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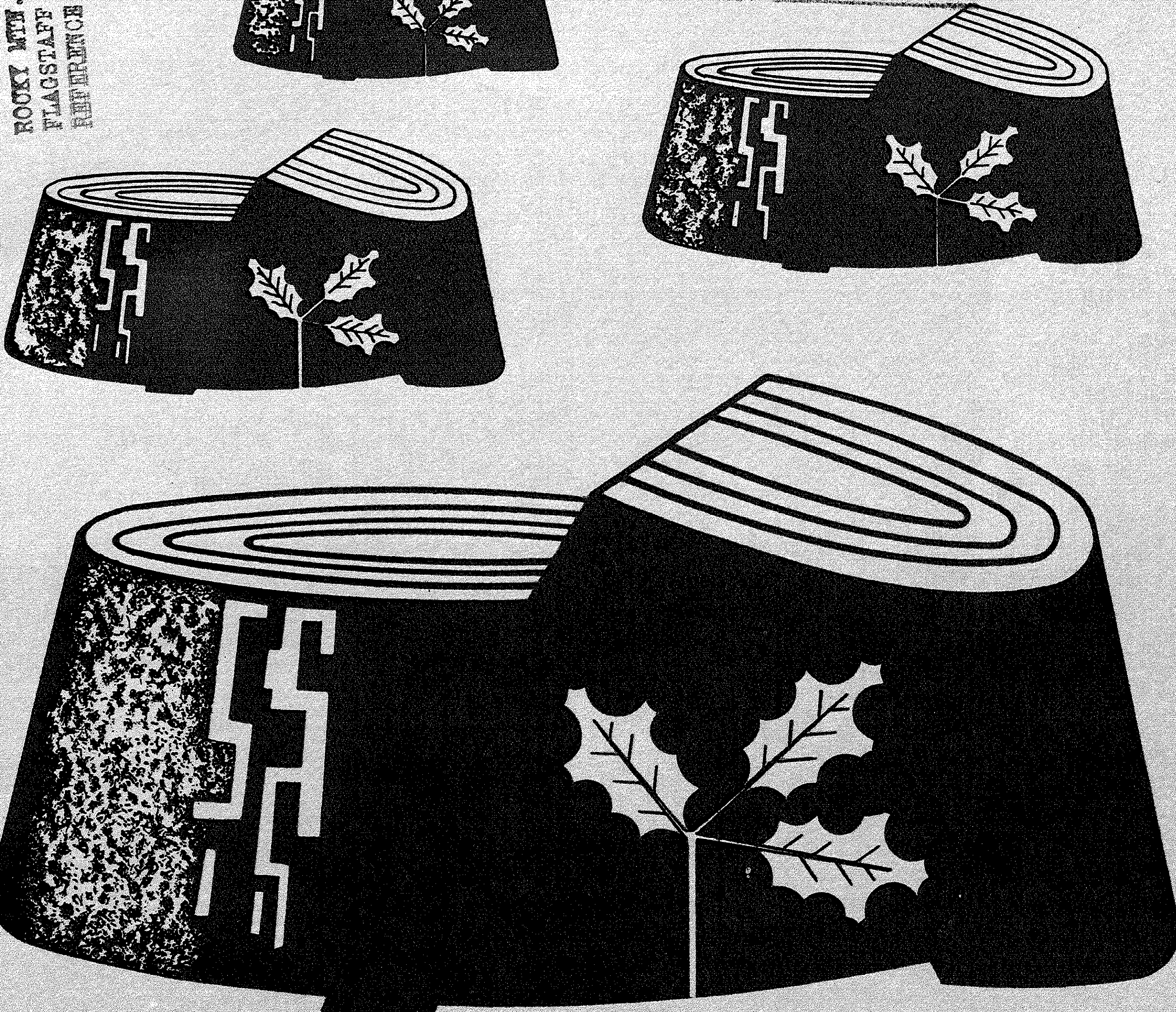

A GUIDE FOR EVALUATING THE ADEQUACY OF OAK ADVANCE REPRODUCTION

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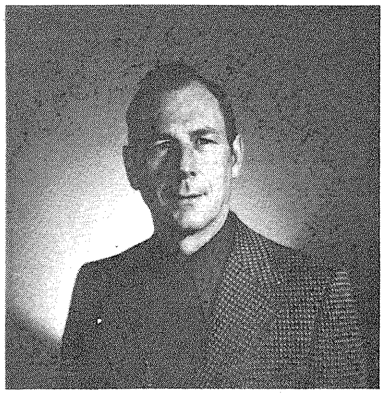

Ivan L. Sander received his B.S. and M.S. degrees in Forestry from the University of Missouri. In 1953 he began Forest Service research at Columbia, Missouri, in oak wilt control. From 1955-1961 Sander worked in hardwood silviculture research at Berea, Kentucky. He continued this line of research at Athens, Ohio, from 1961 to 1965, and at Berea, Kentucky, 1965 to 1970. Sander transferred to oak regeneration and stand density research at Columbia, Missouri, in 1970, and in 1975 was appointed Project Leader of Timber Management Research there.

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Richard F. Watt has a BS degree from the New York State College of Forestry, an MS from the Yale School of Forestry, and a Ph.D. from the University of Minnesota. Watt first worked with the Forest Service in Idaho on silvicultural and mensurational problems in western white pine. Moving to St. Paul, he served both as a research administrator and a project leader in silvicultural and physiological ecology research in the black spruce and northern hardwood types for 13 years. Watt later moved to Columbia, Missouri, where he led the oak silviculture project for 7 years. At present he is a specialist in hardwood silviculture and urban forestry on the Resource Management Staff, State and Private Forestry, Upper Darby, Pennsylvania. Watt has numerous publications on silviculture, photoperiodism, mineral nutrition, and herbicides.

WHAT DO YOU THINK?

Realizing that the needs and interests of our two major "clients"--the scientist and the practitioner--are different, we have been concerned whether our publications have been in a form and style equally useful to both. So we have decided to try a new format for some of our publications, one that might serve this dual purpose better.

The paper is divided into two separate parts: Application and Documentation. The Application section is specifically intended for the man on the ground or in the mill who has a particular job to do or problem to solve. This section describes briefly the situation and the problem, and then goes immediately to the solution, emphasizing the how-to-do-it aspect. It is a complete story in itself; the busy manager need read no further.

The Documentation section describes the details of the research process. It is for the reader interested in laboratory and field procedures, tabulations, statistical analysis, and philosophical discussion. This section, too, is self-contained.

Our purpose is to separate the practical aspects of our research results from the strictly academic ones yet still make both available to all readers. If the practitioner wants to find out how we arrived at our recommendations, the details are in the Documentation section for him to examine. If the scientist has a practical bent, he can turn to the Application section and see the results in action.

It is for you to decide whether we have created a well-matched team or a two-headed monster. <u>We would like to have your opinion</u>.

A GUIDE FOR EVALUATING THE ADEQUACY OF OAK ADVANCE REPRODUCTION

Ivan L. Sander, Paul S. Johnson, and Richard F. Watt

APPLICATION

The purpose of this guide is to enable the user to determine in advance of harvest whether reproduction is adequate to reasonably ensure the regeneration of an oak stand. The guide is based on studies of survival and growth of oak reproduction on a range of sites from site index 50 to 75 for black oak.[1] The guide assumes oaks will be grown in even-aged stands and that the final harvest cutting will completely remove the overstory.

The guide requires inventories of (a) the overstory and (b) the oak advance reproduction. Both inventories should be made at the same time and tallied on a form like figure 1. If the oak advance reproduction inventory shows there are insufficient oaks to replace the stand, the overstory inventory is used to determine whether or not stump sprouts from overstory oaks are likely to be numerous enough to make up the deficiencies in advance reproduction. The inventory routinely used in silvicultural stand examinations to estimate overstory basal area and number of trees per acre will satisfy the requirements for (a) above if all oaks 1.6 inches d.b.h. and larger are included in the number of trees per acre (Roach and Gingrich 1968).

TO USE THIS GUIDE

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 1).

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
10-30	40
30-50	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 1).

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 oak trees 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. 1).

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[1] *Caution is advised in using this guide in stands having a site index above 70 feet, where there is often a great abundance of fast-growing nonoak competitors. On these good sites the minimum size of advance oak reproduction may need to be larger than that used in this guide.*

Sample point number	Dbh class	Black oak	White oak	Scarlet oak	North. red oak	Chest. oak	Other spp.	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							
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	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 spts per acre	2-5	22	48	24	4			Total per acre
	6-11	5	6	2	2			
	12-16	4	1	2	1			
	17+	0	0	0	1			
	Total	31	55	28	8			122

Date ____________

Compartment 1

Stand 1

1/735-acre plots

Total No. 40

Stocked

Net Stocked

Percent Stocked 43

Adv. Repro. Adequate no

Adv. Repro. + stump sprouts Adequate YES

Figure 1.--*Example tally form for recording overstory trees, oak advance reproduction stocking, and for computing the number of expected oak stump sprouts. The tally was made on 1/20-acre plots.*

b. Note that there are 26 black oaks 2 to 5 inches in diameter per acre. Multiply 26 by 0.85 (from table 1) 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 1.

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 0 for the 17+-inch class) and note that all these classes sum to 31. Do the same for all oak species.

d. Summing all oak species and all size classes gives a total of 122 expected stump sprouts per acre (fig. 1).

7. Note that the sample data from figure 1 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 stocked plots to meet minimum stocking requirements at the next lowest percent down from 43 (i.e., 40). Opposite 40 note that 97 stump sprouts are needed to make up the deficiency in advance reproduction.

Stocked 1/735-acre plots (Percent[2])	*Stump sprouts required* (Number per acre)
59	0
55	21
50	46
45	71
40	97
35	122
30	147
25	172
20	198
15	223
10	248

8. Because the computed value (122) exceeds the tabulation value (97), 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.

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[2] *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.*

DOCUMENTATION

BACKGROUND

Oak Advance Reproduction

It is firmly established that the oak component of new stands following harvest cutting depends on size, number, and distribution of the oak advance reproduction (Sander 1971, 1972; Sander and Clark 1971). However, oak advance reproduction varies greatly under mature or nearly mature stands throughout the oak range in the eastern United States, even within small areas. For example, in West Virginia, a range of 25 to more than 55,000 oaks per acre was reported (Tryon and Carvell 1958). Numbers ranged from about 2,000 to 5,000 trees per acre in Ohio, while in Indiana only 230 per acre were found (Sander and Clark 1971). In Missouri, the number of oaks varied from about 300 to 2,000 per acre.[3] Some of this reported variation is attributable to site quality; in general, oak advance reproduction is more abundant on average and poor sites than on good sites (Arend and Gysel 1952, Carvell and Tryon 1961, Phillips 1963, Sander and Clark 1971).

The abundance of oak advance reproduction alone is not a good indicator of whether or not oaks will be a major component of a new stand after harvest cutting. For example, in southwestern Wisconsin, 900 to 4,000 advance oaks per acre were judged to be inadequate because they were too small to successfully compete with associated vegetation (Arend and Scholz 1969). Thus, tree size as well as tree numbers must be considered.

Oak advance reproduction exists as either true seedlings or sprouts. The root systems of sprout advance reproduction are usually considerably older than the stems, are relatively large, and are capable of supporting much greater stem growth than those of true seedlings. For example, in 12-year-old stands that developed after clearcutting in Illinois, stems from true seedlings averaged less than 2 feet tall and all were suppressed; stems from sprout advance reproduction less than 4.5 feet tall averaged 14 feet and 6 percent were codominant or larger; and stems from advance reproduction over 4.5 feet tall averaged 23 feet tall and 63 percent were codominant or larger (Sander 1972).

Similar height growth patterns were found in a Missouri study where 10 years after clearcutting true seedlings planted at the time of cutting averaged 2 feet tall (McQuilkin 1975). All sprouts from advance reproduction averaged 16 feet tall. However, of the advance sprouts over 3 feet tall, 50 percent attained a height of 19 feet or more; of the advance reproduction 1 to 3 feet tall, only 14 percent attained this height.

In Ohio, growth of new oak sprouts that developed after cutting advance reproduction stems was related to the diameter of the old stem at the ground line (Sander 1971). Three years after cutting, the largest advance reproduction stems produced the fastest growing sprouts, and unless the old stem diameters were at least 0.5 inch, few new sprouts became codominant or larger. Seven-year measurements showed that oak advance reproduction must be larger than 0.6-inch diameter at the ground line before a significant proportion (more than 60 percent) of the new sprouts originating from it will be dominant or codominant.[3] Thus tree diameter or height can be used as an indicator of total plant size and the potential of the root systems to support vigorous shoot growth after the overstory is removed.

The Role of Stump Sprouts

Stump sprouts should also be considered when evaluating potential oak regeneration before clearcutting because they are the most rapidly growing oak component of new stands. For example, 5-year-old white, black, scarlet, northern red, and chestnut oak stump sprouts in Virginia averaged more than 10 feet in height (Roth and Hepting 1943). In Missouri the average height of oak stump sprouts at age 5 for white, black, and scarlet oak was over 12 feet, and 83 percent of them were at least 10 feet tall.[3] Although tree crown class was not determined in these studies, trees that can attain a height of 10 feet at age 5 are assured a position of codominance or better.

Although decay in stump sprouts has sometimes been of concern, oak sprouts originating at or below ground level have a low probability of becoming infected via the

[3] *Unpublished data, North Central Forest Experiment Station, Columbia, Missouri.*

parent stump (Roth and Hepting 1969). However, if many sprouts persist on a single stump, they may develop sweep in the lower portion of the bole. This can be avoided if clumps are thinned in early cleanings.

The oak species vary considerably in their capacity to produce stump sprouts. Although several factors influence stump sprouting, stump diameter is most often and most easily related to the proportion of stumps that sprout. In general, a larger proportion of small stumps sprout than do large stumps (Rogers and Rogers 1959, Spaeth 1928, Roth and Hepting 1943, Johnson 1975, Wendel 1975). The data in table 1 were compiled from several of the sources cited above and are thus reasonably representative of the eastern oak forest.

Table 1.--*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.

ESTABLISHING A FUTURE STOCKING GOAL

The determination of the minimum amount of oak advance reproduction for adequate stocking in a new stand requires first defining "adequate stocking." At some future stage of stand development there must be enough dominant and codominant oaks in the stand to furnish some minimum stocking level. The stage chosen for this guide is when the mean stand diameter is 3 inches--the lowest mean stand diameter shown on Gingrich's (1967) stocking chart. The goal is to have the stand 30 percent stocked with codominant and dominant oaks at this mean stand diameter. Total stand stocking will be higher because trees of other species and probably some smaller oaks will be present.

A study in Missouri showed that unmanaged oak stands reached a mean stand diameter of 3 inches at age 20 to 25, and the dominant and codominant trees average 4.5 inches in diameter.[4] According to Gingrich's (1967) equation for defining minimum tree area requirements, one 4.5-inch tree contributes 0.136 percent stocking. To meet the goal of 30 percent stocking then requires 30 ÷ 0.136 or 221 codominant or larger trees averaging 4.5 inches in diameter when the mean stand diameter is 3 inches.

MINIMUM SIZE REQUIREMENTS FOR OAK ADVANCE REPRODUCTION

Data from an Illinois study were used to ascertain the average survival and growth potential of six different classes of oak advance reproduction (Sander 1972). The study, which included black, white, scarlet, and northern red oaks, documented the growth and survival of more than 1,200 trees developing over a 12-year period in clearcuttings. From this data base, oak advance reproduction with a minimum height of 4.5 feet was identified as the only class that would significantly contribute to future acceptable growing stock. Sixty-three percent of the advance reproduction of the minimum size attained dominance or codominance after 12 years. To facilitate calculation of stocking needs, this value was adjusted for anticipated mortality to stand age 20 by assuming a mortality rate of 1 percent per year.[5] Based on this adjustment, 51 percent of oak advance reproduction 4.5 feet tall or taller would be expected to attain a position of dominance or codominance at a mean stand diameter of 3 inches.

MINIMUM NUMBER OF OAK ADVANCE REPRODUCTION REQUIRED

The minimum number of oaks 4.5 feet tall or taller in the advance reproduction (NAR) required to reasonably ensure the future stocking goal of at least 221 dominant and codominant oaks when average stand diameter is 3 inches can be calculated by the formula:

$$NAR = 221/0.51 = 433 \quad \text{(Eq. 1)}$$

where 221 = the minimum number of dominant and codominant oaks needed for minimum

[4] *Based on 36 plots in an oak stand density study.*

[5] *This is the average annual mortality rate for the first 12 years of stand development.*

acceptable stocking at a mean stand d.b.h. of 3 inches and 0.51 = the expected proportion of oak advance reproduction 4.5 feet tall or taller which will be codominant or larger at a future mean stand diameter of 3 inches. These 433 trees should be well-distributed.

SAMPLE PLOT SIZE AND NUMBER

The appropriate unit for sampling oak advance reproduction should be related to the average size (4.5 inches d.b.h.) of dominant and codominant trees when the mean stand diameter is 3 inches. Solving Gingrich's (1967) minimum tree area equation reveals that a 4.5-inch tree requires 1.36 milacres of tree area or 1/735 acre of growing space. Theoretically, then, on any given acre the opportunity exists for each 1/735 acre to contain one 4.5-inch tree. Thus the appropriate plot size is 1/735 acre (4.3 feet radius). At or beyond a mean stand diameter of 3 inches, more than one codominant or larger tree would not be expected to persist within this sample space.

There is little experience or data on which to base the number of 1/735-acre plots required to adequately sample advance reproduction; the number of plots listed in the tabulation (point 2, application section) is only a reasonable estimate of the minimum needed. If greater precision is required, a preliminary sample can be used to estimate confidence limits and the required number of plots for a given level of precision based on the binomial distribution can be calculated (Freese 1962).

NUMBERS OF STUMP SPROUTS REQUIRED TO COMPENSATE FOR DEFICIENCIES IN STOCKING OF OAK ADVANCE REPRODUCTION

Data from a Missouri study on oak stump sprouting were used to determine the proportion of stump sprouts that were 10 feet tall (approximately codominant or larger) after five growing seasons. The study, which included white, black, and scarlet oaks, showed 83 percent of stump sprouts attained or exceeded this size. To facilitate calculation of stocking needs, this value was adjusted for anticipated mortality to stand age 20 by assuming a mortality rate of 0.75 percent per year.[6] Based on this adjustment, 74 percent of oak stump sprouts would be expected to occupy a position of dominance or codominance at a mean stand diameter of 3 inches.

The number of stump sprouts per acre (N) needed to make up deficits in advance reproduction stocking was then computed as follows:

$$N = \frac{221 - (0.51(735 \times P))}{0.74} \qquad \text{(Eq. 2)}$$

where 221 and 0.51 are defined as in Equation 1; 735 = the maximum number of 1/735-acre plots in 1 acre; P = the proportion of 1/735-acre sample plots which is stocked with at least one oak 4.5 feet tall or taller; and 0.74 = the expected proportion of oak stump sprouts that will be codominant or larger at a mean stand d.b.h. of 3 inches. If P is expressed as *percent* of stocked 1/735-acre plots, Equation 2 can be reduced to:

$$N = 299 - 5.06P. \qquad \text{(Eq. 3)}$$

CONCLUSION

This is a preliminary guide because the best information presently available is still incomplete. We hope silviculturists will apply the guide conscientiously, and at periodic intervals after harvest cutting, test its validity by inventorying reproduction. We hope users will share their results with us. Only in this way can we be aware of the guide's shortcomings or strengths and what revisions are needed. It will be revised as experience in application and new information dictates.

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[6] *This is the average annual mortality rate for stump sprouts based on 32-year data (Roth and Hepting 1969).*

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Gives instructions for conducting an inventory of oak advance reproduction prior to final harvest cutting to evaluate the potential for successful oak reproduction in new stands. The potential for oak stump sprouting is also considered.

OXFORD: 236.4:231.1:231.5:176.1*Quercus* spp. KEY WORDS: regeneration, *Quercus*, silviculture, surveys, stocking.

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