen. Tech. Rep. NC-39. North Cent. For. Exp. Stn., St. Paul, Minnesota.

U.S. Department of Agriculture, Forest Service. 1973. Silvicultural systems for the major forest types of the United States. Agric. Handb. 445, p. 66-69.

U.S. Department of Agriculture, Forest Service. 1971. Oak symposium proceedings. 161 p. Northeast. For. Exp. Stn., Upper Darby, Pennsylvania.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1977--767279/21 REGION NO. 6

Sander, Ivan L. 1977. Manager's handbook for oaks in the north central States. USDA For. Serv. Gen. Tech. Rep. NC-37, 35 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Presents a key for choosing management options. Discusses silvicultural treatments to ensure reproduction and regulate stand density for efficient timber production. Also discusses water, wildlife, esthetics, and their effects on timber production.

OXFORD: 176.1 *Quercus* spp.:187(77)61.2.
KEY WORDS: *Quercus*, mixed stands, regeneration, thinning.

Sander, Ivan L. 1977. Manager's handbook for oaks in the north central States. USDA For. Serv. Gen. Tech. Rep. NC-37, 35 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Presents a key for choosing management options. Discusses silvicultural treatments to ensure reproduction and regulate stand density for efficient timber production. Also discusses water, wildlife, esthetics, and their effects on timber production.

OXFORD: 176.1 *Quercus* spp.:187(77)61.2.
KEY WORDS: *Quercus*, mixed stands, regeneration, thinning.

Nature is beautiful...leave only your footprints.