STOCKING, GROWTH, AND YIELD OF OAK STANDS

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ABSTRACT. An appraisal of stocking in even-aged upland oak stands is a prerequisite for determining the cultural needs of a given stand. Most oak stands have sufficient stocking to utilize the site, but are deficient in high-quality trees. Thinning such stands offers a good opportunity to upgrade the relative quality of the growing stock and enhance the growth and yield potential. The physical yields of timber products from thinning are greatest when thinning is begun at an early age. Thinnings should be made from below at 10- to 15-year intervals.

THE BASIC CONCEPT of a forest as a renewable resource capable of producing a continuous supply of products depends on the ability of the forest to grow. Consequently the planning of forest-management activities depends on our ability to appraise stocking and to predict growth and yield.

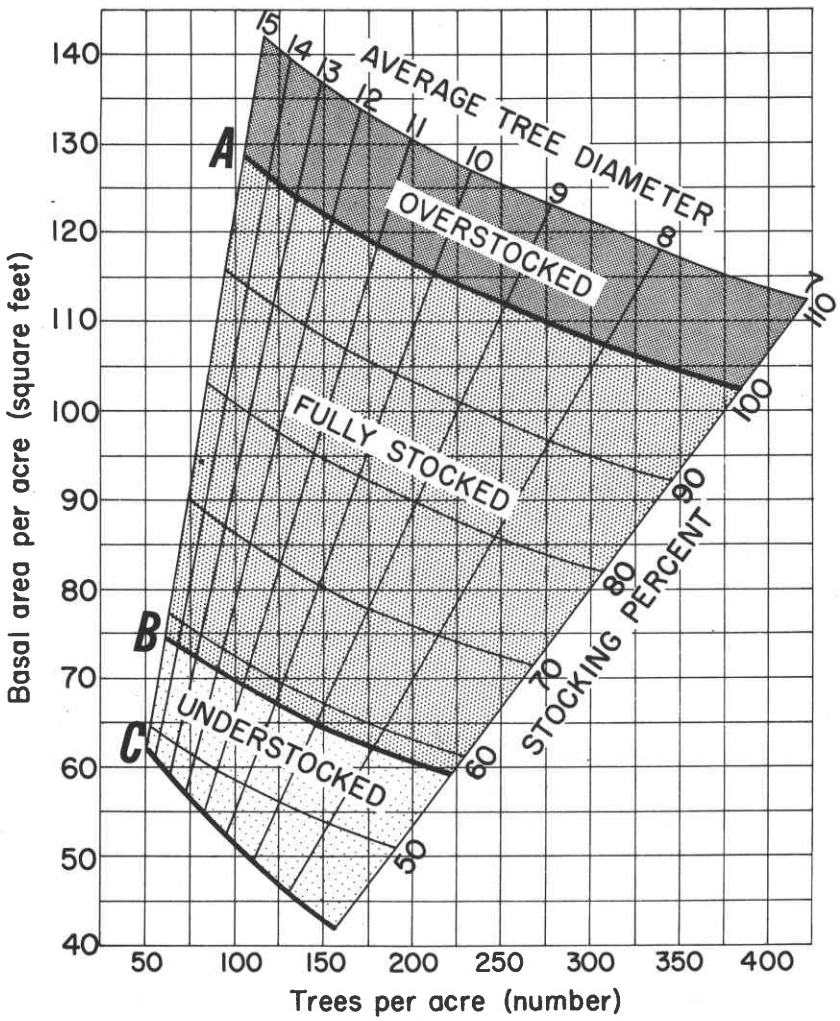
Until recently there was very little published information about the stocking, growth, and yield of oak stands. Schnur's *(1937)* yield tables, developed from normal unthinned stands, were the principal source of information about oaks. However, since 1960 some new information has become available that deals with fundamental relationships of the stocking, growth, and yield of oak stands. This information will be summarized in this paper together with new information from our research in even-aged upland oak stands.

The oak-hickory forest type comprises more than 100 million acres of commercial forest land, or nearly one-fourth of the commercial forest land in the United States *(USDA Forest Service 1958)*. Although many important species are components of this broad type, the predominant species are oaks. A description of average conditions of this broad type is of little value except in a general way. Most of the oak stands are less than 100 years old, are even-aged, and generally are overstocked with trees and understocked with high-quality stems. Seventy-four percent of the trees in eastern hardwood forests have been classified as low-grade or cull *(USDA Forest Service 1958)*.

STOCKING

Stocking can be specified in terms of either site occupancy or growth. A stand is considered fully stocked when the trees utilize the available growing space. In this respect most even-aged upland oak stands are fully stocked. Regardless of the system

Figure 1.—Relation of basal area, number of trees, and average tree diameter to stocking percent for upland central hardwoods. Tree-diameter range 7-15 (left) and 3-7 (right).

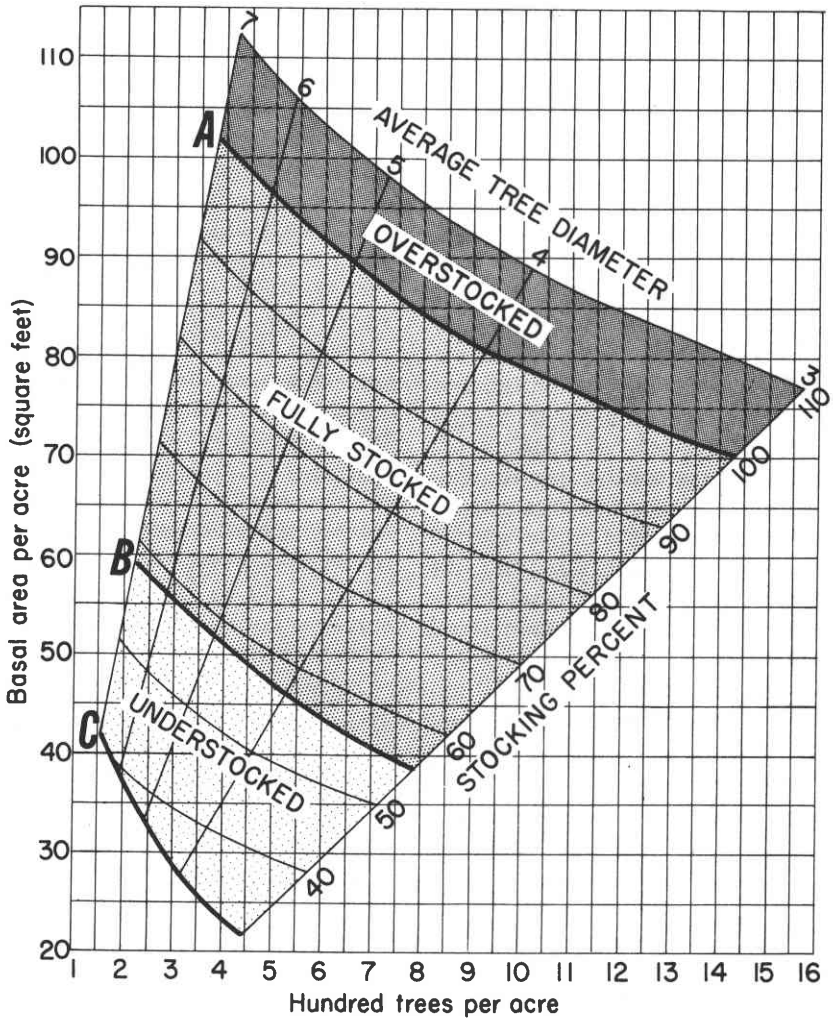


of cutting used or the abuse that a stand undergoes, some assortment of trees quickly occupies the site. The quality of the stocking may be poor in terms of desired species, stand structure, and growth; but nevertheless the site would have to be considered fully occupied.

The processes of natural mortality cause overstocked stands to seek a point of equilibrium that permits better site occupancy of the residual stand. On the other hand, understocked stands quickly reach a point of full site occupancy because natural mortality is low and individual tree growth is high. Unless oak stands are severely damaged by fire, heavy grazing, or insects and disease, they remain in a fully stocked condition. Even heavy cutting will not keep a stand from eventually reaching a fully stocked condition. Actually, from a growth and yield standpoint, overstocking may be more serious than understocking in upland oak stands.

Thus if stocking is based only on the site being occupied by trees, most oak stands would have to be considered fully stocked.

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. (Average tree diameter is the diameter of the tree of average basal area.)



But growth and yield depend on the type and quality of trees that comprise the stocking. In this respect most oak stands are under-stocked. A living cull tree of a given diameter will utilize the same amount of growing space and offer the same competition as a desirable tree. To remove such trees might temporarily leave the stand understocked in terms of site occupancy. To leave such trees affects the growth potential and yield of the stand. This is the present dilemma about stocking of the oak forests.

Stocking standards have been established for oak stands. These standards define the range of stocking within which the growing space is fully utilized. The upper range of stocking was determined from a study of fully stocked stands that have had no record of fire, cutting, or other disturbances that would have influenced stocking. From this study we were able to determine the minimum space a tree of a given diameter needs to survive.

The lower range of stocking was determined from a study of open-grown trees where competition was not a factor in the

site. Favoring this type of tree in the thinning will produce higher volume growth returns.

Our research has shown that the quality of the site as measured by site index has only a minor effect on the diameter growth rate of oaks. Within the upland oak species there are differences in diameter growth rates. Scarlet oak and northern red oak are the fastest growers, black oak is intermediate, and northern white and chestnut are the slowest. Also, there are strong species-site interactions in which the faster growing oaks are more predominant on the higher quality sites. This relationship, together with the influence of site quality on tree height, is the major factor that contributes to the higher volume growth and yield on good sites.

BASAL AREA GROWTH

Basal-area growth in even-aged upland oak stands varies greatly with stand age. In young stands less than 20 years of age net basal-area growth per acre will average about 4 square feet per acre per year. As stand age increases, net basal-area growth decreases. At age 70, net basal-area growth per acre per year is less than 1 square foot. Estimates of net basal-area growth are useful in establishing the optimum stocking for maximum growth and site utilization. Table 3 shows the relationship of net basal-area growth to stocking percent and stand age. Maximum net basal-area growth obtained between 50 and 60 percent stocking; the recommended residual stocking increases with stand age.

Our research has shown that net basal-area growth is not influenced by the quality of the site. Net basal-area growth is a function of the average tree size and the number of trees comprising the stocking. Actually, for a given stand age, net basal-area growth may be higher on a poor site than on a good site, because the stocking on the poor site is made up of more trees of a smaller average diameter than the stocking on a good site at the same age.

YIELD

Yield from a forest is generally expressed in terms of products or volumes that can be harvested. The possibilities of producing different kinds and amounts of products are so great that they cannot be fully discussed here. Physical yields from cultural operations in forest management depend on the stand age when thinning begins, the thinning policy used, the quality of the site, and the management objectives. The feasibility of any cultural operation is generally determined by an investment analysis.

The results of one of our growth-and-yield studies involving a planned series of thinnings at a 10-year interval have been recently published *(Gingrich 1971)*. The study showed that one of the most important factors to consider when managing for maximum timber production is the stand age when thinning begins. The yield increase in cubic-foot volume and standard cords when thinning is begun at age 10 is more than 50 percent greater than the yields when thinning is begun at age 60. The latest age to begin thinning, for any significant

Table 3.—*Net basal-area growth per acre per year for even-aged upland oak stands by stocking percent and stand age, in square feet.*

Stand age (years)	Stocking percent								
	20	30	40	50	60	70	80	90	100
20	2.50	2.95	3.15	3.25	3.20	3.10	2.90	2.70	2.40
30	2.15	2.70	2.90	3.00	2.95	2.85	2.60	2.30	1.90
40	1.75	2.20	2.50	2.60	2.55	2.40	2.10	1.75	1.25
50	1.25	1.55	1.80	1.90	1.95	1.80	1.60	1.25	.75
60	.90	1.05	1.15	1.20	1.20	1.10	1.00	.80	.45
70	.50	.65	.80	.85	.90	.85	.70	.55	.35
80	.25	.45	.60	.65	.70	.65	.55	.40	.20

pulpwood production, is between 30 and 40 years, and for sawtimber between 50 and 60 years.

Yields for even-aged upland oak stands are shown in table 4. On all sites, the yield increase from stands that were thinned to a residual stocking of 60 percent at a 10-year interval was at least 25 percent greater than the yield from unthinned stands. In many cases the yield increase was much greater. The cord volume removed by thinning alone is more than 50 percent of the total yield of unthinned stands. The same is true for board-foot volume on the better sites. The cumulative cord yields (34.0) for site 55 when thinning is begun at age 20 are about equal to the normal yields (33.3) from unthinned stands on site 65. The board-foot yield from thinning increases as the site quality increases.

Table 5 is an example of how yield information can be used to obtain silvicultural recommendations. The best option is selected on the basis of the greatest cumulative yield for each site, stand age, and management period. These data show the desirability of early thinnings for all sites where maximum timber production is the objective. In the 40-year management period, the best option for board-foot production is to start thinning on all sites. When pulpwood production is the objective, the best option for stands 40 years and older is to regenerate and thin.

However, for the shorter 20-year management period there are generally two or three options that will produce similar yields, particularly on sites 65 and 75 for stands 30 years and older. Factors other than physical yields may have to be considered in making a decision. However, when a 10-year management period is used in stands that are 30 years and older and never have been thinned, the best option, especially for pulpwood yields, is often to leave stand alone.

These comparisons have ignored economic factors. However, except for this, the recommendations apply to even-aged upland oak stands that are thinned at 10- to

Table 4.—*Yields per acre for even-aged upland oak stands. A comparison of cumulative yields for a 50-year management period when thinnings are started at different ages. Thinning interval = 10 years.*

Stand age when thinning begins (years)	Cumulative yields[1] 50 years later		Volume removed by thinning during period		Yields without thinning	
	Cords[2]	*Bd. ft.*[3]	*Cords*[2]	*Bd. ft.*[3]	*Cords*[2]	*Bd. ft.*[3]
			SITE INDEX 55			
20	34.0	7,350	14.0	1,540	24.4	2,800 (age 70)
40	41.4	11,880	16.6	2,700	26.5	7,000 (age 90)
60	41.8	11,550	19.2	2,970	28.4	8,900 (age 110)
			SITE INDEX 65			
20	42.0	12,600	17.8	3,570	33.3	7,200 (age 70)
40	48.2	14,580	21.6	3,870	37.6	9,100 (age 90)
60	52.2	17,380	25.6	5,610	40.9	10,600 (age 110)
			SITE INDEX 75			
20	57.4	19,880	25.9	6,160	43.0	11,200 (age 70)
40	63.4	24,120	29.7	8,280	49.2	13,400 (age 90)
60	62.7	22,550	29.7	9,020	51.0	14,100 (age 110)

[1] Yields from thinnings + residual stand at end of period.
[2] Includes all trees 4.6 inches in diameter and larger, to a 4-inch top, inside bark.
[3] Includes all trees 10.6 inches in diameter and larger, to an 8.5 inch top, outside bark (International ¼-inch Log Rule).

15-year intervals with a residual stocking of 60 percent, and where maximum timber production is the objective.

SUMMARY

After more than 20 years of USDA Forest Service research on the growth and yield of upland oak forests, we can now confidently make recommendations for the management and culture of oak stands based on the physical yields of timber products.

Whether to thin or not depends on many factors. Most even-aged upland oak stands are overstocked for best growth and yield but are understocked with desirable high-quality trees. Thinning offers a good opportunity for upgrading the quality of the residual stand while at the same time enhancing the growth potential.

The following general thinning guides are applicable to most even-aged upland oak stands:

1. Early thinnings will yield a higher volume return than thinnings that are made in older stands. However, many early thinnings will remove unmerchantable material, and the costs involved must be weighed against the lower volume return from later thinnings.
2. In even-aged upland oak stands, greater volume yields are obtained when thinning is done from below. The dominant stand usually contains the highest vigor trees, the best stems, and the preferred species for the site.
3. A single thinning, unless followed by a planned series of thinnings at 10- to 15-year intervals, is of doubtful value. But if only one thinning is done, it will yield greatest returns, in terms of physical yields, if done at an early age.
4. Species composition does not appear to be an important factor in thinning oak stands. However, there are important species-site interactions. Small increases in yield can be expected by favoring the

Table 5.—Best silvicultural options[1] for previously unthinned stands by stand age and site, based on predicted yields in cords and board feet. Options are: (1) leave stand alone, (2) start thinning, (3) regenerate without future thinnings, and (4) regenerate with thinnings.

Stand age (years)	Site 55		Site 65		Site 75	
	Cords	*Board feet*	*Cords*	*Board feet*	*Cords*	*Board feet*
PERIOD OF MANAGEMENT: 20 YEARS						
10	2	2	2	2	2	2
20	2	2	2	2	2	2
30	2	2	2, 1	2, 1	2	2
40	2, 1	2	1, 2, 4	1, 2	2, 1	1, 2
50	2	2	2, 4, 1	1, 2	2, 1, 4	2, 1
60	2	2, 1	2, 4	2, 1	4, 2, 1	2, 1
PERIOD OF MANAGEMENT: 40 YEARS						
10	2	2	2	2	2	2
20	2	2	2	2	2	2
30	2	2	2, 4	2	2, 4	2
40	2, 4	2	4, 2	2	4, 2	2
50	4	2	4	2	4	2
60	4	2	4	2	4	2

[1] Where two or more options are listed, the physical yields are about equal.

white oak group on sites less than site index 70 and by favoring the red oak group on sites over site index 70. The performance of species other than oaks that are commonly found in upland oak stands is not definitely known except for yellow-poplar. Yellow-poplar grows as fast or faster than the associated oaks on all sites where it maintains a dominant position. Potential stem quality, spacing, and tree vigor are factors that deserve as much and perhaps even more consideration than does species when thinning even-aged oak stands.

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