EVEN-AGED SILVICULTURE FOR UPLAND CENTRAL HARDWOODS

Agriculture Handbook 355

Forest Service
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EVEN-AGED SILVICULTURE FOR UPLAND CENTRAL HARDWOODS

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FOREWORD

Since World War II the U.S. Forest Service has given increased attention to silvicultural research on upland hardwoods in the Eastern and Midwestern States. These upland hardwoods cover more than one-fourth of the commercial forest land in the United States. Most of this acreage is readily accessible to forest industries and to the population centers of the East and Midwest. Some of the finest hardwoods in the world are grown here.

The past practice of selection cutting in overmature and defective stands of these hardwoods has often resulted in a gradual deterioration of both species composition and tree quality for timber production. However, on some special areas of these hardwood forest lands, esthetics, recreation, or other values are more important than timber, and therefore selection cutting may still be the most desirable cutting practice. Long-term timber profits from lands so cut, of course, will almost always be less than timber profits obtained by even-aged management and clear cutting of mature hardwood stands. A careful balancing of all benefits will have to be made in each individual case where there are strong competing demands.

Clear cutting, as a means of reproducing even-aged stands composed of preferred species, has shown great promise as an efficient and productive method of growing timber. The orderly renewal of our forests and the development of thrifty young stands will assure our Nation a continued adequate supply of quality wood products while at the same time increasing the value of the forest resource.

This handbook brings together the results of more than 20 years of research and experience, both public and private, in the culture of upland hardwood stands. Many of the recommendations given have been applied successfully on public and private lands for several years. This handbook is an elaboration and expansion of the Timber Management Guide for Upland Central Hardwoods prepared by the same authors under the former Central States Forest Experiment Station, last issued in December 1962 and revised through 1965.

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Contents

Acknowledgment

Most of the research on which this publication is based was conducted by personnel of the Division of Timber Management Research in the former Central States Forest Experiment Station of the U.S. Forest Service with headquarters at Columbus, Ohio. This research was directed, and to a large extent organized, by A. G. Chapman. Other members of the division also contributed, to an extent that is not adequately shown by mere citations of literature. In addition, personnel of the Division of Timber Management in the Milwaukee, Wis., regional office of the National Forest System, and on the supervisors' staffs of National Forests in Region 9 of the Forest Service made a number of contributions to the text; they also conducted extensive field tests that could not otherwise have been made.

Most of the research pertaining to Ohio was conducted on two experimental forests furnished by the Mead Corporation, which also provided some financial assistance and technical help. Ohio University, Athens, Ohio, and Berea College, Berea, Ky., contributed office space and facilities. Berea College also provided experimental areas, supplies, and field assistants.

The contributions of all are gratefully acknowledged by the authors.

Even-Aged Silviculture for Upland Central Hardwoods

Introduction

This is a guide to silviculture only; it must not be confused with a management plan, for which it is no substitute. In this guide we attempt to specify only the method of treatment that should lead to the most efficient production of timber within the relatively small area of a timber stand. We do not consider here other land uses nor important questions of timber management such as regulation of area or allowable cut, except where these factors influence silvicultural decisions.

The main exception to this limitation is the section on small woodlands, because on small woodlands the usual concept of sustained yield—continuous, relatively uniform yields at short intervals—is rarely feasible. Either the yields are too small or the intervals are too long. In this situation desirable silvicultural objectives will often require modification to make management for timber production practical.

Because the guide was written solely as a guide to efficient timber production, its recommendations should be modified as necessary where other objectives are predominant or where coordination for multiple use requires a sacrifice in timber production to increase benefits from other forest resources: water, wildlife, range, and recreation.

The guide was prepared primarily for practicing foresters—Federal, Extension, State, and private. It is based on silvicultural observations, consultations with experienced forest managers, and research findings. Most of the research cited was conducted on federally and privately owned experimental forests located in the more heavily timbered parts of Ohio, Indiana, Illinois, Iowa, Missouri, and Kentucky. Related literature from other adjacent areas with upland hardwoods which showed closely similar results has been cited where appropriate. However, outside this six-State area, recommendations in this guide should be applied only with caution.

Forest Description

Upland central hardwood types cover more than 27 million acres, two-thirds of all forest land in the Central States (U.S. Forest Service 1965). Even before settlers arrived, the dominant features of these upland forests was their great variety of species. However, two broad associations were distinguishable, primarily in the unglaciated areas, one for dry sites and the other for moist sites.

On the drier sites (the ridges, upper north slopes, and middle and upper south slopes) the forests were made up predominantly of oaks. In Missouri, white and black oaks made up most of the forests with a good representation of blackjack oak, post oak, hickory, shortleaf pine, and an occasional red oak, scarlet oak, or blackgum. On the poorest sites blackjack and post oak comprised the bulk of many stands. In Iowa, bur oak was common.

In the eastern part of the region (Illinois, Indiana, Kentucky, and Ohio), chestnut oak took the place of blackjack and post oak on the poorest sites. Also, the stands had less pine, more red oak, and contained many other species, chiefly beech, sugar maple, yellow-poplar, red maple, ash, and blackgum.

On the moister sites (lower slopes and coves) the mixture generally contained fewer oaks and a greater variety of other species. In Missouri and Iowa white and red oaks were still the most numerous species, but sugar maple and beech were well represented, and a number of other species were common: elm, walnut, ash, hickory, and basswood.

Farther east the mixture was even more heterogeneous. The principal species were beech, yellow-poplar, white oak, and sugar maple. Red oak was common, however, and hickory was usually present. White ash, black oak, walnut, blackgum and red maple occurred frequently. In the easternmost part of the region (Ohio, eastern Kentucky, and adjoining areas), many other species were found, especially basswood, buckeye, hemlock, cucumbertree, and occasionally sycamore and cherry.[1]

[1] For more complete descriptions, see Braun 1950.

Although these two broad associations can be distinguished in general terms, there was rarely a clear dividing line between them. Furthermore, nearly all of the species can survive on most sites in the region, and the present composition of a stand usually depends more on the past history of the area than on site quality. So the present forest types, which are variable mixtures of many species but predominantly oaks (fig. 1), are not necessarily dependable guides to the species best suited to the sites they now occupy.

The species to favor and manage (or to reintroduce) should be selected from those known or believed to have been present originally. Among these species the selection should depend on how fast each species can be expected to grow desirable products compared with other species on that site.

Silvicultural Objective

The objective of the silviculture outlined in this guide is to grow full yields of the highest value products the site can produce in a relatively short time. Presumably most of the volume will be high-quality sawtimber and some veneer trees, but pulpwood and other small products will be obtained from thinnings or may even be the final crop, especially on the poorer sites (Roach 1964).

This objective can be realized by controlling the density and composition of the growing stock through intermediate cuttings scheduled to achieve maximum yield, yet preserving the desired residual stand. Mature stands must be harvested to regenerate the most desired species for the site in adequate numbers. Site preparation or other cultural measures should be applied where necessary.

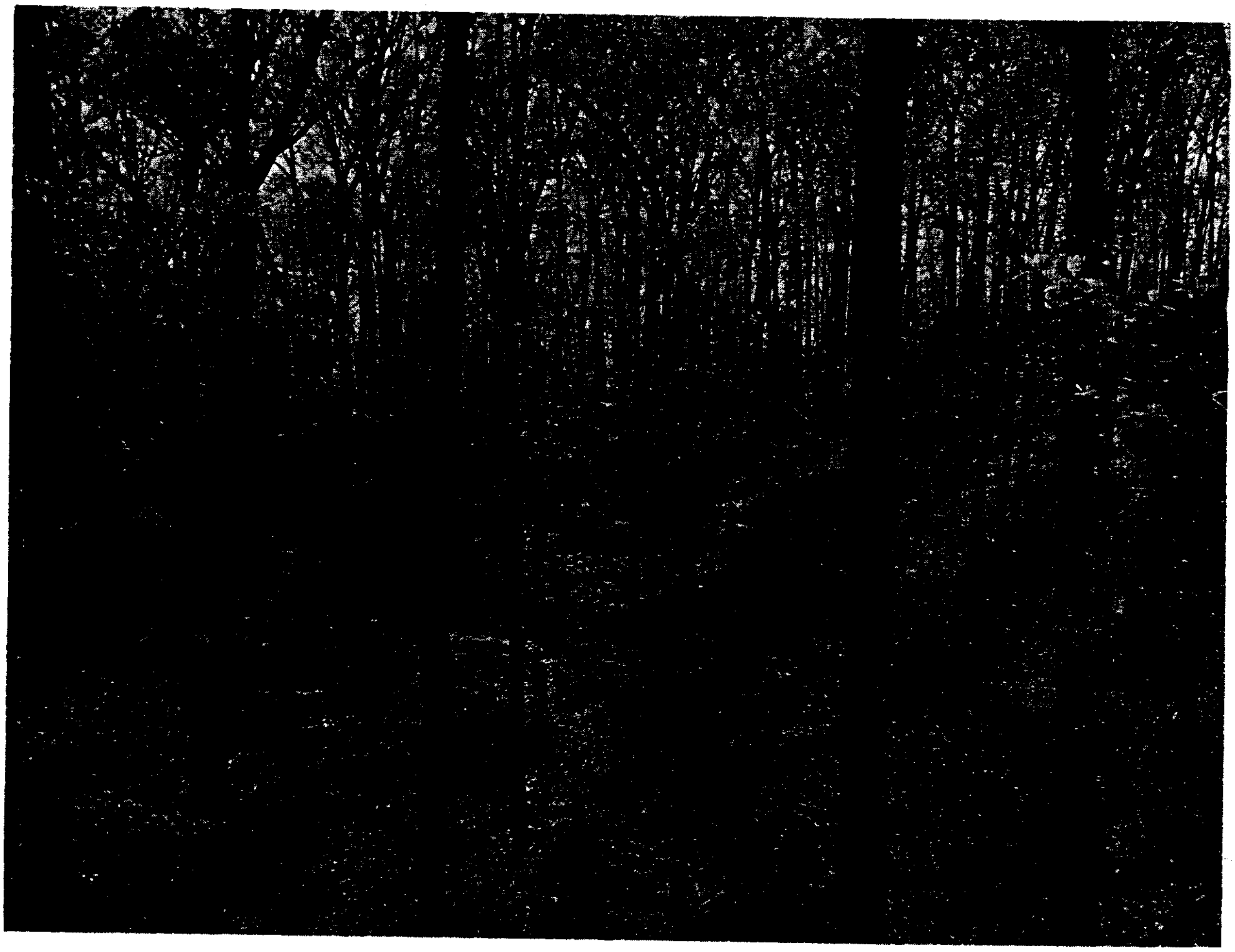

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FIGURE 1.—A good stand of upland central hardwoods. Oaks are the predominant species.

Silvicultural System

Upland central hardwoods should be grown in **even-aged** stands (Roach 1962, 1963). In this silvicultural system two distinct types of cuts are recognized during the rotation: **reproduction** and **intermediate.** The reproduction cut is made only once during a rotation, usually in a mature stand. However, understocked stands or stands with undesirable species may sometimes need a reproduction cut before they are mature to quickly improve composition or achieve full utilization of the site. (An early reproduction cut may also be used to adjust the amount of area occupied by trees of a certain age class, but this has a management objective, not a silvicultural one.)

All other cuts between the time the stand is reproduced and the next harvest cut are intermediate cuts. Intermediate cuts may have several objectives such as improving species composition, releasing desirable trees, and controlling spacing; but reproduction is of no concern during this phase.

(The silviculturist should bear in mind that he is not required to prescribe some kind of cut in every stand he examines. At any given time some stands will be growing satisfactorily in their current condition. The proper treatment for these is to let them alone for a while.)

Reproduction Cuttings

Upland hardwoods cannot be reproduced with satisfactory composition or growth by individual tree selection or by group selection where groups consist of only a few trees (Minckler et al. 1961). Upland hardwoods are best suited to even-aged silviculture.

Clear cuttings should be used for regeneration (Roach 1963, Sander and Clark). At the time of the harvest cut, all trees larger than about 2 inches d.b.h. (or 25 feet tall) must be removed or killed. Frilling and treating with herbicides are much more effective than girdling alone (Ryker and Minckler 1962). If pole-size trees of unwanted species are numerous (20 or more per acre) their stumps should be treated to reduce sprouting, and this work should be done as soon after logging as possible. It is not usually necessary to cut or kill anything smaller than 2 inches d.b.h.; but if many of these smaller stems are cut, the stubs should be treated to prevent sprouting. Desirable reproduction can usually compete with the advance small stems, but it is hard put to compete with new sprouts that develop when the original small stems are cut (fig. 2).

It is important that no trees larger than about 2 inches d.b.h. (or about 25 feet tall) be left after a regeneration cut, regardless of how

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FIGURE 2.—Dense sprout clumps of undesirable species prevent the proper development of more desirable species.

good they may look at the time. If left, these "lonely hearts" invariably deteriorate in quality (fig. 3). Although some will die following exposure (Trimble and Smith 1963) many of them become wolf trees (Roach 1963). If there are enough desirable small trees to provide acceptable stocking, they constitute the main stand. Where scattered larger trees (overwood) are present, they should usually be removed.

Natural regeneration after clear cutting upland hardwoods comes both from seed and from advance reproduction. Perpetuation of oaks and hickory in the new stand depends almost entirely on advance reproduction (Arend and Gysel 1952, Bey 1964, Carvell and Tryon 1961, Kuenzel and McGuire 1942, Liming and Johnston 1944, Sander and Clark, Weitzman and Trimble 1957), which is nearly always present in large number in mature stands, except possibly on the best sites, provided the stands have been protected from grazing.

Advance reproduction is predominantly seedling sprouts: small plants 1 to 8 or 10 feet tall with root systems several years older than the tops (Krajicek 1961, Liming and Johnston 1944, Merz and Boyce 1956, Paulsell 1963). After clear cutting, seedling sprouts usually

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FIGURE 3.—"Lonely hearts" that were left in a clear-cut opening. Many new branches have developed on the boles in the 10 years since the cut was made, thus ruining their future quality. Height growth has been nil.

generate one or more new stems—usually from the root collar, especially if the old stem was broken during logging, but occasionally from part way up the old stem if it was unharmed by logging. These new shoots have excellent form and grow well, quickly surpassing the old stem, which usually dies within a few years. The new seedling sprouts, together with stump sprouts from pole-size stumps, will provide the oak and hickory component in the new stand (Joranson and Kuenzel 1940, Spaeth 1928). Acorns or hickory nuts that germinate during or after a clear cutting provide new seedlings, but growth of the seedlings is slow. Rarely will any new oak or hickory seedlings reach a dominant or codominant position in the rapidly growing new stand.

Yellow-poplars in the new stand come primarily from two sources: seedlings from seed that accumulates in the litter (Clark and Boyce 1964) and stump sprouts from trees removed during the harvest cut. Yellow-poplar stump sprouts grow very rapidly and are usually of acceptable form and quality, but they often arise in multiple-stemmed clumps that will later be difficult to thin. Seedlings are usually much more numerous; they grow very well, although less rapidly than the sprouts, and on average and better sites furnish a good component of yellow-poplar for the new stand (Sander and Clark, Merz and Boyce 1958).

White ash, black cherry, and sassafras usually arise from both advance reproduction and seedlings. Again their seedling sprouts grow more rapidly than the seedlings. Aspen comes in usually as seedlings; but if aspen was present in the old stand, root suckers are numerous. Red maple, sourwood, dogwood, and shrubs usually appear as multiple-stemmed sprout clumps (Sander and Clark).

Since oaks and hickories in the new stand come from advance reproduction, while yellow-poplar, some of the ash, much of the black cherry, and perhaps other species arise from seed already present, there is no need to leave seed trees, to wait for a seed year, or to schedule the regeneration cut after the seeds fall.

There may be a slight disadvantage to cutting in late summer if maximum yellow-poplar is desired, because brush broken during logging will sometimes resprout the same summer while, even if the stored yellow-poplar seeds germinate, some of the seedlings will not become established before winter. Other yellow-poplar seeds will germinate the next spring, but for many of them it will be too late.

However, it has been observed that any reduction of yellow-poplar reproduction from this cause is not sufficient to justify restricting harvest cutting to a particular time of year. Certainly the time of cutting seems to be less important than the prompt killing of residual culls after a regeneration cut, especially if they shade much area. Particularly on good sites, competition between tree reproduction and brush sprouts is severe, but many brush species, being more tolerant, are less affected by a light overstory. If cleanup work after a regeneration cut is delayed 1 year, the brush gains a big advantage and the number of trees is reduced.

Still, regeneration on clear-cut area is nearly always prompt and numerous (Sander and Clark). Such areas are unsightly for a few years (fig. 4), and although brush species, blackberries, and vines may appear to dominate, timber species are numerous and well

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FIGURE 4.—A recent clear-cut area on a good site. The few large stems remaining have been girdled and poisoned.

distributed. By 5 years after the cut, the new timber stand is becoming apparent (fig. 5); by 10 years after the cut, it is clearly evident (figs. 6 and 7).

Intermediate Cuttings

Intermediate cuttings should maintain adequate density in the size class of the main stand—the bulk of the dominant and codominant trees. Whether the stand is strictly even-aged or decidedly uneven-aged makes little difference. In both kinds of stands the structure is surprisingly similar: *unmanaged, even-aged sawtimber stands of upland hardwoods consistently display the wide range of tree diameters that is also characteristic of uneven-aged stands* (Gingrich 1967). *Cutting systems that periodically remove the large trees to encourage the small ones only lengthen rotations,* because most trees thus promoted to crop trees have grown so slowly for much of their lives that they are not vigorous enough to respond efficiently.

The objective should be not to lengthen rotations but to grow, as rapidly as is consistent with quality, enough crop trees to provide a fully stocked stand at maturity, together with enough other trees to provide trainers, intermediate products, and a pool from which to select crop trees. In managed even-aged stands this means choosing crop trees from the upper half of the diameter range. In many present stands it means conserving and favoring the most prominent size class. Trees much larger than those of the main stand should be removed; trees much smaller should be discriminated against by leaving a dense enough main stand to fully occupy the site.

In deciding when and how to make an intermediate cut, decide first on the stand that should be left, then cut to achieve it. Reproduction is of no concern at this time and cutting

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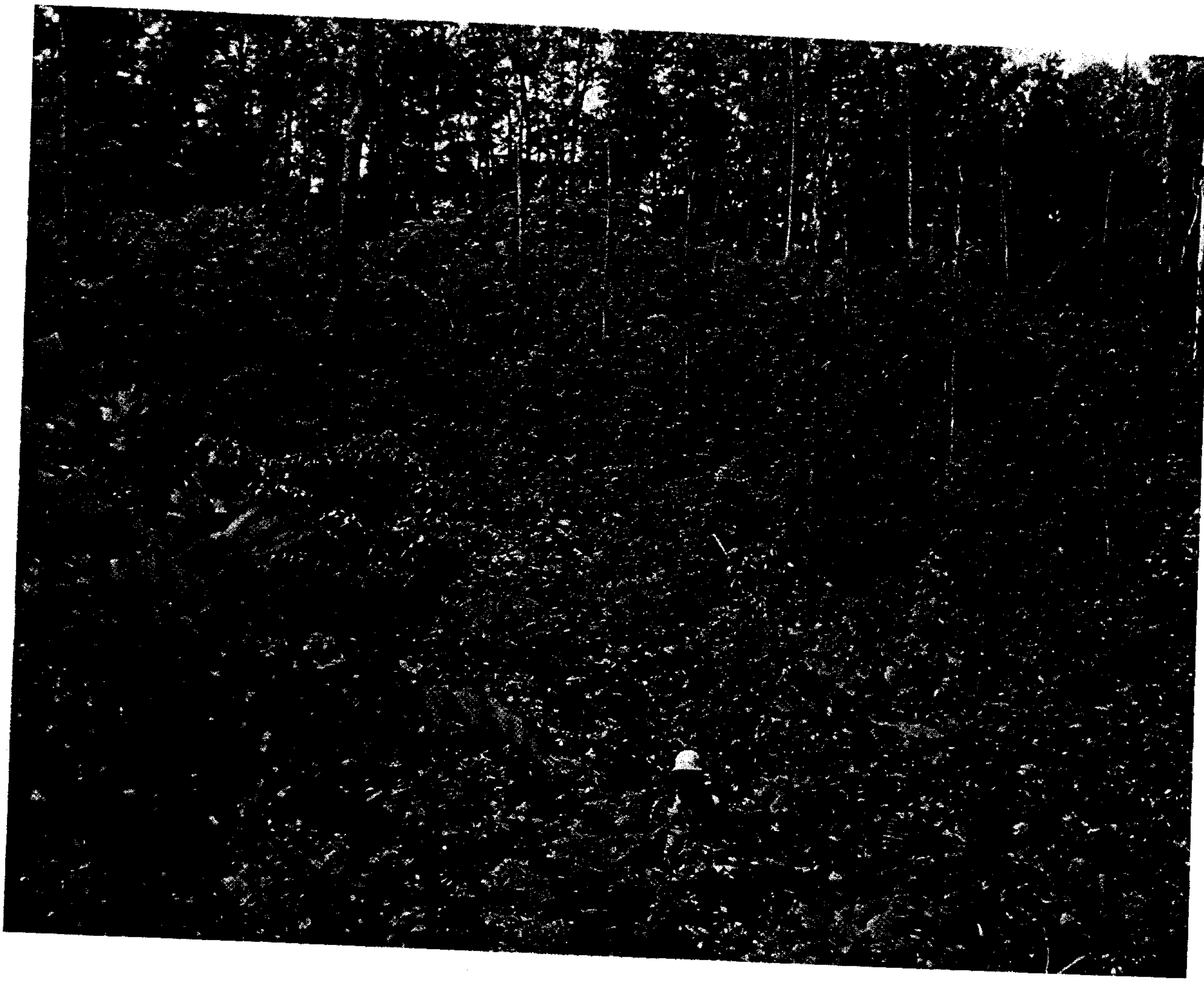

FIGURE 5.—The same area as figure 4 five years after clear cutting. Some of the girdled trees still remain but many have fallen.

with due attention to spacing should provide the basis for picking trees to be left.

The major effort toward improving stand composition should be made when stands are of sapling size (trees 1 to 2 inches in diameter) (fig. 8). Stands that have fewer than 200 well-spaced stems per acre of desirable species in a dominant position should be cleaned. But do not attempt to eliminate all undesirable stems. Instead, select potential crop 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. In general, don't select suppressed or poor intermediates for crop trees unless they are the only available representatives of the species desired. The smaller the tree, the slower its response, the more release it requires, and the more likely it is to need another release later (Walters 1963, Williams 1964).

However, cleanings are expensive and the cost must be carried for long periods at compound interest. High priority should be given to cleanings on the best sites where good possibilities exist to increase the yield of high-value species and high-value products in the final crop. On poor sites there are few high-value species to begin with, and there is even less chance to grow large, high-value trees in practical rotations.

Where pulpwood markets exist, cultural treatment for many young stands may be delayed until a light commercial thinning can be made (25 to 30 years on average sites). Even if returns do not quite equal costs, however, this thinning should be applied because such stands will have been 100-percent stocked for some time and diameter growth will be slowing down. This thinning is a compromise; its object is not to gain a temporary profit, but to provide growing space for the residual trees.

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FIGURE 6.—Well-established 10-year-old sapling stand regenerated by clear cutting on a good site—oak site index 75.

It allows these residual trees to maintain or increase their diameter growth and will improve quality and species composition without the greater earlier expense of a cleaning.

This first thinning should remove any fast-growing trees that show a tendency to become wolf trees, especially trees of undesirable species and poorly formed stump sprouts. If composition is otherwise adequate, additional trees will need to be cut only to improve spacing among the dominants, codominants, and perhaps the better intermediates. It is important that enough good, well-spaced dominant and codominant trees be left to provide good stocking. Thinnings must never spoil the main stand, and the first thinning, even if scheduled as an economic compromise, is no exception. Never select suppressed or poor intermediates for crop trees in pole stands.

If short rotations are required, however, the first thinning should not be delayed beyond the time when the stand averages about 3 inches d.b.h. (20 to 30 years) even if no market exists for small products. Failure to thin early lengthens the rotation.

The first thinning is only the beginning. Periodic thinnings are required thereafter to keep crop trees growing rapidly. However, no thinning should reduce stand density to a point where the site cannot be fully utilized. Cutting to lower densities wastes growing space, encourages a tolerant understory, and reduces quality by lowering the crowns of crop trees (fig. 9). Even light thinnings, of course, reduce competition for growing space, thereby lessening the effectiveness of natural pruning. Whether a tree has many or few branches seems to be partly determined by genetics and partly by its growth rate as well as the degree of competition. Therefore, in selecting crop trees *favor the cleanest, fastest growing stems* where possible.

Thinnings and improvement cuts should not be continued indefinitely. Since crop trees

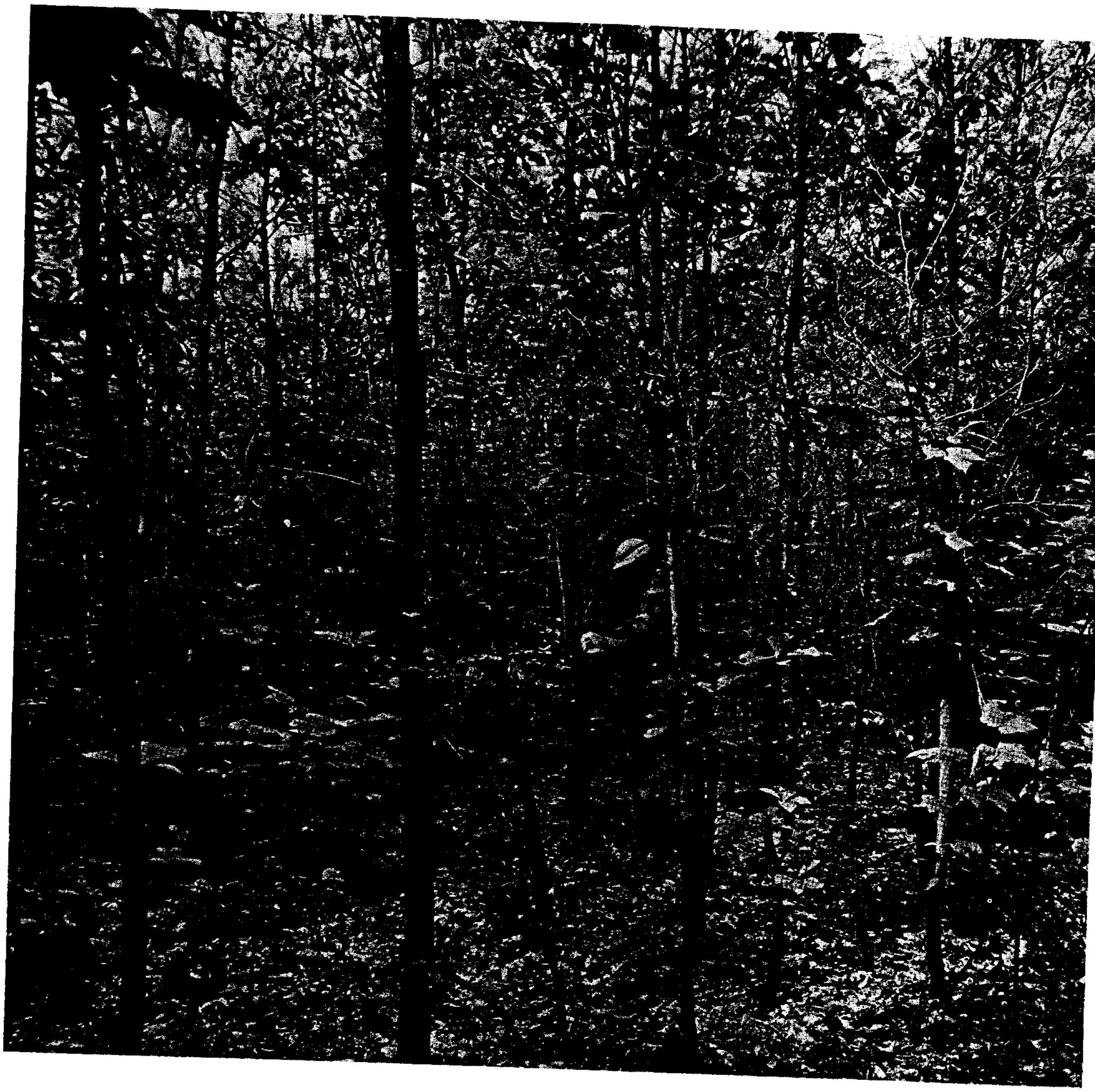

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FIGURE 7.—Well-established sapling stand 10 years after clear cutting on a poor site—oak site index 45.

should be spaced to fully use the area, maintaining their growth requires that the effects of a thinning be distributed to all parts of the stand. When trees become large, or when cutting to the lowest permissible level of stocking removes only a few trees per acre, relatively few trees in the residual stand will be benefited. For example, cutting only a few trees per acre could remove the periodic growth of the stand but would release only a few trees and thereby defeat the purpose of thinning. A practical guide is to complete stocking-control cuttings by the time a stand has reached about three-fourths of rotation age.[2] For oaks the stop-thinning age is about 60 to 70 years on medium sites, and less on better sites (fig. 10). Thinning *may* be called for in *previously unthinned* stands approaching this age because crop trees will be much smaller in diameter than in stands of the same age that have been thinned regularly. Response will be slow, but mortality of desirable stems will be reduced.

[2] Personal correspondence from Donald J. Morriss, U.S. Forest Service, Washington, D.C.

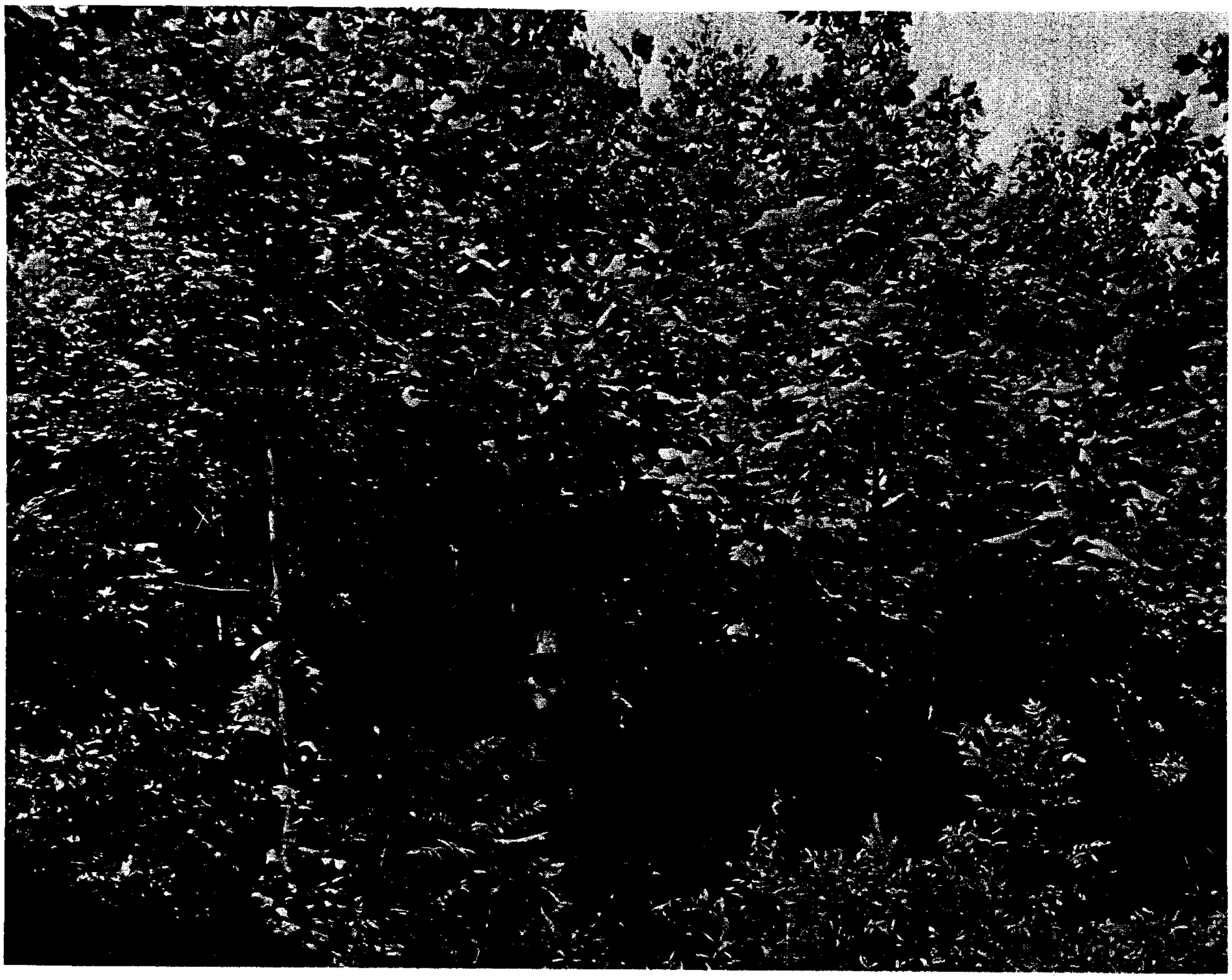

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FIGURE 8.—Dense sapling stands are prime candidates for improving species composition through clearings. Many potential crop trees begin to show their superiority at this time.

Selecting Cutting Areas

The silvicultural system merely outlines the principles of cutting under which certain products are grown over large areas of forest type. But a silviculturist cannot manage a forest type all at once; he has to work with one stand at a time. The first thing he must decide is what areas he will consider and treat as separate stands.

Uniformity of stand conditions throughout an area has usually been the primary basis for setting stand boundaries. This is because timber cutting is the major tool of silviculture, and the kind of cut to apply depends on conditions within the stand. Thus the more uniform the stand, the easier it is to prescribe the proper cut, and the more accurate the prescription.

Site quality should be considered too. If a stand covers a wide range of site quality, it will also contain a wide range of growth rates, and probably of species composition. Sooner or later a single kind of cut will no longer be applicable in all parts of the stand. So stand boundaries should preferably be restricted to relatively uniform site conditions.

These two factors, the desirability of uniform stand conditions and uniform site quality, tend to keep stands small. There are other silvicultural factors that tend to encourage large stands.

Sooner or later a stand matures and will be clear cut for regeneration. When this occurs, a period will follow in which the stand is simply an opening in the forest filling with reproduction. For achieving adequate regeneration of upland hardwoods, there seems to be no silvicultural reason to place an upper limit to the

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FIGURE 9.—This mixed-oak sawtimber stand was thinned too severely, causing an undesirable tolerant understory to develop. The quality of the residual trees has declined, with too much branching.

size of opening that may be made: 40-acre clear cuts have regenerated as quickly and completely as 1-acre clear cuts (Sander and Clark). However, there are silvicultural limits to the minimum size that is practical.

Residual trees around the edge of an opening develop many new branches and lose quality (fig. 11). Since the larger the opening, the smaller its perimeter is in relation to the area exposed, fewer trees will be affected by branching around one large opening than around several smaller ones with the same total area (table 1).

Also, a zone affected by surrounding stands exists along the edge of an opening (fig. 11). The width of this border zone varies, but commonly ranges between 10 and 20 feet. The percentage of an area occupied by zones of these widths increases very rapidly as opening size is reduced below about 2 acres (fig. 12). Because reproduction grows slowly in the border zone, average growth rate will be low and a longer rotation will be necessary if there are many small openings or if there are many long narrow ones.

TABLE 1.—*The perimeter exposed by different size circular openings totaling 10 acres*

Number of openings	Opening size	Total circumference
	Acres	*Feet*
2	5	3,310
5	2	5,230
10	1	7,395
20	½	10,470

Several management factors should also be considered in setting stand boundaries.

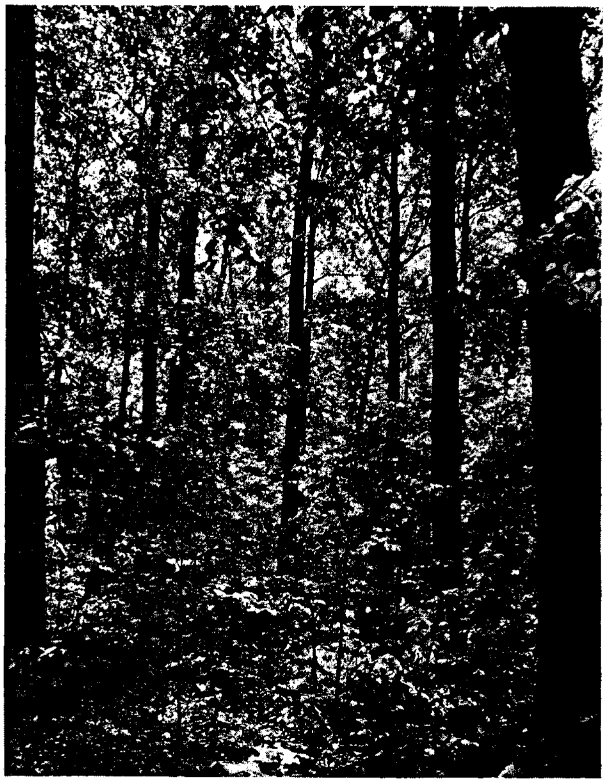

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FIGURE 10.—This stand is too old to thin. The quality and species composition of this stand cannot be altered significantly and the residual trees will respond little to thinning.

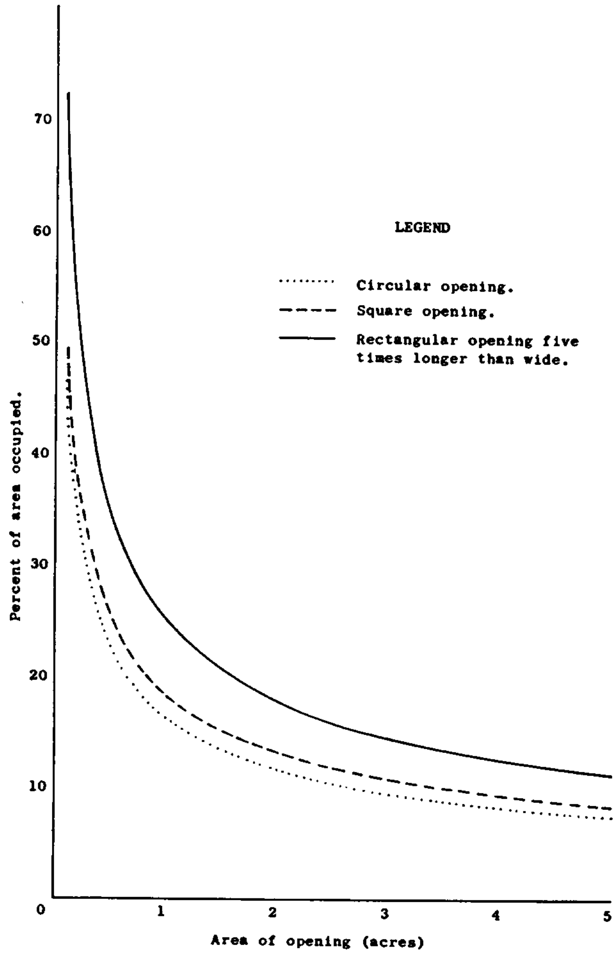

FIGURE 12.—The percent of a clear-cut opening that would be occupied by a border zone 10 feet wide.

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FIGURE 11.—Excessive branches develop on the lower bole of trees that are left around the permieter of a clear-cut opening. Note also that the new reproduction is shorter near the edge of the opening.

Although they may seem out of place in a silvicultural guide, they are too important from an economic standpoint to ignore.

1. The first of these factors is access. If stand boundaries are based only on silvicultural considerations, it is easy to end up with many little stands, some of which will inevitably be found tucked away in odd corners of the tract, and no road nearby. Small stands yield small volumes and won't pay for much roadbuilding. There is no use singling out these stands on the basis of intensive silviculture if they cannot be reached economically to provide the periodic treatments they will require. They should be included as parts of adjacent stands and treated when the surrounding area is treated.

2. Another factor is the tendency for stands to become permanent cutting areas for future management. Of course, the present decision about stand boundaries is not irrevocable. During the next cut large stands may be subdivided and similar adjacent stands may be combined. But as time passes, repeated cuts will usually accentuate the differences that caused the stands to be designated separately in the first place, and later adjustments of stand boundaries will be increasingly difficult. From the very beginning, stands should be designed to provide workable size units for the future. They must be at least large enough to detect on maps of common scale (fig. 13).

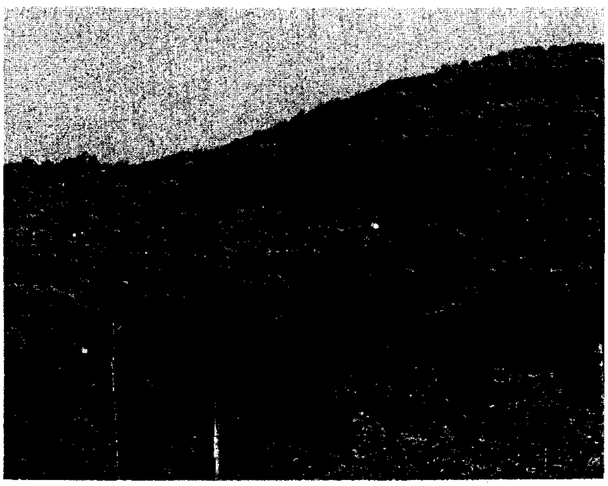

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FIGURE 13.—A view of a recent 3-acre clear-cut opening. Openings of this size and larger can readily be mapped and will provide a good record for management control.

3. Finally, the size of the whole tract will influence stand size. In a 40-acre woodland it is not difficult to keep track of 1-acre stands. Obviously, it is a different story on a 50,000-acre property. Not only will a large number of small stands make control difficult and expensive; it will also limit the efficiency and usefulness of large equipment and mechanization.

There is no "optimum" size of stand to fit all conditions and tract sizes. Compromises are inevitable. On large properties and where deer populations are heavy, individual stands may be 50 acres or more, provided they are not so large that they cannot be conveniently laid out and treated.

In the broken topography of the Central States, such large stands will contain a wide range of site quality and normally a variety of stand conditions. Silvicultural prescriptions, especially for intermediate cuttings, will be imprecise and correspondingly difficult to apply. On small properties and where deer are little threat to tree reproduction, stands may be as small as 1 or 2 acres. Operating costs will be higher in small scattered stands; average quality will be somewhat lower because of increased branching; and the lower average growth rate will probably require slightly longer rotations.

In laying out stand or cutting-area boundaries, first decide on the probable size of stand that will conveniently fit a practical level of management for the property. Then make a careful stereoscopic examination of aerial photos of the tract. After some experience you will be able to distinguish among many different stand conditions directly from the photos. Stereoscopic examination will also reveal topographic features, which are good guides to both site quality and probable access routes to individual stands.

With these factors in mind, draw tentative stand boundaries on the photos. Try to restrict each stand to a single condition class of timber, but keep the area of each stand within the limits previously decided. If relatively large stands are desired, it will not often be possible to restrict each one to a single condition class, but it is a goal to work toward. When the stands are examined in the field, take the photos along and make any necessary adjustments in boundaries at that time.

This procedure will save much time. It will also reduce the number of small or odd-shaped stands, often inaccessible, that are likely to result from a field examination alone.

Site-Species Relations

The purpose of silviculture is to grow the greatest amount of the desired products as quickly as possible. The species, its yield, and the rate at which it grows are all influenced by the quality of the site. Therefore, after he has selected his stand or cutting area, the silviculturist must decided its **site quality.** This will serve as a guide in deciding what species to favor in the area and what rotation objective to set; both of these things are necessary before an appropriate treatment can be determined.

Three broad site classes have been established and the species have been recommended for each (table 2). Site indexes are for black oak because more is known about soil-site relations for black oak (tables 3 and 4) than for any other species in the region, and because it is one of the most common and widely distributed trees (Carmean 1961, 1965, 1966). Species recommendations are generalities and should be modified as desired to fit local markets. Preferred species should be those that grow rapidly to rotation diameter on the site, produce high-value products, and have a consistently dependable market.

Site Class 75+

(Black oak site index of 75 feet or more)

These sites are found on lower slopes and in coves (fig. 14), and on many north and east-

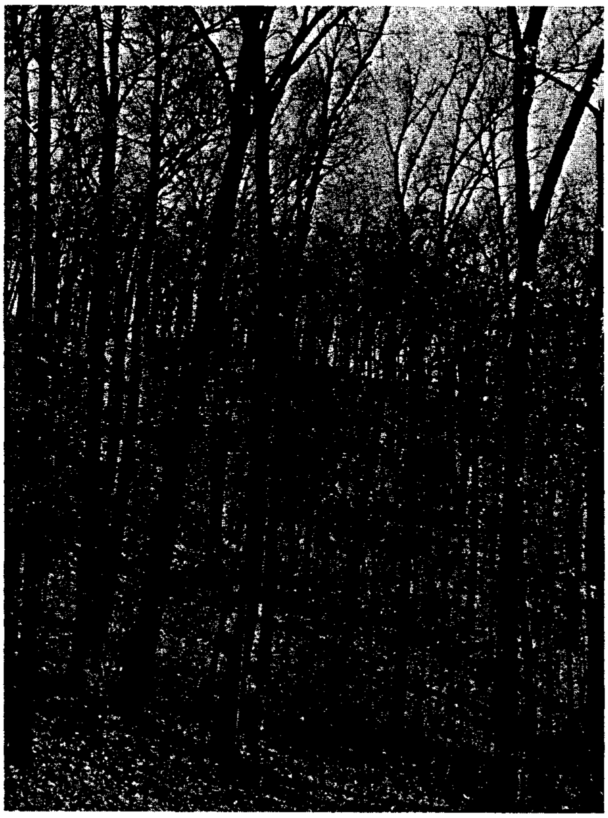

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FIGURE 14.—A good site for mixed hardwoods. This stand is on a lower concave slope with a southeast aspect. Mature trees will range from 100 to 120 feet in height. (Note man in foreground.)

TABLE 2.—*Site-species recommendations*

Preferred species	Satisfactory species	Species undesirable as crop trees[1]
SITE CLASS 75+ (Black oak site index 75 feet and over)		
Yellow-poplar	Black oak	Beech
Northern red oak	Scarlet oak	Maples
Black walnut	Black cherry	Hickory
White oak	Sycamore	Blackgum
	White ash	Buckeye
	Basswood	
	Sweetgum	
	Hemlock	
SITE CLASS 55–74 (Black oak site index 55 to 74 feet)		
Yellow-poplar	Scarlet oak	Beech
Northern red oak	Chestnut oak	Maples
White oak	Sycamore	Hickory
Black oak	White ash (better sites)	Blackgum
		Elms
	Black walnut (better sites)	Post oak
	Aspen	
	Shortleaf pine	
SITE CLASS 40–54 (Black oak site index 40 to 54 feet)		
Black oak	White oak	Beech
Scarlet oak	Aspen	Maples
Chestnut oak	Pitch pine (poorest sites)	Blackgum
Shortleaf pine		Elms
	Virginia pine (poorest sites)	Sourwood
		Black cherry
	Yellow-poplar (better sites only)	Ash
		Post oak
		Blackjack oak
		Sycamore
		Hickory

[1] Where special markets exist—for example, blackgum for container veneer or red maple for furniture squares—any of these species may be satisfactory.

middle slopes. Surface soils are deep (A horizon at least 7 inches), loose, and well drained, and contain much organic matter. Indicator plants that help to identify good sites include black snakeroot, wild hydrangea, beggarticks, rattlesnake fern, false Solomon's seal, trillium, wild geranium and broadleaf sedge.

East of the Mississippi River yellow-poplar is easy to reproduce on these sites, and pure stands are feasible because enough good yellow-poplar seedlings will outstrip competition to provide a fully stocked stand at maturity. The species will generally take care of itself until old enough to require thinning, at which time the faster growing sprouts of other species can be removed.

A seed source is required, of course, but there is no need to wait for a seed year or to cut at any particular time of year. Yellow-

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TABLE 3.—*Predicted site index for black oak growing on medium-textured, well-drained upland soil (Muskingum, Montevallo, Berks, Wellston, Gilpin, Lite, Dekalb, Hartsells, Neotoma, Chillicothe, and Pope series) in southeastern Ohio*[1]

Slope position	Depth of A_1 and A_2 horizons (inches)				
	< 2.0	2.1-3.0	3.1-5.0	5.1-8.0	> 8.0
Ridges	55	59	64	68	73
Upper third	57	62	67	72	77
Middle third	60	65	70	75	80
Lower third	62	67	73	78	83
Bottom	67	72	78	83	89

[1] Adapted from Carmean 1966.

Corrections:

Aspect.—Ridges and bottoms are assigned no aspect. For positions on slope the values given are for aspects ranging from southeast through northwest (azimuths between 124° and 328°). For NNW (328° to 355°) and ESE (95° to 124°) aspects, add 2 feet. For the northeast quarter (355° to 95°) add 4 feet.

Slope shape.—Values are for straight slopes. For convex slopes subtract 2 feet; for concave slopes add 2 feet.

Slope steepness.—For slopes greater than 30 percent, subtract 3 feet.

poplar seeds that have accumulated in the litter are nearly always adequate to provide a fully stocked stand (Clark and Boyce 1964). If a seed source is lacking, yellow-poplar seedlings may be planted in the openings made by harvest cutting, but they must be planted the first spring after cutting and they may need later release from competing vegetation.

Black walnut is scarce and should be established by planting large, well-balanced seedlings in some of the clear-cut openings as soon after logging as planting conditions permit (Williams 1965, Boyce 1966). If red oak is scarce in the overstory, seedlings may be planted at the same time as the walnut. However, because pure stands of either species are not feasible on already forested sites, the goal should be to provide only a good representation of both in the final stand. Planting site preparation and later cleanings will be needed for both species; if these treatments are not planned and performed, planting will be a waste of money.

Oak advance reproduction may be sparse on these sites. If many oaks are desired in the next stand, the amount of dominant oak reproduction in the new stand may be increased by cutting some stems (especially those 1 to 2 inches in diameter) of advance oak reproduction by a slanting ax cut as near the ground as possible. Usually within a year well-formed, rapidly growing sprouts develop (fig. 15).

These sites should produce 24- to 28-inch sawtimber on a 60- to 75-year rotation if crop-tree growth is maintained by regular thinnings.

Site Class 55 to 74

(Black oak site index of 55 to 74)

These medium sites occupy most midslopes, upper north slopes, many lower south slopes, and many broad ridges with deep, well-drained soil; the A horizon is usually 3 to 7 inches in depth. Most of the upland hardwood area in the Central States is medium site (fig. 16).

In the East, yellow-poplar reproduces (assuming a satisfactory seed source) and maintains itself well. Most of the associated reproduction will be oak but there will be a good mixture of other species, especially on the better sites. Under management the amount of yellow-poplar and other desirable species will increase, but on the upper slopes oaks

TABLE 4.—*Predicted site index for black oak growing on fine-textured upland soils with restricted internal drainage (Rarden, Coolville, Keene, Upshur, and Lathem soil series) in southeastern Ohio*[1]

Texture of upper subsoil (B_1 horizon)	Slope shape	Depth of A_1 + A_2 horizons (inches)							
		Less than 1.5	1.6–2.5	2.6–3.5	3.6–4.5	4.6–5.5	5.6–6.5	6.6–7.5	More than 7.6
Fine-textured clays (less than 30% silt)	Convex[2]	45	49	52	56	61	65	70	76
	Linear	47	51	55	59	63	68	74	79
	Concave[3]	50	53	57	62	67	72	77	83
Light-textured clays (30–40% silt)	Convex[2]	53	56	59	62	65	69	73	77
	Linear	56	59	62	65	69	72	76	80
	Concave[3]	58	61	65	68	72	76	80	84
Silty clays, silty clay loams, clay loams (more than 40% silt)	Convex[2]	58	61	63	66	69	71	74	77
	Linear	61	64	66	69	72	75	78	81
	Concave[3]	64	67	70	72	75	78	82	85

[1] Adapted from Carmean 1966. [2] Usually ridges and upper slopes. [3] Usually lower slopes and midslopes.

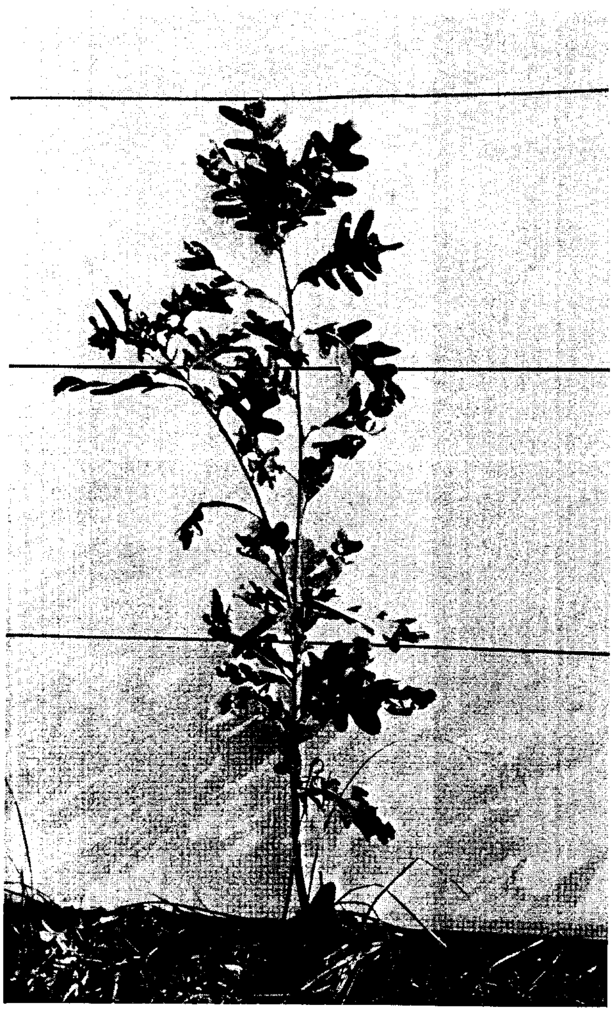

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FIGURE 15.—This white oak seedling sprout developed in 1 year after the old poorly formed stem was cut off at the ground.

will nearly always form the bulk of the stand.

In the West, white oak, black oak, and red oak will comprise most of the stand. Walnut should be favored on the better sites.

On medium sites it seems feasible to produce 20- to 24-inch crop trees on a 75- to 90-year rotation with proper thinning.

Site Class 40 to 54

(Black oak site index of 40 to 54)

These sites occupy upper south slopes; dry, rocky or cherty ridges; and ridges that have shallow, heavy-textured soils with poor internal drainage. Depth of the A horizon is usually less than 3 inches. Typical understory vegetation includes dryland blueberry, dittany, povertygrass, pussytoes, New Jersey tea, cinquefoil, hawkweed, and wild rose.

These sites belong almost exclusively to the oaks (fig. 17). Yellow-poplar may increase with management on the better poor sites, but it should not be relied upon for final crop trees because one or two unusually dry summers will kill much of it. On the poorest sites, shortleaf and pitch pines may increase and should be favored, although it is questionable whether pine growth and value will be enough greater than other species to justify the cost of converting to pure pine by planting. Planted pines will need to be released from sprout competition at least once and perhaps several times (Minckler and Ryker 1959, Walters 1959).

In Missouri, shortleaf pine will increase and should be favored. Conversion to pine or pine-oak is often feasible.

Cultural work on these sites should be limited. On the poorest sites, stands should be treated primarily as protection forests. When they provide a commercial harvest, consider it a bonus. Cultural work should be limited to killing "lonely hearts" during regeneration cuts, or, in Missouri, aerial spraying of herbicides to promote or release pine reproduction.

If markets for pulpwood exist, the poorest sites should probably be managed on a rotation of 50 to 60 years; on the better sites this rotation may be shortened to 40 or 50 years. Sixteen- to 18-inch sawtimber will take 90 to 120 years with adequate thinning.

Stand Densities

After the cutting area has been selected and the most suitable species and rotation objective decided for it, the condition of the present stand must be determined. The first consideration is stocking. How efficiently is the stand using the area it occupies? The answer requires a familiarity with stocking standards or appropriate stand densities.

Basal area has long been one of the best measures of density available, but it doesn't tell the whole story by itself. For example, describing a stand as containing 50 square feet of basal area per acre does not reveal whether it is a small pole stand or a sawtimber stand. If the former, it may be well stocked; if the latter, it is understocked. Density of stocking is adequately described, therefore, only if both basal area and average tree size are known.

Study of the structure of central hardwood

F-517735

FIGURE 16.—A typical young stand of upland hardwoods on a *medium* site. This is the predominant site class for upland hardwoods in the Central States.

stands shows that differences in tree size may be compensated for by using **number of trees per acre** along with basal area to denote stocking. This is convenient because basal area and number of trees per acre are both easy to determine in the field while average tree size is not. Furthermore, the estimate of stocking will not be influenced by the age of the stand and the quality of the site.

Stocking standards were developed (Gingrich 1967) so that, knowing number of trees per acre and basal area per acre, one can read the percent stocking and average tree diameter directly from the graph (fig. 18). This graph shows how completely a particular stand is occupying its area and also how much of the stand may be removed without wasting growing space.

Upland central hardwoods can be grown at a wide range of stand desinties and still fully utilize the growing space. Total growth *per acre* will be about equal for stands of similar site and species composition falling anywhere between the *A* and *B* lines on figure 18. However, diameter growth of *individual trees* will vary greatly within this density range; the fastest diameter growth will occur in stands near the minimum density required for full site utilization—about 58 per cent of full stocking (curve *B*).

At the *B* level, with proper spacing, each tree presumably has all the growing space it can use (fig. 19). Thus at lower densities some growing space is wasted and the growth of products will be reduced. Moreover, extensive branching reduces the quality of residual trees, and reproduction and brush develop in a heavy understory.

On the other hand, in stands with stocking greater than 100 percent, individual trees grow slowly, natural mortality is excessive, and stocking comes gradually down to the *A* level (or comes down quickly during the next dry summer).

The *C* line on the chart shows the stocking necessary for a stand to reach *B* level (or full site utilization) within 10 years on site class 55 to 74. On better sites the time interval between *C*- and *B*-level stocking is only 5 to 8 years; on poorer sites 12 to 15 years. The *C* line is thus a reference point useful in predicting how long it will be before a stand efficiently occupies its area.

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FIGURE 17.—Upland hardwoods on a *poor* site.

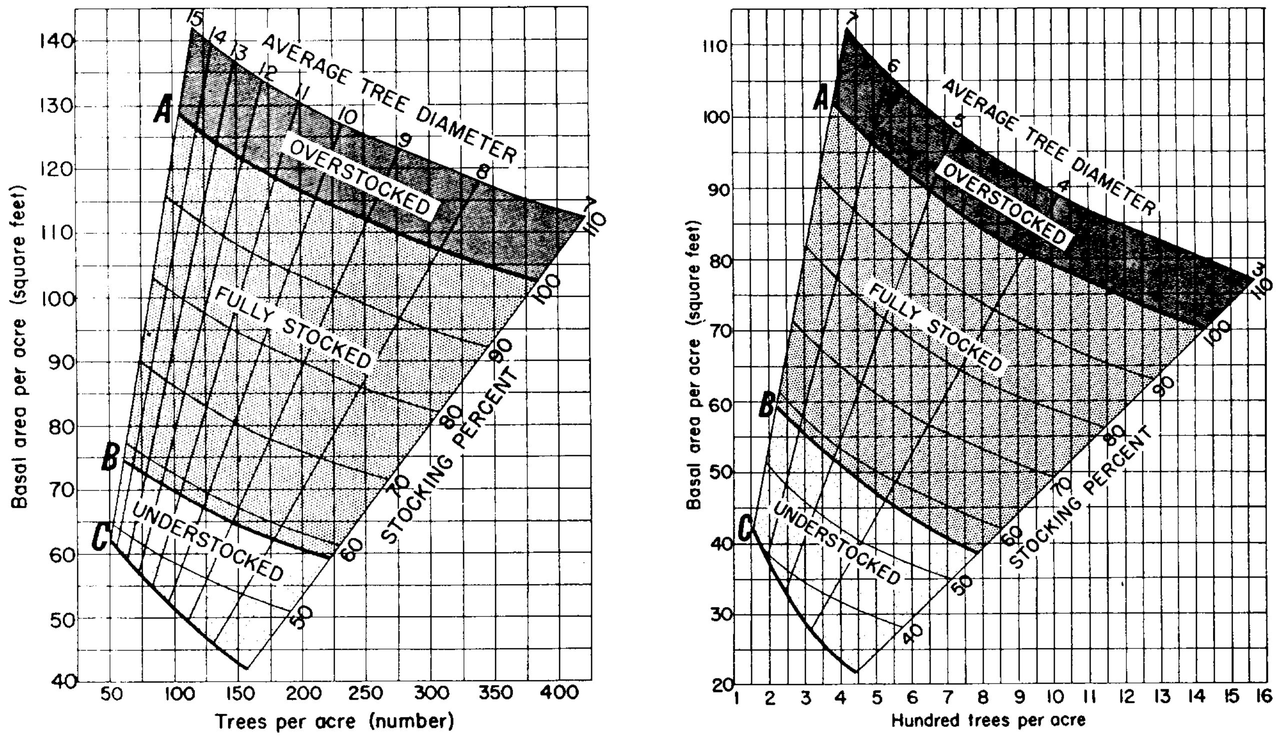

FIGURE 18.—Relation of basal area, number of trees, and average tree diameter to stocking percentage for upland central hardwoods. Tree-diameter range is 7–15 inches in chart at left; 3–7 inches in chart at right. The area between curves *A* and *B* on both charts indicates the range of stocking where trees can fully utilize the growing space. 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.)

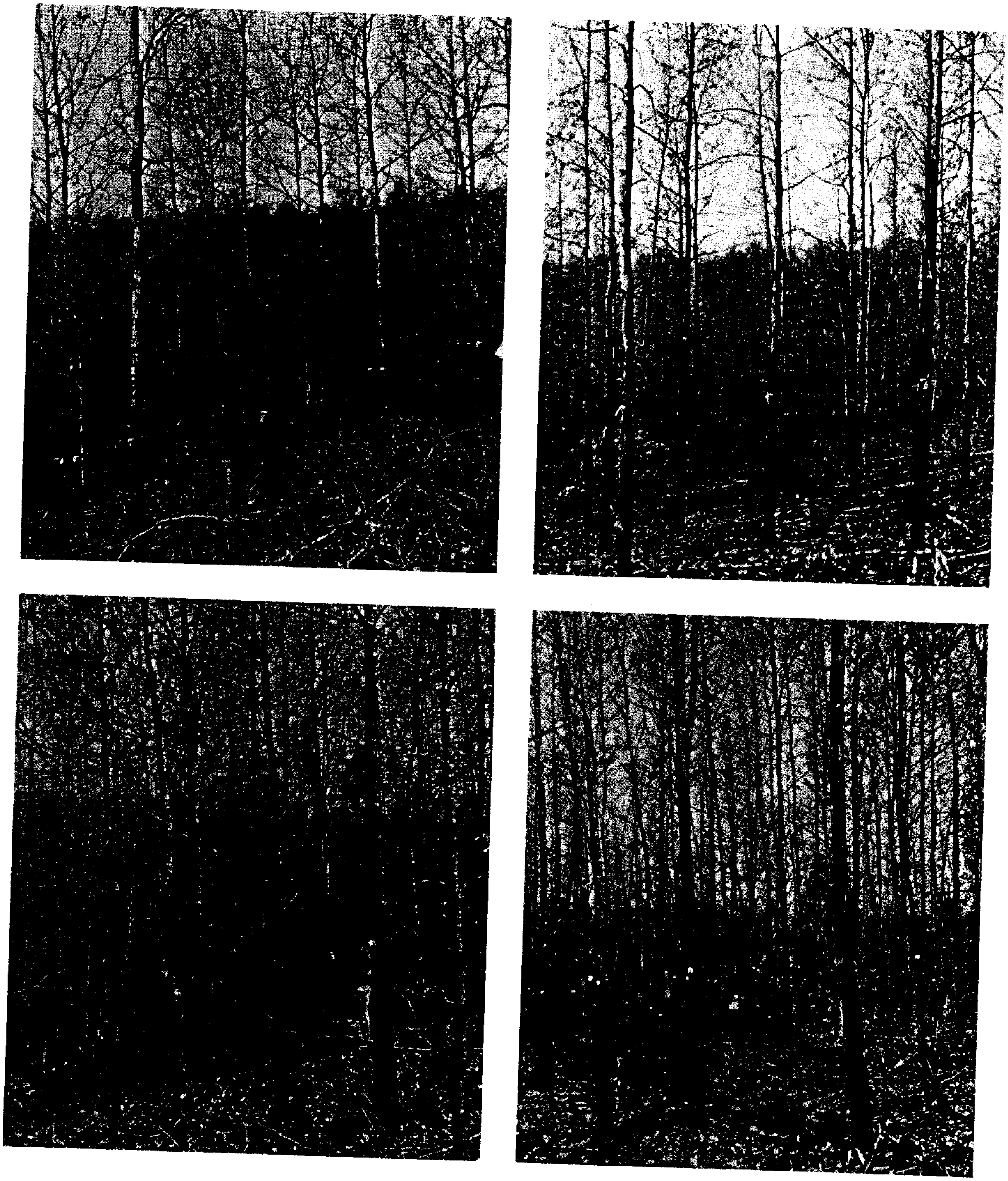

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FIGURE 19.—Small pole stands showing four levels of stocking: *Upper left, A,* an understocked stand (30 percent stocking); *upper right, B,* stand near "B" level (55 percent stocking); *lower left, C,* stand at 70 percent stocking; *lower right, D,* stand near the maximum level of stocking (95 percent).

Stand Inventory

To compare the stocking of his stand with the stocking standards, the silviculturist obviously needs some density information. This can be obtained by a simple inventory of basal area per acre and number of trees per acre. But since potential treatments for the stand will be influenced also by the quality of growing stock and the present merchantable volume, the basal-area inventory should be broken down by size and quality classes.

Tree Classes

The diameter limits of the tree size classes described below were selected to conform with normal forest survey and National Forest procedure merely for convenience. They may be modified as desired. For example, 12- to 14-inch trees are often poor quality for sawtimber and are sometimes classified as pulpwood. In such cases the diameter ranges may be adjusted for more accurate classification, setting 14 inches as the minimum diameter for sawtimber. If this is done the poletimber limits may be adjusted also (say 8 to 13 inches) to reflect merchantable pulpwood sizes more realistically. However, for uniformity the same classification should be used throughout the tract or working unit.

The quality subclasses were selected for simplicity, and these too may be modified as required. For example, the suggested field tally form (fig. 20) lists culls only by total basal area. In determining the size of a timber-stand-improvement (TSI) job, it will often be convenient to know the distribution of cull trees by size classes as well. Nevertheless, the quality classes used have worked well in practice, and they should not be so expanded as to make classification cumbersome. As listed, they give the man on the ground (who knows local timber and markets best) the leeway to call a tree or species acceptable or undesirable that in a different area would be classified differently. In general the criterion for acceptable growing stock is whether the tree in question is good enough, in the opinion of the man on the ground, to be permitted to occupy valuable growing space for the time foreseen.

Timber that can be sold for sawlogs is classified in one of two categories: *mature timber* and *sawtimber*.

Mature Timber

Mature timber is timber that has reached the diameter specified for the site and rotation, as discussed under "Site-Species Relations" and modified as necessary for individual forests.

Sawtimber

(11 inches d.b.h. and larger)

1. *Acceptable growing stock (AGS)*.—These are salable trees that are not large enough to be mature, but are of good species, form, and quality and would be satisfactory as crop trees in a final stand on the site, or as a potential product for a future intermediate cut within 20 years.
2. *Undesirable growing stock (UGS)*.—These are salable trees that are not mature for the site, but are not desired in the stand because of species, defect, or poor form.

Poletimber

(6 to 11 inches d.b.h.)

Timber that is too small for sawlogs, but that could be sold as pulpwood or other small products where such markets exist, is divided into two categories:

1. *Acceptable growing stock (AGS)*.—Trees salable for small products, and of such species, form, and quality that they are suitable for crop trees if this size class is managed as the main stand, or that are suitable to leave as potential products for future intermediate cuts within the next 20 to 40 years.
2. *Undesirable growing stock (UGS)*.—Trees salable for small products, but because of species, form, or quality, should not be allowed to occupy the site for 20 to 40 years.

Small Trees

(Down to 2 inches d.b.h.)

Trees of commercial species that are too small to be sold for small products are classified as:

1. *Acceptable growing stock (AGS)*.—Trees that are of acceptable species, form, and quality and could be selected as future crop trees if this size class were selected as the main stand, or that would be suitable to leave for 40 to 60 years as potential products for future intermediate cuts.
2. *Undesirable growing stock (UGS)*.—Trees that are sound and might eventually provide merchantable products if left to grow, but that are not acceptable on this site because of species, form, or condition.

Culls

Culls in any size class are live trees that are not now and never will be merchantable

LOCATION:
Compartment__________ Stand No.__________ Date__________

BASAL AREA TALLY

Sample Point Number	Mature	Sawtimber		Poletimber		Small trees		Cull	Tree count (No. trees per 1/20-acre plot)
		AGS	UGS	AGS	UGS	AGS	UGS		
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
Total1/									
Per acre2/									

DESCRIPTION:
Site class: 75+__________ 55-74__________ 40-55__________
Rotation objective (diameter)__________
Basal area: AGS__________Total__________
Present main stand (size class):__________

Average tree diameter:__________
Percent stocking:__________

Required basal area: C level__________ B level__________
Basal area that may be removed in intermediate cut
(Total minus B level):__________
Stand mature__________Stand immature__________

PRESCRIPTION:
Regeneration cut__________Intermediate cut__________No cut__________
What will be marked for cutting and killing?

____

____

____

____

1/ With 10-factor prism and 10 points, the totals are per-acre figures.
2/ With other than 10-factor prisms or fewer than 10 points, adjust totals to give per-acre figures.

FIGURE 20.—Tally sheet: basal area and tree count.

for the principal products to be harvested from the site.

Basal Area

The angle gage or wedge prism makes it easy and quick to determine basal area in the field by the point-sample technique. The following discussion is based on the use of a 10-factor gage because this size has proved well suited for central hardwoods. Usually 10 or more point samples should be taken at random in the cutting area selected, although if the cutting area is carefully chosen so that stand conditions are uniform throughout, as few as five point samples may be adequate. Uniformity of the tallies among sample points should be used as a guide.

At each sample point, judge by eye the size and quality class of each tree picked up by the angle gage. Tally each tree in its proper column on a field form (fig. 20). After 10 sample points, the total for each column gives the basal area per acre for that tree class. If fewer or more than 10 sample points are used, the column totals must be multiplied by a conversion factor to arrive at the basal area per acre. The sum of all the columns is total basal area per acre. The AGS columns may be combined to show how much of the stocking is worth saving and managing. Other columns may be combined to show the basal area in merchantable trees. Knowing the amount of salable timber present is often helpful in deciding whether or not a certain kind of cut is feasible.

Tree Count

At each sample point a tree count should be made. An easy way to do this is to place a colored pole at the sample point, then walk around it on the circumference of a 1/20-acre circle, counting the trees as the line of sight from observer to center pole passes them. A rangefinder set at 26 1/3 feet or a light rope of this length (the radius of a 1/20-acre circle) is convenient for keeping the observer at the proper distance. List on the tally sheet the number of trees at each point and, at the end of the inventory, add them up and convert to a per-acre basis.

An alternative method of getting the tree count is to use conversion factors for number of trees per acre based upon the sizes of trees tallied through the angle gage. This method has the advantage that the observer doesn't need to leave the plot center or carry along a rangefinder. But it has the disadvantage of requiring closer diameter estimates and more calculations than are otherwise necessary.

With this method each tree picked up by the angle gage during the point sample is tallied for basal area as before (fig. 20). Then its diameter is estimated to the nearest 2-inch class and it is tallied again, by diameter class, on a separate sheet. When the inventory is complete, multiply the number of trees in each diameter class by the conversion factor for that class. Add all the converted numbers together and divide the total by the number of sample points. With a good sample the result will be the average number of trees per acre in the stand. The conversion factors are:

D.b.h. (inches)	*Per-acre conversion factor (basal area factor 10)*
2	458
4	115
6	51
8	29
10	18
12	12.7
14	9.4
16	7.2
18	5.7
20	4.6
22	3.8
24	3.2
26	2.7
28	2.3
30	2.0

A word of caution: there may be a tendency to ignore 1-, 2-, and 3-inch trees during the tree count because they add very little to the basal area and stocking percent. Neglecting to count them, however, will result in a larger average tree diameter for the stand, hence higher stocking requirements. This is more serious in pole-size and small-tree stands than in sawtimber stands.

In general the following rules of thumb have worked satisfactorily in deciding the minimum diameter to include in the tree count:

- If the sawtimber and mature-timber classes together account for *more* than half the basal area, ignore trees smaller than 3 inches d.b.h.
- If sawtimber and mature timber together account for *less* than half the basal area but these classes and pole-size trees *combined* amount to more than half the basal area, ignore trees smaller than 2 inches d.b.h.

- In other stands count all trees 1 inch d.b.h. and larger.
- In any stand ignore dead trees and small trees of brush species (dogwood, sumac, alder, sourwood, etc.) that will obviously never reach the main canopy.

The size limits above apply to the tree count only; in determining basal area, tally any live tree that is picked up by the angle gage.

Stand Diagnosis

The silviculturist is now ready to judge the quality of stocking in his stand and decide the size class that must sooner or later provide his main harvest.

Determining Stand Quality

Find the point on the stocking chart (fig. 18) that represents your total basal area per acre and number of trees per acre. The position of this point in relation to the lines on the chart shows at a glance whether the stand is fully stocked or not. It also shows the average diameter of the stand (note across the top of the graph the numbers signifying average tree diameter). Starting beneath each number, a line runs diagonally down the chart. For any degree of stocking that falls along that line, the average stand diameter is the same (within ½ inch). Now, from the point designated above by total basal area and number of trees, follow down parallel to the line representing the next smaller average diameter. For example, if average diameter comes out to be 4.4 inches, follow down parallel to the line signifying the 4-inch average diameter. When you reach the *B* and *C* curves, note what basal area is shown at each curve for a stand of this average diameter.

Next, compare the basal area of the acceptable growing stock inventoried with the *B* and *C* levels just determined. If the basal area of the acceptable growing stock in the stand exceeds that required for the *B* level, the stand is in good shape because all the growing space can be occupied by acceptable trees. If the basal area of the acceptable growing stock exceeds the *C* level but not the *B* level, the stand is worth saving and managing. It will be several years before the good trees can fully occupy the site, but in view of the poor condition of many upland hardwood stands, we can afford to wait a few years for one that's almost good. In well-stocked, previously unmanaged stands, the acceptable growing stock very often falls right along the *C* level.

The *C* level is a danger point, though. The silviculturist must realize that when acceptable growing stock is below the *B* level, the stand is not growing products as fast as it should. If acceptable growing stock is very far below the *C* level, it cannot be saved without great waste of time and growing space.

Choosing The Main Stand

Intermediate cuttings should strive to make the stand as uniform as possible because a small spread of diameters will simplify the eventual regeneration cut. This means the silviculturist must identify the size class that will provide his main harvest and prescribe a cut that will keep it growing rapidly while discriminating against other size classes.

Identifying the main stand is sometimes easy, sometimes difficult. To keep rotations as short as possible, usually select as the main stand the size class that furnishes the bulk of the dominant and codominant trees. Many stands are uniform enough so that the main size class can be quickly identified simply by inspection (fig. 21). These are the stands we commonly refer to as "sawtimber stands," or "pole stands," or "sapling stands."

However, even-aged stands of mixed species with unequal growth rates among the species often have nearly as wide a range of diameters as do the stands where previous cutting has resulted in three or four different age classes. This wide diameter range sometimes makes it difficult to select the principal size class by inspection alone, especially when the dominant canopy contains much defect. In such cases the basal area tally is helpful. If any size class contains 50 percent or more of the basal area, choose that size class unless it is extremely defective. Preferably, the main size class should also contain *C*-level stocking of acceptable growing stock.

Still there will be some stands that do not have a single predominant size class. One reason is that the point of separation between size classes is somewhat artificial. A 10-inch tree is little different from an 11-inch tree, but one is classified as poletimber, the other as sawtimber. When the average diameter of trees in the main stand (not necessarily of the total stand) is near a size class limit, some trees will be in one class and some in the other. In such a case, the main stand to select for management will be a combination of the two adjacent classes that (1) have together enough acceptable growing stock to meet *C*-level requirements and (2) have together the *most* acceptable growing stock.

There are also some stands in which the acceptable growing stock falls at or above the

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FIGURE 21.—The main size class in this stand is large poles. The trees that compose the main stand are each marked with an "X." (Five marked trees are shown in photo.)

C level, but is distributed among all size classes. Usually this simply means that in many present stands there are more poor trees than good ones, that many of the dominants and codominants are culls or undesirables. If the stand is well enough stocked to make an intermediate cut feasible, a main stand can usually be picked out by inspection aided by the relative proportions of acceptable growing stock tallied for each size class.

Most often the main stand to favor will again be a combination of the two adjacent classes that have the most acceptable growing stock. This is only a tentative assessment of the main stand, but it will serve as a guide during the first cut. A reassessment should be made during the next cut, and its outcome will depend on how the different size classes develop in the meantime.

Steps Leading To "Prescription"

(See fig. 22)

1. Decide on the boundaries of the stand (page 9).

2. Determine the site class of this area and settle on a rotation objective for it (page 12). These factors will help fix a diameter limit for mature trees.

3. Inventory this stand, tallying the basal area by tree classes (page 19) and making a tree count (page 21).

4. Refer to figure 23. Find the point on the chart where total trees per acre intersects the line denoting total basal area. Note how well the stand is stocked and what its average diameter is. (In the example opposite, the trees per acre total 220; total basal area is 90. The

LOCATION:
Compartment 1 Stand No. 1 Date ______

BASAL AREA TALLY

Sample Point Number	Mature	Sawtimber AGS	Sawtimber UGS	Poletimber AGS	Poletimber UGS	Small trees AGS	Small trees UGS	Cull	Tree count (No. trees per 1/20-acre plot)
1		2	1	2	2			1	10
2		5		3	2		1		13
3		1	2	4	1			1	10
4		3	1	1	3		1		9
5		5		1		1		2	11
6		2	2	2	1		2		12
7		3		1	2		1		10
8		3	1		2	1		2	9
9		4	1	1	2	1	1	1	14
10		2	1	2	2		1		12
Total 1/	0	30	9	17	17	3	7	7	110 X 2 = 220
Per acre 2/									

DESCRIPTION:
Site class: 75+ ______ 55-74 X 40-55 ______
Rotation objective (diameter) 20-24" Sawtimber
Basal area: AGS 50 Total 90
Present main stand (size class): Small sawtimber - large poles

Average tree diameter: 8.7"
Percent stocking: 82 %

Required basal area: C level 51 B level 65
Basal area that may be removed in intermediate cut
(Total minus B level): 25
Stand mature ______ Stand immature X
PRESCRIPTION:
Regeneration cut ______ Intermediate cut X No cut ______
What will be marked for cutting and killing?

Kill 7 sq. ft. of culls; remove 0-7 sq. ft. undesirable small trees; 12-17 sq. ft. undesirable poles by TSI (next time commercial thinning removing undesirable sawtimber)

1/ With 10-factor prism and 10 points, the totals are per-acre figures.
2/ With other than 10-factor prisms or fewer than 10 points, adjust totals to give per-acre figures.

FIGURE 22.—How to apply stocking percentages to a specific stand (point sample estimate using a basal area factor of 10).

stand is about 81 percent stocked and has an average diameter of about 8.7 inches).

5. On the chart (fig. 23), from the point determined in step 4, follow down to the left, parallel to the nearest lower average diameter line, noting the basal areas where your new line crosses the *B* and *C* curves. (In the example, *B* level is 65 square feet; *C* level is 51 square feet).

6. Compare the amount of acceptable growing stock (AGS) in your stand with the basal area required for *C*-level stocking. If the AGS basal area is approximately equal to or exceeds *C*-level requirements, the stand is worth saving and managing (page 22).

7. If the stand is worth managing, decide on the size class that will form the main stand for future management (page 22).

8. Deduct the basal area required for *B*-level stocking from the total basal area in your stand. The result is the amount of basal area that may be removed in an intermediate cut (25 square feet per acre in the example).

9. Within the limit of the "cuttable" basal area, devise a cut that will preserve the main stand while promoting its most rapid growth. The following section outlines treatments recommended for some of the more common conditions found in upland hardwood stands.

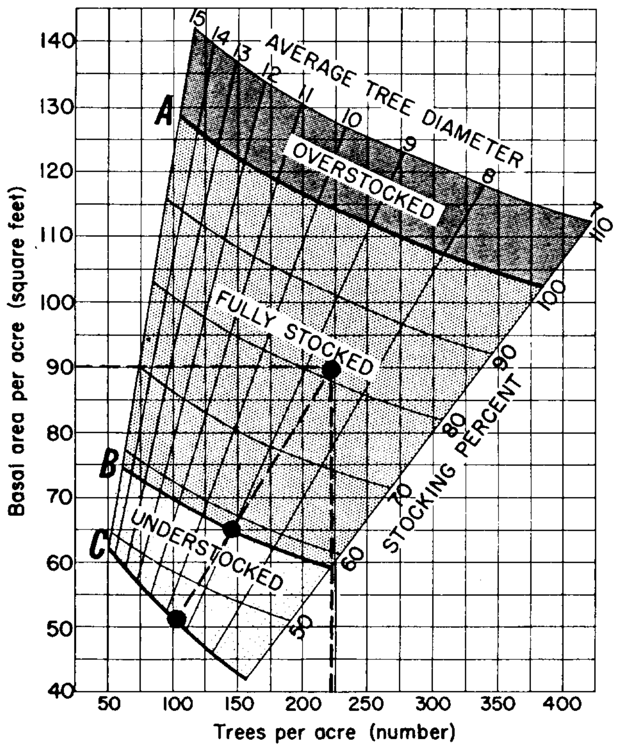

FIGURE 23.—An example of how *B*- and *C*-level basal area is determined for a specific stand.

Silvicultural Prescriptions For Upland Hardwoods

Having identified his stand, measured it, and chosen the size and kind of trees that he will manage, the silviculturist is at last ready to prescribe a treatment. If the stand is mature, he will reproduce it. If it is immature, he will either prescribe some kind of intermediate treatment or prescribe no treatment. Some of the various alternatives are given below. They are based on the size and quality of growing stock and how well the amount present compares with the *A*, *B*, and *C* levels of stocking. Some prescriptions in this section are special cases of those preceding. When, through use of the key, you come to one of these, don't hesitate to go back a few paragraphs to the beginning of the section (signified by letter headings in boldface) to get a more complete story.

Key

A. Mature stands (more than 50 percent of the basal area in mature trees)
- B. Total stocking above *B* level
- BB. Total stocking below *B* level

AA. Immature stands (less than 50 percent of the basal area in mature trees)
- C. Total acceptable growing stock below *C* level
  - D. Sufficient volume for commercial sale
  - DD. No commercial sale feasible at present
    - E. Commercial sale possible within 10 to 15 years
    - EE. Commercial sale not possible within 15 years
- CC. Total acceptable growing stock above *C* level
  - F. One size class predominant in stand (contains more than 50 percent of the total basal area or has enough acceptable growing stock to meet *C* level)
    - G. Sawtimber class predominant
      - H. Stand nearly mature; trees of the main stand are within 2 to 4 inches of rotation diameter

I. Stand more than 90 percent stocked

II. Stand 60 to 90 percent stocked

III. Stand below *B*-level stocking

HH. Stand more than 4 inches from maturity on good sites; more than 2 inches on poor sites

J. Stand more than 80 percent stocked

JJ. Stand less than 80 percent stocked

GG. Pole- or small-tree class will provide *C*-level stocking of acceptable growing stock

FF. No single size class predominant

K. Two size classes combined will provide *C*-level stocking of acceptable growing stock

L. Total stocking 80 percent or more

M. Sawtimber and poletimber classes

MM. Poletimber and small-tree class

LL. Total stocking less than 80 percent

KK. Three size classes combined provide *C*-level stocking of acceptable growing stock

N. Total stocking 80 percent or more

NN. Less than 80 percent

A. Mature stands (fig. 24) are those in which more than 50 percent of the basal area is in trees that have reached the size desired for the site. At least 75 percent of the basal area should be contained in the merchantable saw-timber and cull classes.

B. Well-stocked mature stands are ready to be regenerated by clear cutting the merchantable timber and killing all other trees larger than about 2 inches d.b.h. Normal logging operations, especially with tractor skidding, nearly always create enough disturbance to insure suitable seedbeds and adequate seedling reproduction.

BB. In poorly stocked mature stands, regeneration cutting is high priority. Clear cut the merchantable timber and kill the remainder. Usually these stands have a heavy understory. If the understory contains 400 or more good stems of desirable reproduction per acre, no further treatment is necessary, but the area should be checked in 5 years to determine the need for cleanings. If, however, desirable reproduction is scarce, scarification with a bulldozer blade during or immediately after logging or treatment with herbicide spray or mist may be beneficial (none of these operations has been sufficiently tested to justify conclusions). Do not disk the area unless disking can be followed immediately with a herbicide spray that covers the exposed stems or stubs of undesirable species to control sprouting.

AA. Immature stands contain less than 50 percent of the total basal area in mature trees, regardless of stand structure. Normally, these stands should be carried to maturity with thinnings and improvement cuts applied as necessary.

C. But when the amount of acceptable growing stock is below the *C*-level, seriously consider regenerating the stand (fig. 25). At this low level of stocking it will be some time before acceptable trees are fully utilizing the site: more than 5 to 8 years on good sites, 10 years on medium sites, 12 to 15 years on poor sites. It will often be better to start over with a new stand that will be fully stocked in a short time than to waste growing space for a long period. However, no rigid rule can be set. The point to remember is that at any stocking below *B* level, some production will be lost. At *C*-level stocking, losses could represent 10 to 20 percent of the rotation yield. Since few products are obtained from young stands and since young stands increase rapidly in stocking, understocking is less serious in young stands than in old. Likewise it is less serious on poor sites than on good. The silviculturist will have to decide in each case how far below *C* level is too far, but there is some point of understocking where it pays to start over rather than perpetuate a monster.

D. One factor that will influence the timing of the regeneration cut is how much merchantable timber is available. If the merchantable volume is sufficient to pay the cost of killing the rest of the stand, regenerate the stand as soon as feasible, especially on good sites (see BB).

DD. If there is not enough merchantable volume to make a commercial sale, a choice must be made depending on how soon you want to get the land back into full production.

E. If a few more years' growth (10 to 15 years) will provide a commercial cut, wait rather than sacrifice too much of the past growth, especially since it costs money to get rid of it. In this situation do nothing now, but plan to reproduce the stand within 10 to 15 years as soon as a commercial cut is possible.

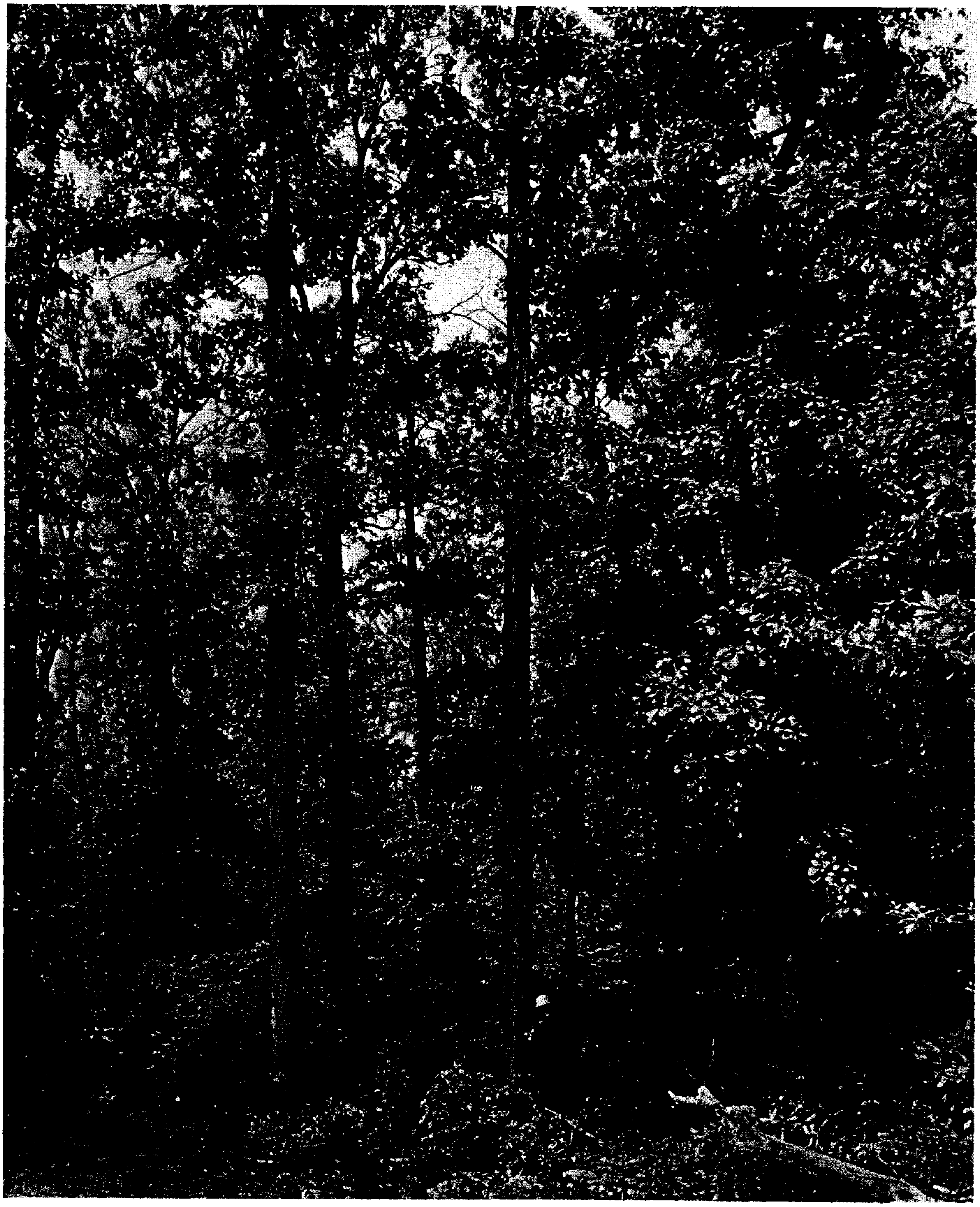

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FIGURE 24.—A mature stand of mixed-oak sawtimber ready for a regeneration cut.

F-517743

FIGURE 25.—This immature stand should be regenerated. There is no future for the present stand because tree quality, species composition, and stocking are all poor.

EE. If a longer wait is required for a commercial cut, or if there isn't enough growing stock to provide much additional volume, put the area back into production now. This will be expensive, and since logging will be light (scattered merchantable trees may be removed when nearby areas are logged), some scarification or other site preparation probably will be required. But sooner or later the cost of past maltreatment must be paid whether as an outlay for silvicultural improvement or as a sacrifice of productivity for many more years while nature does the improvement. The better the site, the more pressing the need for prompt action (see BB).

CC. In immature stands with enough acceptable growing stock to meet *C*-level requirements, thinnings and improvement cuts should be applied periodically to maintain rapid growth on crop trees. The trick here is to pick out the size class that will form the main stand and manage the trees in this class to maturity.

F. The easiest stands for which to prescribe an intermediate cut are those with a single predominant size class.

G. In sawtimber stands the amount of thinning that should be done depends mostly on how near the stand is to maturity.

H. If the stand is nearly mature (more than half the trees are within 4 inches of rotation diameter on good sites, 3 inches on medium sites, or 2 inches on poor sites), whether to cut or not, and how much to cut depends strongly on stocking.

I. If the stand is very well stocked (90 percent or more) and almost 4 inches from maturity (or 3 inches, or 2 inches depending on site class), a very light improvement cut might be applied to remove some culls and undesirable species. But do not reduce the stand below about 75 percent of full stocking and do not make any large holes in the stand because of possible adverse effects on quality of residual stems.

Warning: In the past too much emphasis has been placed on making improvement cuts in stands of this kind. Because such stands contain good volumes of desirable trees, and because pressure is always heavy for a "good" commercial cut, more often than not "improvement" became merely a term used to cover up high-grading: cutting from above, cutting too heavily, and cutting the more desirable species. In these stands it is better not to cut at all than to overcut.

II. In stands 60 to 90 percent stocked, wait. Oak stands this age do not respond well to thinning, and partial cuts only encourage a tolerant understory.

III. Stands that are nearly mature but poorly stocked (below *B* level) are sometimes encountered. Many of these have grown for some time in a parklike condition; others may be the result of past overcutting (fig. 26). If they contain acceptable growing stock adequate to meet *C*-level requirements, they should be left to grow. More often, however, timber quality is apt to be low and acceptable growing stock scarce. Such stands should be regenerated: as soon as possible for cutover stands—whenever convenient for open-park stands. Site should be prepared as judgment dictates. Much reproduction is often present in stands where recent cutting has reduced total stocking to below the *C* level (for example, after a shelterwood cut). On the average, the reproduction grows slowly and in a few years it may be overtopped by an understory of tolerant brush (fig. 27). The overstory should be removed as soon as possible in these stands, before the desirable reproduction is lost and the quality of residual trees deteriorates further.

HH. Well-stocked stands more than 4 inches from maturity on good sites (or 2 inches on poor sites) are prime candidates for thinnings and improvement cuttings (fig. 28). However, stocking must not be reduced below the *B* level, and cutting *must not spoil the main stand.* (Again, to do so lengthens the rotation.) As much of the required basal area as possible should be left in trees of the principal size class. The volume that may be re-

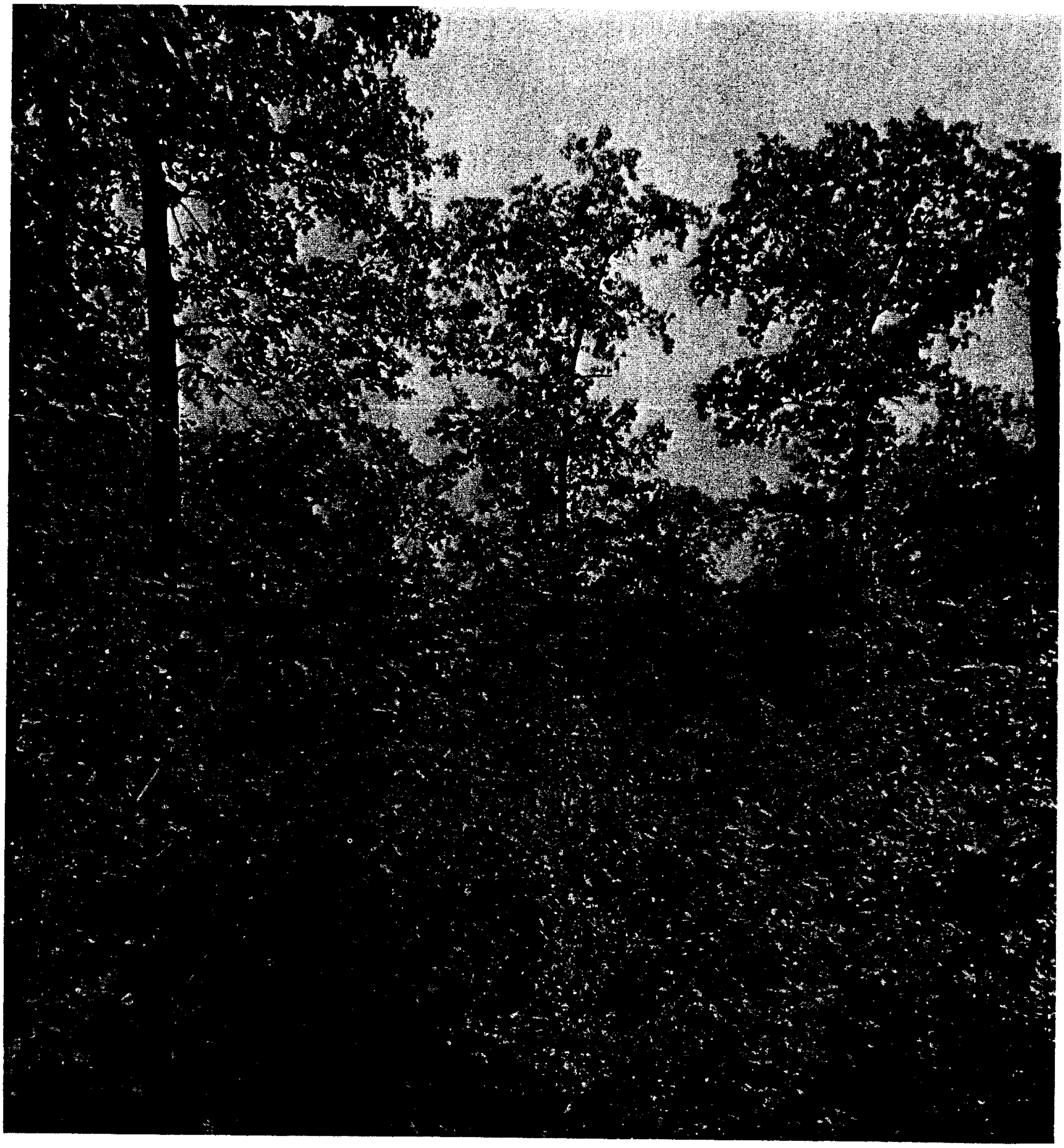

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FIGURE 26.—This stand has been cut too heavily, leaving an irregular crown canopy. The residual mature trees generally will deteriorate in quality and in the meantime desirable reproduction will not develop properly.

moved will thus depend on how well the stand is stocked.

J. If the stand is 80 or 90 percent stocked, especially if it has been cut 10 to 20 years previously, thinning to the *B* level should yield enough volume for a commercial operation, but heed the warning in Section I. If there is not enough volume for commercial thinning, reduce the stocking to *B* level by killing culls and unmerchantable undesirables. If the stand is 90 to 100 percent stocked and has developed naturally, or at least shows no evidence of previous cutting, it should be thinned—but do not reduce total stocking below 70 percent in this first cut. In stands this age that have

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FIGURE 27.—This shelterwood cut has encouraged a tolerant stand of reproduction at the expense of more desirable intolerant species. Many of the boles of residual overstory trees develop excessive branching, thus reducing quality.

developed normally, the trees have endured intense competition and their crowns are small. Thinning from 100 percent stocking down to 60 percent stocking in one cut frees more space than the remaining trees can quickly occupy. Many trees will be affected by bole sprouting and lose quality.

JJ. When the initial stocking is not much above the *B* level, a cut is not often necessary, and in any event should be light. Don't reduce total stocking below the *B* level. Down to this limit, cutting may remove large culls, mature trees, and small culls (in that order). In such stands if the trees that would be marked for cutting do not represent a commercial cut (considering also the cut from nearby areas), stay out of the stand until the next cutting interval. Thin it to the *B* level only by girdling the larger culls during timber-stand-improvement work, but heed the warning in Section I.

GG. Not all stands are sawtimber stands, of course, and if there is enough acceptable growing stock in one of the smaller size classes to provide *C*-level stocking, that class should form the main stand for future management. If the total stand is more than 80 percent stocked, it should receive a thinning or an improvement cut. Often when such a stand is encountered, there will be scattered sawtimber trees of an older age class in the overstory. The prescription is to remove the old sawtimber in one cut and kill the larger culls and undesirable growing stock as necessary to reduce the stand to the *B* level of stocking. Kill suppressed and poor intermediate culls and undesirable growing stock only if they will be released by the cutting or are interfering with potential crop trees. Thereafter thin as needed.

There is one special case: Sometimes there will be a few fast-growing trees the same age as the main stand but just big enough to be tallied in the next larger size-class—for example, small sawtimber trees in a large-pole stand. Such trees should be considered as part of the main stand. If of acceptable quality they should be retained in the stand and favored.

FF. Many stands do not have a single predominant size class (page 22).

K. Such stands will often have adjacent size classes (sawtimber plus poletimber or poletimber plus small trees) which between them contain enough acceptable growing stock to meet *C*-level requirements. These stands are well worth saving.

L. If the stand is well stocked it qualifies for an improvement cut. But remember that this cut must be made to favor and improve the main stand, not just to find volume for a commercial operation.

M. When the sawtimber-poletimber classes together are considered the main stand, it will usually denote one of two fairly common situations:

(1) The first is an even-aged stand in which the average diameter of the dominant or codominant trees is close to the dividing line between poles and sawtimber. This stand will have a uniform appearance; it represents a stand that is just growing out of the poletimber stage but has not quite reached the sawtimber stage. It may be considered either a very young sawtimber stand or a rather old pole stand. The same prescriptions apply as in sections HH or GG.

(2) The second situation is an uneven-aged stand that has developed after a heavy cut many years earlier. This stand will appear less uniform than the one above, but appearance will depend on how long ago the cut was made and how heavy it was. Usually, single sawtimber trees and small clumps of sawtimber trees will be interspersed among the poles. The largest sawtimber trees often have wide crowns with heavy limbs, and their boles appear short for the site (fig. 29). These are the larger residual stems left after a previous cutting. The medium- and small-sawtimber trees often are the old poles that were left after the earlier cut. The present poletimber is a new age class that developed after cutting. If the stocking of these new poles approaches *C* level and the larger of them approach the size of the smaller sawtimber, consider the poletimber as the main stand and favor this class in an improvement cut. Do not reduce the stand

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FIGURE 28.—Stands such as this one need thinning. There is enough stocking in acceptable trees to fully utilize the growing space after the less desirable trees are removed.

below *B*-level stocking, but thin it to this level by killing culls of sawtimber and pole sizes, and cutting from above among the larger sawtimber. Save the best of the small sawtimber along with the good poles.

If, on the other hand, the acceptable small sawtimber approaches *C*-level stocking and the new poles contribute relatively little stocking, favor the sawtimber class. Save the best poles, but make up the rest of the stocking necessary for *B* level from the sawtimber class, removing only as many culls and mature sawtimber trees as necessary to reach *B* level. In this kind of stand it is important to favor the small sawtimber because many stands that look uneven-aged, aren't. What appears to be a clean young pole (of the new age class) is often an intermediate or suppressed old pole (Gibbs 1963). When released these old poles respond slowly (Minckler 1957) but branch excessively (Brinkman 1955; Krajicek 1959). Before putting too much reliance on them, bore some and see how old they are.

MM. If the poletimber and small-tree classes combined have more acceptable growing stock than the pole-sawtimber classes, they should be considered together as the main stand and managed accordingly. Again, this kind of stand may result from two different origins.

(1) It may be an even-aged stand just approaching small pole size (fig. 30). There may or may not be an overburden of scattered sawtimber, but the younger age class will appear quite uniform. If scattered large trees are present, they should be removed. The younger age class should be thinned to *B*-level stocking, saving the cleanest stems in the upper two-thirds of the diameter range within this age class. See also section GG.

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FIGURE 29.—A two-storied stand composed of scattered residual sawtimber overtopping young poles. In this case the upper story of larger trees should be removed and the younger poles managed as the main stand.

(2) Or this stand may be an uneven-aged stand resulting from one or more previous heavy cuttings. This stand will be less uniform than (1) above and will probably have an overstory of culls and sawtimber (fig. 31). This overstory should be removed together with undesirable poles to reduce the stand to *B*-level stocking. The age of the larger poles may be questionable, but if they are of good form, save them until the next cut and see how they develop. Make up the rest of the stocking for the residual stand from among the small poles and larger stems in the small-tree class. It is too early to choose definitely the size class that will provide the final crop in this stand, but there is no hurry. In the meantime, the present intermediate cut should strive to leave a more uniform stand than now exists. At least one more cut will be required before this stand is well regulated.

LL. If two size classes must be combined in order to have *C*-level stocking of acceptable-quality trees, but total stocking is light, let the stand alone unless there are a few big culls that can be girdled during timber stand improvement operations. Come back in 10 years; by then the stand should be well stocked and will qualify for an improvement cut.

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FIGURE 30.—An even-aged stand on the borderline between the small tree and poletimber classes.

KK. There are also some stands in which the acceptable growing stock falls near the *C*-level, but is distributed among all size classes (fig. 32). Choose a tentative main stand composed of the two adjacent growing-stock classes that together have the most acceptable growing stock (page 22) and tailor a cut to favor both classes. Usually these will be the sawtimber-poletimber classes.

N. If the stand is well stocked, there will often be enough merchantable volume in mature or defective timber to pay the cost of making the cut and girdling the culls, but no one is going to get rich on this kind of timber. This cut will be the first in a series aimed at bringing order and uniformity to a hodgepodge resulting generally from previous disturbances: fire, storm, animals, or cutting —especially commercial selection cuts. Girdle the culls (there will probably be many), cut the mature timber, the larger undesirable sawtimber, and enough undesirable growing stock in smaller size classes to reduce the stand to *B*-level stocking. Don't reduce it below *B* level, though, even if this means leaving some undesirable growing stock temporarily. Leave all the *desirable* small trees and small poles. Some may grow into the main stand. Next time, concentrate the cut in the smaller sizes. Continue to favor *desirable* small stems but discriminate heavily against undesirable small stems. It will be several cutting intervals before this stand is regulated. In the meantime remember that we are trying to shape the stand so that when it is ready to be regenerated, it will contain mostly large timber. While another aim of intermediate cutting is to stimulate growth on the main stand, the process cannot be hurried. Until the main stand is evenly spaced and sufficiently well stocked to fully utilize the site,

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FIGURE 31.—Another two-storied stand of scattered old sawtimber overtopping a young age class of large saplings and small poles.

growth can't be shifted to it. There's no use discriminating against desirable small trees that may provide products before their space is needed by a crop tree. Of course, when they are in the way of crop trees they should come out whether they make products or not.

NN. In an irregular stand that is lightly stocked there is little margin above the *B* level available for cutting. And if the stand has been understocked for some time, it probably has a heavy understory containing many tolerant trees. However, site preparation is expensive, and if total acceptable growing stock is above the *C* level, let the stand alone unless it is feasible to kill a few of the larger culls. The stocking will build up and gradually thin out the understory. Come back in 10 years and take another look. By that time the stand will probably resemble the one just discussed (N) and an improvement cut may be possible.

It can be argued that the two stands last discussed should be regenerated immediately. The acceptable growing stock of the main size class is below the *C* level, and it is questionable whether the desirable small trees will grow to product size by the time the main stand is mature. There are several reasons for waiting. *First,* many stands need treatment worse than these two. The stands furthest from achieving full site utilization should be renovated first; in the meantime stands like the two just discussed will be growing more products even if not the best. *Second,* to reproduce these stands immediately means many small products, unsalable trees, and added site preparation costs. In effect, the treatment recommended is a compromise. The rotation is lengthened slightly to bring a larger percentage of the present stand to product size.

Application To Small Woodlands

Except possibly in very small tracts exposed constantly to drying winds, upland central hardwoods take no account of the size of woodland in which they grow. Thus recommendations made on a purely silvicultural basis apply equally well to both large and small holdings, and the prescriptions in this guide have been developed without any consideration for the size of tract involved. But there are some practical *management* limitations to the size and frequency of reproduction clear cuttings that may be made in small woodlands.

Management problems of upland central hardwood forests are properly beyond the scope of this guide.[3] However, nearly 55 percent of the commercial forest area in the Central States is in tracts of *100 acres or less*, and much emphasis has been placed on the need to improve the general forest condition and productivity of these small woodlands. Therefore, it seems appropriate to discuss briefly the extent to which the smallness of the property may require modification of the general recommendations made earlier.

Probably the two most important factors in setting the management for a small tract are (1) the objective of the owner (2) the minimum size of cut that is operable (if performed or contracted for by the owner) or salable (if sold as stumpage). Both factors vary widely, of course, from place to place and even from year to year. Consequently, in preparing a management plan for a small property, a general average must be assumed for each factor for the period of time foreseen. Naturally it is useless to assume that the owner's objective is maximum timber production if it isn't, or to assume so small an operable volume that it will not attract an operator.

If the owner's objective *is* maximum or most efficient timber production, and *if* regulation of the cut for regular periodic yield is required, the assumed operable cut will fix the amount of area to clear cut at one time. Of course the average condition and stocking of the whole woodland will enter into this calculation. The amount of regeneration area initially calculated may be reduced according to the additional volume that can be obtained from thinnings and improvement cuts in the rest of the tract. Be careful not to reduce the amount of area slated for regeneration so much that it loses its benefits for desirable composition and rapid growth of the reproduction. We recommend as a rule of thumb that it be *not less than an acre*, preferably larger.

Also, *be extremely careful not to make the thinnings and improvement cuts in the rest of the tract too heavy.* Sufficient stocking must be retained to carry future cuts. In the past, too much emphasis has been placed on making improvement cuts in sawtimber stands. In previously unmanaged stands of upland central hardwoods, if the timber is old enough that an improvement cut yields sawtimber products from the main stand, the stand is probably too old to benefit much. (However, trees of a scattered, older overstory are prime candidates for removal.) Don't worry about cutting too lightly during this improvement cut; central hardwoods are long lived and durable.

Once the amount of area to be regenerated during each cut has been calculated and the length of the rotation decided upon, the total area contained in the tract will fix the cutting interval. For example, if the tract contains 20 acres, if the rotation is fixed at 80 years, and if 4 acres must be cut each time to make a feasible operation, the minimum cutting interval is going to be 16 years: cutting 4 acres each time means that after 5 cuts the woodland will be completely cut over. Spreading 5 cuts over an 80-year rotation means 16 years between cuts (table 5).

The amount of area to be regenerated in each cut can be increased if the cutting intervals are correspondingly lengthened. Thus, rather than fool with a small cut every 2 or 3 years on a woodland, it will probably be better to make larger cuts at 5- or 10-year intervals.

However, there is no way to shorten the long cutting intervals on small woodlands; timber just doesn't grow overnight. So do not be deluded into thinking that the minimum cutting interval just calculated can be shortened by using selection management. Once a minimum operable cut has been established and the cutting interval determined from it, the volume to be removed and the minimum

[3] For a more complete discussion, see Roach 1965.

Table 5.—Minimum cutting intervals (in years) for different rotation lengths, cutting areas, and woodland areas

Minimum cutting area (acres)	Minimum cutting interval								
	20-acre woodland and rotation of (years)—			40-acre woodland and rotation of (years)—			60-acre woodland and rotation of (years)—		
	60	80	100	60	80	100	60	80	100
2	6	8	10	3	4	5	2	2	3
3	9	12	15	4	6	7	3	4	5
4	12	16	20	6	8	10	4	5	6
5	15	20	25	7	10	12	5	6	8

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FIGURE 32.—Acceptable growing stock here is above C-level but is distributed among all size classes. This is a better quality stand than the average for this condition class because it is on a good site and has not been disturbed for many years.

cutting cycle that may be used in selection management *will be exactly the same* as those already determined for even-aged management. After all, over a rotation (or over the length of time that it takes a seedling to reach maturity) total growth will be the same for both systems: they must balance out. Therefore, if regulation of the cut for periodic yield is required, using a shorter cutting period than that calculated will mean running out of timber some time during the rotation regardless of whether the management system is even-aged or uneven-aged.[4]

There is, of course, no need for the area slated for each regeneration cut to be all in one piece. It is convenient if each regeneration area, by itself, provides an operable cut; but on small woodlands this is not a necessity. In fact, on 20- to 60-acre woodlands present stands can be utilized to better advantage if cutting areas are carefully fitted to uniform site and stand conditions; the usual range is 1 to 5 acres. (See CUTTING AREAS, page 9.) Small properties have an advantage over larger ones in this respect; they can be examined and treated much more intensively without ending up with so many separate small stands that control is lost. In general, the larger the tract the larger the individual clear-cut patches should be; otherwise control becomes very difficult.

The foregoing discussion presupposes both an objective of maximum timber production and rather strict regulation to provide uniform, periodic yields. Actually, strict regulation is not necessary, and probably is not even practical on small properties.

For one thing, in small cutting areas of 1 or 2 acres, the inventory procedure given previously in this guide must be revised because the area is too small to apply the point-sample technique. A diagnostic inventory of the total property, or of several component parts of it, should be made instead. This will permit some rational planning as to how, when, and where cutting will proceed but cannot provide specific prescriptions for individual 1-acre areas.

For another thing, if timber yields can be scheduled only at 10-year intervals, does it make much difference if one cutting interval is 6 years and the next is 14 years? Indeed, is it worthwhile to try to schedule them at all? Some owners of small woodlands will use their timber like insurance policies against unforeseen expenses. Others will exploit the woodlands as soon as there is an operable cut. Neither of these methods is the way to maximum timber production, but neither method destroys the productivity of the land; they simply disrupt the regularity of the returns. In the long run it is more important that the cutting areas be cleaned up after each cut than that the cuts be rigidly scheduled.

Furthermore, on small properties the difference in returns between maximum timber production and haphazard timber production is not great. For example, in normal unmanaged stands on site index 70, timber production for stumpage at current prices might average $1.00 to $1.25 per acre per year over a 60-year rotation. With good management, we should probably double that. On a 20-acre woodland this would amount to perhaps $20 to $25 extra per year (less management costs). Twenty-five dollars a year is not a strong incentive for an owner of a small woodland to practice intensive silviculture, particularly when he learns of the work involved.

[4] That selection cutting has failed so often is not the fault of the system. Cutting cycles have commonly been calculated by using periodic annual growth from a sawtimber stand instead of mean annual growth of that stand over a rotation. The latter is of course much less than the former until the culmination of mean annual increment.

Consequently, the objective of maximum timber production is not binding on small properties, and other objectives become relatively much more important. As the importance of other uses increases, silviculture of timber production should be modified as necessary to meet the dominant objectives. The larger the property, the more the emphasis that may be placed on timber production, and the more substantial the returns will be.

General Rules

Obviously there are more different kinds of stands than there are standard pigeonholes to put them in. But pigeonholes are not substitutes for judgment anyway. The examples and prescriptions cited merely explain the principles involved. Successful application of the principles depends on the judgment of the person doing the marking. But if these rules are followed, you can't go very far wrong:

1. Select an area of uniform site and stand conditions as a cutting unit, but don't make it so small that it is impractical to treat and maintain as a unit. On each area match the species to favor, the rotation diameter, and the amount of cultural work to the quality of the site.
2. Don't worry about the intermediate and suppressed crown classes; on each unit tailor the cut to the needs of the main stand where most of the value lies. This is the only way to shorten rotations and reduce interest charges.
3. Maintain rapid growth of the main crop by regular thinnings and improvements cuts.
   a. Clean the stand early to regulate species composition if the quality of the site and value of the intended products can justify the expense.
   b. Keep residual basal areas up to at least the minimum stocking required for full utilization of the area (*B* level). Otherwise growing space will be wasted and growth of products reduced.
   c. Keep spacing in mind (table 6). Residual trees should be distributed as evenly as possible over the area, and this is as important in early cuts as later.
   d. Do not encourage a tolerant brushy understory by nibbling away at a stand in the 10- to 20-year period (depending on site quality) immediately preceding a regeneration cut. It is too late for a worthwhile thinning.
4. Regenerate mature stands by clear cutting in order to get the maximum amount of desirable intolerant species and the most rapid growth on all species.
5. But *do not leave pole-size trees or large saplings* in clear-cut openings. They become wolf trees. If you are going to make an opening, *make a real one!*

And finally, after some experience it should not be necessary to follow the whole procedure of a tree count, inventory, and diagnosis in every cutting area chosen. The condition and treatment of many areas will be obvious. The procedure will then serve as a check on the accuracy of a cutting prescription and as a guide in doubtful cases.

Table 6—Growing Space Required for Individual Trees for Full Site Utilization[1]

Diameter (inches)	Maximum stocking (A)[2] Tree area	Maximum stocking (A)[2] Spacing	Minimum stocking (B)[3] Tree area	Minimum stocking (B)[3] Spacing
	Milacres	Feet	Milacres	Feet
2	0.42	4.6	0.82	6.5
3	.74	6.1	1.33	8.2
4	1.14	7.6	1.96	9.9
5	1.59	9.0	2.70	11.6
6	2.11	10.3	3.56	13.4
7	2.69	11.6	4.55	15.0
8	3.34	13.0	5.66	17.0
9	4.04	14.3	6.88	18.7
10	4.82	15.6	8.22	20.4
11	5.65	17.0	9.70	22.1
12	6.54	18.1	11.30	23.8
13	7.51	19.4	13.00	25.6
14	8.54	20.8	14.80	27.2
15	9.62	21.9	16.80	29.0

[1] Any combination of trees whose combined tree area is 1,000 milacres represents maximum stocking of 100 percent; 735 milacres—73.5 percent, etc. Stands with an average stand diameter over 3 inches containing from 570 to 590 milacres of tree area are at the *B* level of stocking.

[2] Determined from the application of the tree-area ratio (Chrisman and Schumacher 1940) to Schnur's (1937) stand tables for even-aged upland oak forests.

[3] Adapted from the crown competition factor (CCF) developed by Krajicek, Brinkman, and Gingrich (1961).

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Tree Species Mentioned

Alder ------------- *Alnus* spp.
Ash, white -------- *Fraxinus americana* L.
Aspen ------------- *Populus* spp.
Basswood --------- *Tilia* L.
Beech ------------- *Fagus* L.
Blackgum --------- *Nyssa sylvatica* Marsh.
Buckeye ---------- *Aesculus* L.
Cherry, black ----- *Prunus serotina* Ehrh.
Cucumbertree ----- *Magnolia acuminata* L.
Dogwood ---------- *Cornus florida* L.
Elm -------------- *Ulmus* spp.
Hemlock ---------- *Tsuga* (Endl.) Carr.
Hickory ----------- *Carya* Nutt.
Maple
  red ------------- *Acer rubrum* L.
  sugar ----------- *A. saccharum* Marsh.
Oak
  black ----------- *Quercus velutina* Lam.
  blackjack ------- *Q. marilandica* Muenchh.
  bur ------------- *Q. macrocarpa* Michx.
  chestnut -------- *Q. prinus* L.
  northern red ---- *Q. rubra* L.
  post ------------ *Q. stellata* Wangenh.
  scarlet --------- *Q. coccinea* Muenchh.
  white ----------- *Q. alba* L.
Pine
  pitch ----------- *Pinus rigida* Mill.
  shortleaf ------- *P. echinata* Mill.
  Virginia -------- *P. virginiana* Mill.
Sassafras --------- *Sassafras albidum* (Nutt.) Nees
Sourwood --------- *Oxydendrum arboreum* (L.) DC.
Sumac ------------ *Rhus* spp.
Sweetgum -------- *Liquidambar styraciflua* L.
Sycamore --------- *Platanus* L.
Walnut, black ----- *Juglans nigra* L.
Yellow-poplar ----- *Liriodendron tulipifera* L.

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