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North Central
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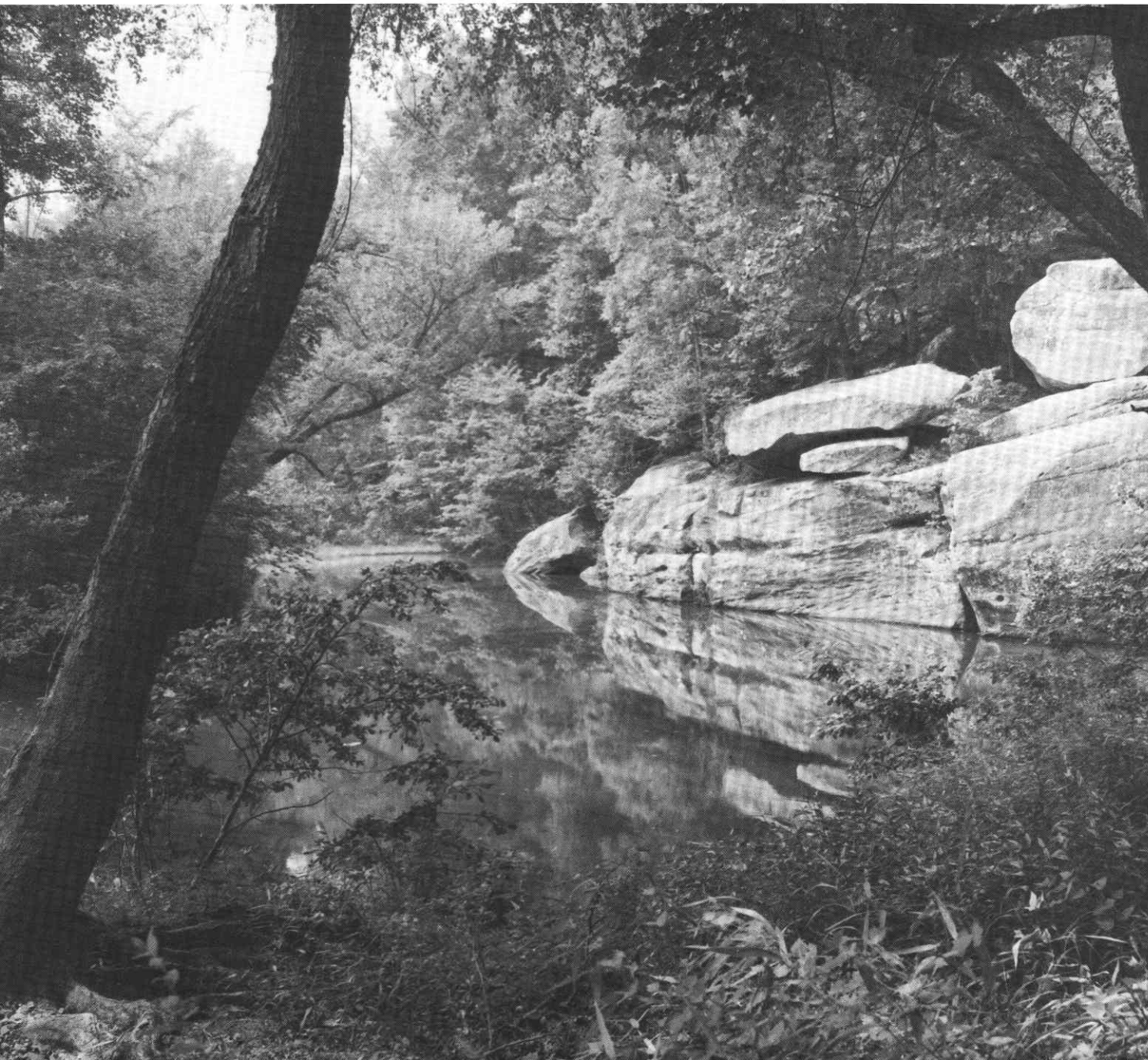
Central Hardwood Notes



CENTRAL HARDWOOD NOTES

F. Bryan Clark, *Technical Editor*

Jay G. Hutchinson, *Editor*

A cooperative project by the USDA Forest Service
Northeastern Area, State and Private Forestry
Northeastern Forest Experiment Station
North Central Forest Experiment Station
Southern Forest Experiment Station

FOREWORD

The *Central Hardwood Notes* brings half a century of research results and forest management experience together under one cover for day-to-day use by natural resource professionals and landowners. The expertise of 93 scientists and practitioners from the USDA Forest Service, universities, State conservation agencies, and industry has been consolidated in 85 notes on managing the multiple resources of the central hardwood forest. We are grateful for the time and talents the authors put into this book and for the support given them by their employers.

The model cooperative effort that produced the *Notes* began years ago when forest managers called on researchers to provide central hardwoods research results in a practical easy-to-use form. Rod Jacobs, Northeastern Area State and Private Forestry (NA-S&PF), played a significant role in bringing that message to Research. Initial decisions about the contents of the book and potential authors were made by a steering committee made up of technical experts from Purdue University, the Missouri Conservation Department, and the Forest Service including Region 9, NA-S&PF, the North Central Forest Experiment Station (NCFES), the Northeastern Forest Experiment Station (NEFES), and the Southern Forest Experiment Station (SOFES).

Dr. F. Bryan Clark, retired Associate Deputy Chief of the Forest Service and central hardwoods researcher, was Project Coordinator. I also helped to get this project started and keep it on track. Martin Dale, NEFES; Ivan Sander and Bob Cecich, NCFES; and Dave Graney, SOFES; contributed a great deal of time and expertise as technical advisors to the authors. Jay Hutchinson, NCFES, and Bry Clark edited the Notes. Aside from the formally designated cooperators, we received many helpful suggestions of topics and authors from State Foresters, university department heads, National Forest managers, and key industry associations. Although the Notes were published by NCFES, their development was supported equally by NEFES, SOFES, and NA-S&PF.

We encourage you to make copies of individual notes to use in the field or as handouts at training sessions and to use the whole book as an office reference. It is in a looseleaf format so that notes may be easily added. We encourage you to suggest new topics and have included comment cards in the back to assist you in giving us your ideas. By sending in a card, you will also be placed on the mailing list to receive new notes. Please drop one in the mail now with your initial comments and suggestions, and send us one later after you've had a chance to use the *Notes*.

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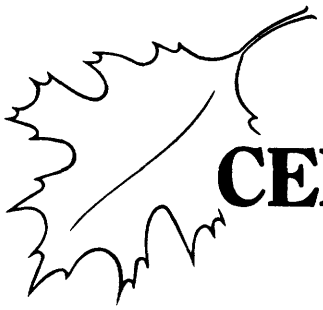

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Sacred Trust

In the wigwams and the tepees
Slept the "prynces of the forest,"
Slept Tecumseh and the Shawnee and their federated brothers.
In the shelter of their wigwams
Slept they all in naive slumber.

To the countries of the chieftains
Came the trappers and the traders,
Came the settlers and the soldiers,
Came the builders and the craftsmen,
Came the raiders of the bounties of the vast primeval woodlands.

And the sound of falling timber
Filled the pristine light of morning,
Stilled the birdsong and the chatter
Of the wildlings of the woodland,
Sent them scurrying to their burrows,
Sent them hurrying for cover
In the mighty oaks and hickories of the province of the "prynces."

Descendants of the great Tecumseh
Walk no more their sacred haunts,
Walk no more among the wildflowers
Learning lessons from the leaves,
From the leaves of all the species growing in their territories.

For those descended from the settlers
Of three hundred years ago,
All the plants and living kingdoms in the regions of the hardwoods
Are a trust to be conserved,
To be improved, to be restored,
All the woodland populations are a trust to be restored
For the peoples of our nation,
For the peoples of the world.

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CENTRAL HARDWOOD NOTES

The Central Hardwood Forest

The central hardwood forest covers a vast area of the United States where the dominant native vegetation is hardwood trees. it is one of the largest forest areas in the country and contains about 100 million acres. The forests include more than 70 hardwood tree species, several conifers, many shrubs and herbaceous plants, and a large number of animal species. This great richness of plants and animals is the result of a wide diversity of soils, geology, geography, and climate. Although much of the original forest was cleared for agriculture, woodlands remain a dominant feature of the landscape. Aside from scenic beauty these forests provide recreation, water, timber products, fuel, and essential habitats for wildlife. The social and economic benefits of the central hardwood forests, while of great value, can be increased substantially with better management.

Central hardwoods, area of application.

Plant and animal associations within the central hardwood forest are both broad and diverse, yet they have enough in common for us to prescribe management techniques in these Notes. For this purpose the central hardwood forest is defined as the general area included in the oak-hickory forest cover type in the National *Atlas,* Major forest *Types,* 1967. However, the Notes do not cover the deep south or the east. Even so, much of the technical information can likely be applied to similar forest types outside the area in the figure. Two forest types geographically associated with the oak-hickory type, the elm-ash-cottonwood (bottomlands) and the oak-pine, are included in the /Votes. But the maple-beech-birch and oak-gum-cypress associated types are excluded.

Climatic factors provide boundaries for the central hardwood forest on the north, south and west. Mountains provide a general boundary on the east. Within this broad forest area, there are numerous plant and animal communities or ecological associations. The area is biologically diverse because of wide differences in site factors which often change abruptly within short distances. In the hill country one can go from a small stream bottom with moist site species to a ridgetop with dry site species in a span of only 600 to 1,000 feet; 3 or 4 different forest types might be encountered. Without a sharp change in topography-such as a bluff or a bench-there would be no sharp boundaries between the forest types. Species associations merge into one another as microclimate and moisture change.

Because of the species and site variation much of the information in the Notes is presented by site, species or species groups. Where possible, reference is made to four distinct tree associations: (1) oak-hickory, (2) oak-pine, (3) mixed hardwoods, and (4) bottomland hardwoods.

The present forests are far different from those at the time of European settlement more than 300 years ago. The impact of man-caused fire, grazing, cutting, and clearing for agriculture followed by abandonment have made profound changes in the mix of tree species and their size, age, and condition. Understory vegetation and animal populations are also greatly different. Even though some of the past impacts were drastic, most of the forest sites still retain their original capacity to support healthy plant and animal populations. Both the gypsy moth and air pollution could potentially change the growth and composition of central hardwoods. In spite of the long history of clearing for agriculture the forest acreage in the central hardwoods has been fairly stable for the past few decades. Future net losses of forest land, through continued encroachment from urban expansion and stripmining for coal, will probably be minimal.

As far as we know, today's forest includes nearly all of the tree species found at the time of settlement. American chestnut, due to the blight, is now gone from the overstory but still persists in the understory as sprouts that live only a few years. American elm has been greatly reduced in many areas due to disease. Aside from these two tree species there is no specific evidence that significant plant genetic potential has been lost. Several species of large mammals have been eliminated but most other animal species have viable populations.

Most of the forest stands are middle-aged having been harvested near the turn of the century. Current growth of the forest exceeds what is removed through harvest and mortality and the growing stock has increased steadily. The negative side of this situation is that economic opportunities to manage young stands are poor due to lack of markets for small, low quality trees. Demands for large, high quality trees

exceed supplies and real prices for this kind of raw material continue to increase. Demand for hardwood timber is projected to nearly double by the year 2030. What really happens in terms of how much timber is harvested and how the forests are managed in the future will depend upon the decisions of thousands of owners in the region. Three-fourths of all the forest land is controlled by small, private, nonindustrial owners who have many different reasons for owning and many different attitudes toward managing their land.

The central hardwood forest provides raw materials for an economically important forest industry that takes advantage of some of the unique characteristics of hardwoods for hundreds of uses. Some of the world's most valuable woods come from this area. Fine furniture, paneling and flooring made from hardwoods have been highly prized since colonial times. And large amounts of central hardwoods are used every day in the manufacture of railroad ties, pallets, lumber and paper. Wood for energy is becoming a more important forest product. These forests also provide an essential part of the environment for one-fourth of the U.S. population. Scenic beauty, water, wildlife and recreation are all very valuable products of the central forests.

The prospects for more benefits from the central hardwood forest are improving as they mature. This does not mean that future forests will automatically be more productive and more profitable. Unless more deliberate management is applied to private land, we may simply go through another cycle of harvesting without regard for future timber crops and without concern for wildlife, water, recreation and esthetics. There is good reason to believe that many forest land owners and managers would improve both comsumptive and nonconsumptive uses of forest land if given practical treatments and alternatives. The land and the growing stock still has the inherent ability to produce quality products for both domestic and international consumption. Through better management and more dedicated land stewardship we can improve present forests for our own benefit and furture forests for generations to come.

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CENTRAL HARDWOOD NOTES

Central Hardwood Forest Types

Each of the four broad forest types, often called associations, that you will read about in these Notes is a complex, highly variable mixture of trees, shrubs, and herbs. This Note describes the species you will generally find in each type.

Oak-Hickory

This upland type is the most widespread and currently covers the greatest area. The great range of climate, soils, and topography over which it occurs results in a wide variety of species. Oaks dominate with white, black, scarlet, and northern red being most abundant throughout the central hardwood forest. Post oak and blackjack oak occur frequently in the western part of the area and chestnut oak may be important in the eastern part of the region. Other oaks that may also be present are southern red, chinkapin, bur, and northern pin. Everywhere hickories are a minor but consistent component. Other important overstory tree species that may be present include black gum, yellow-poplar, red and sugar maples, white ash, elms, American beech, black walnut, and occasionally black cherry.

Many small tree or understory species occur in oak-hickory stands. The most common ones are flowering dogwood, sassafras, redbud, serviceberries, eastern hophornbeam, and American hornbeam. Sourwood is common in the eastern part of the region. The most common woody shrubs associated with oak-hickory are witch-hazel, blueberries, mountain-laurel, and beaked hazel.

Oak-Pine

This upland type generally occurs on the drier sites in the southern part of the central hardwood forest. It is very similar to the oak-hickory type except that shortleaf, loblolly, pitch, and Virginia pines, singly or in combination, make up 25 to 50 percent of the stand. The remainder is made up primarily of oaks but other hardwoods associated with oak-hickory may also be present.

Mixed Hardwoods

This type does not occur west of the Missisippi River except in one small area known as Crowley's Ridge in northwest Arkansas and southwest Missouri. East of the Mississippi River it is found primarily on the moister, more productive sites. It is composed of a greatly varying number of species none of which is generally predominant. The principal species are yellow-poplar, white oak, northern red oak, and sugar maple. White ash, black oak, chestnut oak, red maple, and blackgum occur frequently and hickory is usually present. Many other species may be found in the mixture including basswood, buckeyes, cucumbertree, and occasionally hemlock, black cherry, black walnut, and butternut.

Common understory species include flowering dogwood, eastern redbud, service-berries, American hornbeam, sourwood, and sassafras.

Bottomland Hardwoods

This type occurs on the flood plains and terraces of the many rivers and small streams in the central hardwood forest. The lands it occupies may be subject to annual flooding but do not include areas where water remains permanently (the true swamps) during the growing season. A great number of species occur in highly variable mixtures. Important species that can be found in this association include cottonwood, elm, ashes, river birch, red and silver maples, sycamore, hackberry, sugarberry, pecan, and sweetgum. Nuttall, pin, willow, cherrybark, overcup, swamp chestnut, Shumard, and water oaks may also be present.

Within each of these associations, many individual forest cover types, as defined by the Society of American Foresters, are present.

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CENTRAL HARDWOOD NOTES

Ecological Principles: Climate, Physiography, Soil, And Vegetation

The central hardwood region is a land of transitions in climate, physiography, soils, plants, and animals. Winter temperature and drought are the two most important climatic variables operating on plants and animals. Occasional severe periods of low winter temperatures in the northern half of the region restrict the northern occurrence of many plant and animal species. Summer drought is the most important factor, increasing from east to west in the region and to a lesser extent from north to south. Fire interacts with drought directly and is more ecologically important in the western and southern areas of the region.

Physiography interacts with climate to influence what species occur locally on different slope faces, slope positions, and elevations. North and east aspects are the most mesic or moderately moist sites, along with lower slopes on all aspects, especially in the southern half of the region. Soil is often deeper on lower slopes due to colluvial or gravity-caused deposits and water-holding capacity is greater. The mountains are not high enough to influence precipitation except on the western slope of the Appalachian Mountains. Here, and in the Cumberland Mountains of Kentucky and Tennessee, lower summer temperatures mean less evapotranspiration and more available soil moisture than in other parts of the region.

Soil moisture, aeration, and to a lesser extent available nutrients, exert the main influence on vegetation. Soils of the glaciated area in the northern parts of the region tend to be deep and fertile but surface drainage is often limited. These soils are predominantly mesic or wet depending on microtopography and internal drainage. In southern Illinois, Indiana, and Ohio, internal drainage on level areas is impeded and aeration restricted. These soils are wet during winter and dry during summer.

Soils of the southern hilly regions vary in depth, fertility, and texture. Limestone soils in parts of southern Indiana, central and western Kentucky, and central Tennessee vary from shallow to deep. Plant nutrients are often limited where soil weathering is advanced. Limestone-derived soils tend to support more plant species and are more productive than sandstone soils. Soils are especially shallow and droughty in the Nashville Basin and the Kentucky Bluegrass region. Upland sandstone soils in Tennessee and Kentucky are often shallow and nutrients are usually limited.

Loess deposits of varying depths occur in parts of northern Missouri, Iowa, and from southern Illinois to southern Ohio. These windblown materials form silty soils that are often high in most plant nutrients and favor tree growth. Loess caps may

occur on ridge tops creating better sites than adjacent south or west slopes. Fragipans, which obstruct air and water movements, may develop on level and gently rolling topography. Rooting depth is severely limited and tree growth and composition are adversely affected when fragipans are near the surface.

On bottomland, small variations in relief from just inches to a few feet provide markedly different growing conditions for trees. Low areas of slackwater, or former sloughs, remain inundated or wet most of the year and only support a few tree species. Higher areas can range from poorly to excessively drained and species composition and tree growth can vary from poor to excellent. Productive upland-like, mesic forests occur on higher bottomland areas that have medium to coarse textured soils with adequate moisture and freedom from flooding.

Species occur in north-south and east-west gradients produced by the combinations of climate, geology, physiography, and soils. The pattern of local occurrence can be very complex depending on site conditions and past disturbance. This diversity of species and site presents a wide range of management options.

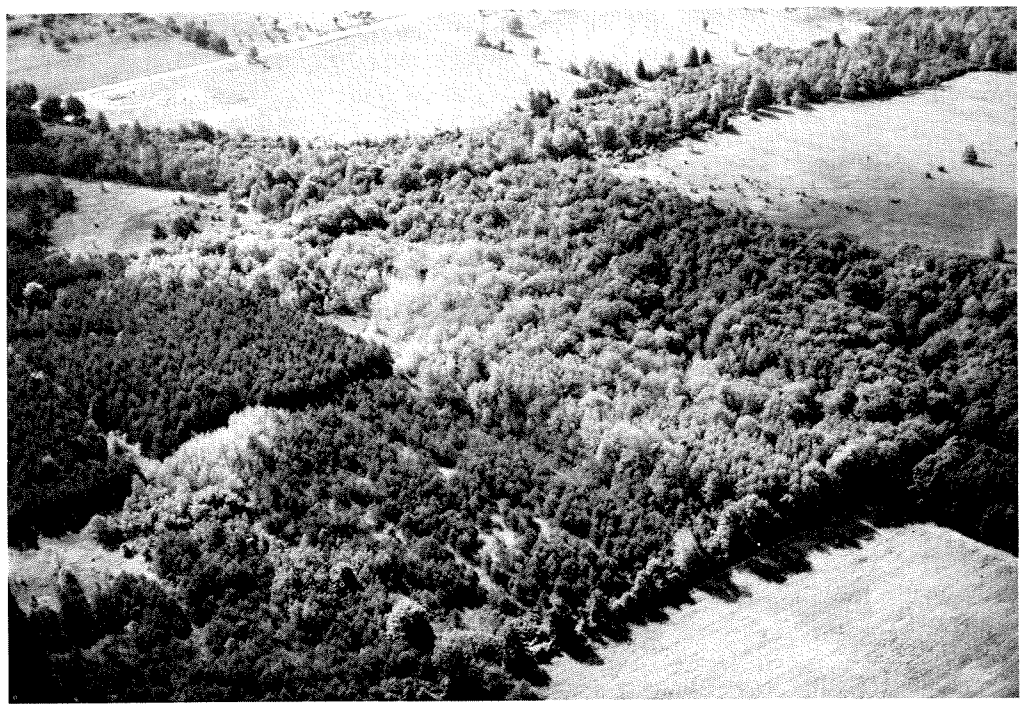
Extremely wet, dry, or infertile sites generally support fewer tree species than mesic sites and are less apt to change in species composition after disturbance. However, severe disturbance on extreme sites may result in decreased site potential, loss of species, and delays in regeneration. On the species-rich mesic sites it is more difficult to predict species composition after disturbances such as timber harvests. However, these sites generally require more understory treatment to shift species composition. Mesic sites can withstand more severe disturbance without loss of species than extreme sites.

The species composition of the overstory of most current forests has been strongly influenced by human disturbance starting in the 1800's. Early Europeans practiced a "slash and burn agriculture" similar to that used by Native Americans in the region. This consisted of clearing understories of mesic forests, girdling overstories, and burning slash piles around standing large trees. Many cleared areas were abandoned after a few years due to low fertility and declining productivity. Natural reforestation followed. The practice of slashing maple stems for sap production reduced the abundance of this species. Other practices such as coppicing for charcoal were important locally. Extensive areas in the southern hilly areas of the region were logged in the early 1900's with little concern for the composition of the new stands.

Widespread burning and grazing continued in these forests until the 1930's. Since that time, the primary disturbance has been periodic timber harvests while disturbance to the understory has been greatly reduced. This has allowed shade tolerant species to re-invade.

Past land use practices have resulted in widespread oak-dominated stands which are not stable ecologically. Currently, over much of the region stands dominated by oaks are trending more toward tolerant mesic hardwoods such as sugar maple on all but the more extreme wet and dry sites. There is evidence that the trend toward domination by sugar maple and other shade-tolerant species will result in lowered biotic diversity.

Another ecological problem confronting the resource manager in the central hardwood region is fragmentation of the forest landscape through agricultural clearing, road systems, and urban development. Fragmentation began in the early 1880's and was nearly complete in the northern half of the region by the 1890's. Forests in the southern half of the region are less fragmented today than they were at the turn of the century due to more public forest land and reforestation of abandoned croplands. However current pressures for pasture, stripmining, and urban development result in continued clearing of forest on private land throughout the region.



Forest fragmentation can result in fewer plant and animal species. (A. Steven Munson)

Fragmentation results in small, isolated woodlands with increased “edge” and potential loss of genetic diversity. Edge areas generally have lower tree and site quality with increased potential for invasion by exotic and/or pest species. Isolated forest stands have less chance to regain genetic diversity lost through poor management. While there is still much to learn about the effects of fragmentation, a general recommendation is to maintain large management units where possible and to increase the size of small forest areas where feasible.

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CENTRAL HARDWOOD NOTES

Genetic Principles

Tree growth is a function of both environment and genetic makeup. All forest management activities during a rotation from establishment to harvest affect the genetic composition and the environment of a stand. Silvicultural practices which fail to take both of these factors into account will reduce forest productivity.

Moderate to strong genetic control has been demonstrated in several central hardwood species for quality characteristics such as growth rate, stem straightness, branch size and angle, response to wounding, pest resistance, and heartwood formation rate. Forest management affects the genetic makeup of the forest primarily through the process of selection that allows trees with certain traits to contribute more offspring to succeeding stands than trees with different traits. The type of trees you select to reproduce the stand can improve or reduce future forest productivity and timber quality.

Many stands throughout the central hardwood forest have been highgraded several times. This practice is dysgenic. It can reduce genetic quality by removing larger, higher quality trees, which may also be of higher genetic quality. Small, poor quality, and probably genetically inferior trees are left to produce future stands. Continued highgrading can produce stands that are genetically incapable of reaching the productive capacity of the site.

Fortunately, we have opportunities to maintain or even increase the genetic quality of central hardwood stands. Artificial reforestation with genetically improved planting stock is the fastest way to obtain genetic improvement. Natural stands can also be improved. Although slower than using artificial regeneration, genetic improvement of natural stands will have a greater overall impact on central hardwood forest productivity because 95 percent or more of all central hardwood stands are being and will be regenerated naturally.

Artificial Regeneration

At present, artificial regeneration of central hardwood species is limited to a few high value species. Black walnut is the only species being managed in plantations on any significant scale. Red oak is being underplanted or interplanted to a limited extent to supplement natural regeneration in clearcuts and shelterwoods.

Plantation productivity can be improved most rapidly using a combination of genetically superior planting stock and good cultural practices. Seedlings from seed orchards of proven genetic superiority are the most desirable planting stock for artificial regeneration. Black walnut seed orchards are being developed by state forestry agencies in the central hardwood region, but these orchards presently produce limited amounts of seed.

Significant genetic improvement can also be obtained quickly by using seed from the best available sources of a species for artificial reforestation. Geographic seed source (provenance) tests for a number of central hardwood species have shown the following: (1) seedlings from local sources, those from near the location of the test site, are usually average or above average in survival or growth, but are seldom the very best seedlings in the tests: (2) seedlings from nonlocal sources, often originating a considerable distance from the test site, frequently outperform those of local origin; and (3) seedlings from other nonlocal sources, again often originating a considerable distance from the test site, are poorly adapted and exhibit poor survival and slow growth. Therefore, use seedlings from good local stands or above average individual trees to establish plantations unless seedlings from nonlocal sources are proven superior in long-term tests. Nonlocal, unproven seedlings for reforestation can lead to severe growth losses and plantation failure.

Natural Regeneration

General Considerations

Genetic improvement in naturally regenerated stands mainly exploits the genetic differences among individual trees within a single stand. Opportunities for genetic improvement during natural stand regeneration are greatest when potential parent trees are selected in advance, either by being favored as crop trees in an intermediate treatment, or by being selected to leave standing in seed tree, shelterwood, or selection harvests.

Stands arising from advanced regeneration established prior to the parent tree selection or established after overstory removal from seed stored in the forest floor (e.g., black cherry, yellow-poplar, and white ash) will likely have a genetic makeup similar to the preceding stand. Opportunities for genetic improvement of these stands occur during weeding and release operations after stand establishment and during thinning before the reproduction cut.

Dense stands of natural regeneration increase your opportunities for selection. You can secure abundant reproduction by preparing optimum seed beds and by timing regeneration cuts to coincide with good seed crops of desired species to increase chances for selection in subsequent treatments. For example, sugar maple can produce over 2.5 million seeds per acre in a single season. Typically, about 50 percent of these germinate, but only 5 percent of the germinants survive to the end of the first growing season. Mortality over the following year reduces the population to less than 0.5 percent of the seed originally produced. However, this still leaves 10,000 to 15,000 seedlings per acre for subsequent selection.

Regeneration Systems

Clearcutting is usually genetically neutral. Depending on the species being harvested and the season of the harvest, stands may originate from advanced regeneration, from seed or sprouts produced by the trees being removed, or from seed

produced by trees surrounding the cleared area. Since no parental selection is imposed during the reproduction cut, little if any change in genetic quality will occur between generations. Genetic improvement can be obtained by selection during release and thinning before clearcutting and by securing abundant regeneration to increase selection opportunities in later stages of stand development.

The shelterwood system can be used to advantage in stands with mixed species to make genetic improvement within species and to improve the proportion of desirable species in the new stand. Remove poorly formed or diseased trees in a preparatory cut and leave the best individuals for seed production. Resistance to disease and the ability to recover from damage (such as logging injury) are moderately to highly heritable in central hardwood species. Give these traits priority along with growth rate, form, and seed production ability when selecting trees to leave for the shelterwood.

The selection system permits continual genetic upgrading of uneven-aged stands if applied conscientiously. However, most central hardwood stands are relatively even-aged, or have at most only two or three age classes; so the mixture of tree sizes often represents differential growth rates as well as different age classes. If only large trees are continually removed in the name of selection silviculture, genetic decline is the inevitable result. Poorly formed, diseased, and weak trees of all size classes must be removed in each cutting cycle, along with mature trees. Illegitimate 'selection systems' such as diameter-limit cuts and highgrading are systematically dysgenic.

Intermediate Stand Culture

Intermediate treatments from the earliest cleaning/weeding operations through commercial thinnings can genetically improve all stands, natural or planted, whether they originate from seedlings or sprouts. Eliminate poor quality trees before they can contribute to the next generation either by pollen, seed, or sprouts. This will enhance both the economic and genetic quality of the residual and subsequent stands. As a general rule, thin from below. Thin from above only to favor desirable but slow-starting species overtopped by less desirable species or to eliminate previously unharvested cull trees.

Summary

The genetic principles applicable to manage central hardwoods are easy to put into practice. Indeed, good silviculture is good forest "germplasm management." Modern forest practices designed to maintain diversity and discriminate against obviously inferior individual trees will result in genetically improved central hardwood stands.

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CENTRAL HARDWOOD NOTES

Forest Regulation Methods And Silvicultural Systems: What Are They?

"Forest regulation methods" and "silvicultural systems" are important forest resource management concepts but there is much confusion about them. They often mean different things to different individuals. Confusion exists in part because "forest regulation methods" and "silvicultural systems" often use the same terminology. Also, the regulation methods described in forestry literature were conceived and developed to produce regular sustained yields of timber products from a forest. Now, there are often resources or values other than timber that may be more important to a forest landowner. Here is how we interpret and use these terms in the Central Hardwood Notes.

Forest Regulation Methods

The regulation method details the way cuttings over the entire forest property will be controlled. There are two methods for regulating cutting-even-age or uneven-age. In the even-age method, cutting is regulated by dividing the forest property into stands that are regenerated as they reach the specified rotation age (maturity). Thus, all trees in each of the stands are of approximately the same age. In a fully regulated forest there is the same total area in each age class. In the uneven-age method (sometimes called all-age or uneven-size), trees of many ages or sizes form a relatively homogeneous mixture in a stand. Cutting is regulated by periodically removing trees of all sizes to achieve and maintain a specified diameter distribution. Enough reproduction must be obtained at each cutting to sustain the diameter distribution. In a fully regulated uneven-aged forest all stands have about the same character, but vary in appearance with time of last cutting.

In theory, strict adherence to either of these methods to control cutting lead to regular, sustained timber yields, provided they satisfy the ecological requirements of the species being grown. When regular, sustained timber yields are not the primary objective, the controls can be adjusted to achieve other objectives. In fact, a forest can be managed using a mixture of both even-age and uneven-age management methods and silvicultural systems, although this is a much more complex and difficult approach to forest management.

Silvicultural Systems

A silvicultural system is applied to individual stands and is designed to grow specific tree species for specific purposes. It details the whole set of cultural treatments that will be applied to a stand, including weedings, cleanings, thinnings, salvage, sanitation, and improvement cuttings, pruning, site preparation, and finally the regeneration method for either natural or artificial regeneration. For convenience, silvicultural systems are commonly named for the regeneration harvest method and may result in even-aged or uneven-aged stands.

Forestry literature defines three standard even-age regeneration harvest methods (silvicultural systems) and two uneven-age regeneration harvest methods (silvicultural systems). Clearcut, shelterwood, and seed tree are even-age regeneration methods. Single tree selection and group selection are uneven-age regeneration methods.

You as a resource manager have much flexibility in designing silvicultural systems and it is not critical that a system conform exactly to the described standards if regular, sustained timber yield is not primary. This flexibility allows you to successfully manipulate forest stands to attain single or multiple-use objectives. The major requirements are that the system applied will: (1) produce the environments required for regeneration, (2) yield acceptable growth of the species wanted, and (3) satisfy the forest property ownership objectives.

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CENTRAL HARDWOOD NOTES

Choosing A Silvicultural System

What to Consider When You Choose a Silvicultural System

Based on the species present and environmental limitations, your choices depend on:

1. Owner objectives.
2. Species selected for regeneration.
3. Growth requirements of desired species.
4. Site productivity.
5. Stand characteristics such as tree age, species, density, and regeneration potential.
6. Existing climatic and soil conditions.

Landowners frequently have definite objectives and preferences that should influence the selection of a silvicultural system. Timber production is not the primary reason many landowners practice forestry, and silvicultural practices must be flexible enough to provide other "products" such as wildlife, esthetics, and recreation.

Silvlcultural Systems for Even-age Management

Even-age management includes clearcutting, shelterwood, or seed-tree silvicultural systems. Clearcutting is harvesting in one cut all trees on an area to create a new, even-age stand. The area harvested may be a patch, strip, or stand. You obtain regeneration through advanced reproduction or new seedlings, through stump or root sprouting, or through planting or direct seeding.

In the shelterwood system, the mature stand is removed in a series of cuts. Regeneration of the new stand occurs under the cover of a partial forest canopy or shelterwood. A final harvest cut removes the shelterwood and permits the new stand to develop in the open as an even-age stand.

In the seed tree system nearly all the trees on a selected area are harvested in one cut. A few select trees of the desired species are left to reseed the area naturally. After regeneration is established, the seed trees are removed. You rarely use this method in hardwoods.

These even-age systems are alike in one respect-you remove all the overstory trees within a short period. The regeneration cut is normally made only once per rotation, and the rotation is marked abruptly by the end of one stand and the beginning of another on the same area. Usually the regeneration cut is followed by a series of intermediate practices such as cleaning, crop tree release, and/or thinning before the next regeneration cut. The rapid removal of the overstory normally favors the regeneration of fast-growing, intolerant species although a

mixture of tolerant and intolerant species is common and provides a variety of species to manage in the new rotation.

A disadvantage of even-age management is that areas look unsightly during and after logging. The unsightliness often persists until regeneration develops into sapling or pole-size stands. Another problem is that clearcuts encourage many landowners to graze livestock in newly harvested areas and severely retard the regeneration. Sometimes deer cause similar problems.

Systems for Uneven-age Management

Uneven-age management includes the selection silvicultural system. In this system, you cut mature and immature trees either singly or in groups at periodic cutting intervals. Regeneration is continuously established and residual trees are provided space to grow and develop. The objective is to create a stand with trees of different ages and sizes.

You reach this goal by a series of periodic partial cuts over the entire stand. The basic idea with selection cutting is to maintain a stand with trees in all diameter classes. Advanced reproduction will be present in the understory or in small openings created by cutting groups of trees. Shade tolerant species eventually dominate uneven-age stands that are managed by single-tree selection. You can encourage greater proportions of intolerant species by creating canopy openings at least a half acre in size. Often crop trees need to be released to maintain the desired stand composition.

Diameter limit cuts are usually not recommended, but they are commonly practiced throughout the region. Some stands with well developed advanced reproduction of the desired species can be cut using a diameter limit. This reduces the overstory shade and releases the emerging dominant understory trees. It also allows you to remove those undesirable overstory trees that are future sources of unwanted seed. If you use diameter limits, consider at least a minimum cutting diameter of 16.0 inches d.b.h. and also remove undesirable trees below this minimum.

Summary and Recommendations

Both the even-age and uneven-age management silvicultural systems have some objectives in common-trees are cut to produce market goods and to ensure regeneration and maintain the desired diameter and age distributions. All silvicultural systems need to include some intermediate cultural practices to maintain vigorous growth of quality trees and ensure the efficient production of the key species.

- If you plan to manage your woodlot, yet want it to remain somewhat esthetically appealing, use a partial cutting practice such as single-tree selection.
- If you want new stands dominated by a variety of shade intolerant and some tolerant timber species and there are no wildlife problems such as severe browsing by deer, use clearcutting or a type of shelterwood.

- If you want to increase the amount of intolerant species in your woodlot, and you do not want to clearcut the entire stand, clearcut small openings of 0.5 to 2.0 acres about every 10 to 20 years.
- If you want to periodically increase deer browse or wildlife "edge species," cut small openings of 0.5 to 2.0 acres every 10 to 20 years.
- If you want new stands dominated by shade tolerant timber species, use partial cutting such as single-tree selection.
- If you cut to a diameter limit, raise the minimum size to at least 16.0 inches d.b.h. Also remove undesirable trees below the minimum cutting diameter.
- If you want timber species and have oak-pine or bottomland hardwoods, use clearcutting, shelterwood, or seed tree practices.
- If you want to increase the number of cavity or den trees in your woodlot leave a few trees such as beech, basswood, blackgum, birch, oaks, hickories, and/or maples.

There are many ways to manage forest stands, and there are no simple rules to meet the wide variety of landowner objectives for all stand conditions. The key to making good silvicultural recommendations is to start with the landowner's highest priority. The burden is then on the forester to inform the landowner of alternatives and guide the development of a management plan. A well informed landowner must at least know the major trade-offs at stake and the consequences of the various alternative silvicultural systems.

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CENTRAL HARDWOOD NOTES

Silvicultural Systems For Oak-Hickory And Oak-Pine

This Note covers only applying the regeneration component of silvicultural systems and assumes that the objective is to reproduce oaks. Thinning and stand maintenance are covered in other notes.

Most central hardwood stands are dominated by oaks, but as we harvest present stands the reproduction will contain larger numbers of other species and fewer oaks. Basic ecological processes are at work so this is likely to occur no matter what silvicultural system you use (see Note 2.01 Ecological *Principles: Climate, Physiography, Soil, and Vegetation).*

When planning harvest cuts to regenerate oak-hickory stands, you must first evaluate the potential of the existing advance oak reproduction to replace the stand *(see* Note 3.02 *Assessing Regeneration Potential).* The results of this evaluation will help you determine which regeneration method is best.

Even-Age Methods

- Seed Tree-This method is not recommended for reproducing oaks. Leaving only a few seed trees per acre will result in poor distribution of the heavy seed and any newly established oak seedlings will not be able to survive the competition from rapidly growing sprouts and other vegetation.
- Clearcutting-This method is appropriate when the amount of oak advance regeneration *plus* stump sprouting is adequate to replace the stand.

Steps to apply clearcutting:

1. Determine size of area to be designated as a stand. Stand size can be variable. The minimum size recommended is 2 acres. Stands smaller than 2 acres have a large proportion of their area in the border zone where reproduction grows slowly because of competition from surrounding trees. Generally you should restrict the stand to a single condition or size class of timber and site quality. Size of the forest property will also influence stand size.
2. Arrange and shape clearcuts so they mingle with uncut stands and blend into the landscape as much as possible.
3. Harvest all merchantable trees.
4. Cut or kill remaining culls and small trees larger than about 2 inches d.b.h. Killing the culls instead of cutting them will provide nesting holes and perches for birds. Cutting some of them will also provide habitat for some other wildlife species *(see* Notes *9.05 Treating Mature Stands for Wildlife; 9.06 Enhancing Wildlife Habitat When Regenerating Stands; 9.07 Stand Size, Distribution, and Rotation Length for forest Wildlife).*
5. Composition of the new stands will vary according to where the forest property is located within the central hardwood forest. In the eastern part of the region

on the more moist, productive sites, the new stands may also contain yellow-poplar, white ash, black cherry, red and sugar maple, beech, and probably minor amounts of other species. On the drier sites the new stands will be essentially pure oaks when they reach 15 to 20 years of age.

- Shelterwood-If there is not enough oak advance reproduction to replace the stand, you should use the shelterwood method. Inadequate oak advance reproduction is most likely on the middle and lower north and east facing slopes throughout the central hardwood forest. The shelterwood method can be used for either natural oak reproduction or for planting oaks (see Note 3.06 *Seeding and Planting Upland Oaks).*

Research to design shelterwood methods that will consistently reproduce oaks successfully is incomplete. Current studies should provide better information in the next 5 to 10 years. The best information available follows.

Steps to apply shelterwood cutting:

1. Determine stand size the same as for clearcutting.
2. Control the understory that will compete with the small oaks by cutting or preferably killing the unwanted species up to about 2 inches d.b.h.
3. Reduce the overstory to about 70 percent stocking. Leave the best dominant and codominant trees as uniformly spaced as possible. Kill all unmerchantable trees larger than 2 inches d.b.h.
4. Monitor seedling establishment and growth and make additional light overstory cuts if needed. Control the understory again if it redevelops to a point where it restricts the growth of oak reproduction.
5. When a survey shows the regeneration potential of the oak reproduction is adequate to replace the stand, remove the remaining overstory trees in one cut *(see* Note *3.03 How To Assess the Oak Regeneration Potential in the Missouri Ozarks).*

The length of time required to get oaks established and let them grow to adequate size is not yet known but will probably be 20 years or more.

Uneven-Age Methods

- Single Tree Selection-This method is not recommended for reproducing oaks because it gradually reduces the number of oaks in the overstory and creates conditions that are more favorable for reproducing shade-tolerant species. Small oak seedlings are unable to grow into the main canopy under a single tree selection.
- Group Selection-This method can be used to reproduce oaks satisfactorily. The groups must be kept small. The diameter of a circular opening should not exceed l-2 times the height of the dominant trees in order to maintain the uneven-age character of the stand.

Steps to apply group selection cutting:

1. Evaluate the potential of the oak advance reproduction to fill each opening (group) created by cutting (see Note 3.03 How *To Assess the Oak Regeneration Potential in the Missouri Ozarks).*
2. If the oak advance reproduction is adequate, harvest all merchantable trees in the group cut or kill all remaining culls and trees larger than 2 inches d.b.h. in the group.
3. If the oak advance reproduction is not adequate to fill the opening, cutting to create the opening will not result in oak reproduction and the opening will be filled by whatever species is present in the understory. In this case follow the procedure for the shelterwood method where the openings will be located. The 70 percent stocking goal may not be attainable in the small groups so take care to leave seed-producing oaks in the planned openings. Removing the lower-story competition may be all that is needed to increase the amount of light needed on the forest floor to regenerate oaks.

Modifications for the Oak-Pine Type

Any of the even-age methods and the group selection method are suitable for regenerating oak-pine stands. Reproducing the pine component is likely to be difficult because the understory will be dominated by hardwoods. As in the oak-hickory type the oak component of the reproduction will come from advance reproduction. Oak advance reproduction is usually well established on oak-pine sites. Thus the goal will be to maintain or increase the pine component. The amount of pine reproduction will be determined by the presence of a seed source and the thoroughness of site preparation *(see* Notes 3.04 *Treatments to Encourage Natural Regeneration* and 3.10 *Seeding and Planting Pines).*

Steps to apply the seed tree method:

1. Leave 10 to 15 of the best seed producing pines per acre indicated by the presence of old cones on the trees.
2. Control unwanted hardwoods in the understory and prepare a seedbed
3. Harvest the seed trees 2 to 3 years after sufficient pine seedlings are established. Take care to disturb the reproduction as little as possible.

Steps to apply the clearcutting method:

1. Clearcut progressively from east to west in strips 100 to 200 feet wide to take advantage of the generally prevailing westerly winds for better pine seed dispersal. Allow 5 to 10 years between cuts.
2. Control unwanted hardwoods and prepare a seedbed as needed.
3. Direct seed or plant if natural seedfall is not adequate.

Steps to apply the shelterwood method:

1. Reduce the overstory stocking to 60 percent leaving seed-producing pine trees as uniformly spaced over the stand as possible. You will probably have to leave oaks in the residual shelterwood stand also.

2. Control unwanted hardwoods and prepare a seedbed as needed.
3. Remove the shelterwood 2 to 3 years after sufficient pine seedlings are established.

Steps to apply the group selection method:

1. Place groups so that seed-bearing pines are along or close to the border of the openings.
2. Control unwanted hardwoods and prepare a seedbed as needed.
3. Remove all overstory trees within the group.

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CENTRAL HARDWOOD NOTES

Silvicultural Systems For Bottomland Hardwoods

Bottomland hardwood forests normally regenerate with species found in the overstory. These species reflect the timing, duration, depth of water, and nature of the sediment in past flooding. The longer water stands during the growing season and the deeper the sediment, the fewer the species that are able to survive. Flooding patterns often change over the life of a bottomland hardwood stand. If conditions moderate, more species can regenerate the site; if flooding worsens and sediment builds up, fewer species can occupy the site.

There are three sources of reproduction in bottomland forests-"advanced" understory seedlings (seedlings already growing), stump and root sprouts from harvested trees, and new seedlings. Advance reproduction over 18 inches tall is the most dependable source of regeneration of moderately tolerant to tolerant species and the only dependable source for oak. Sprouts from the stumps of cut trees under 12 inches d.b.h. are a major source of acceptable regeneration for most species; maples, green ash, and sweetgum are the most prolific. Sweetgum is also a good root sprouter. American elm, sycamore, green ash, sweetgum, boxelder, red and silver maple, black willow, and eastern cottonwood sometimes produce dense new stands from seed.

Bottomland hardwoods can be managed even-aged or uneven-aged. Silvicultural systems you should use for even-age management are clearcutting and shelterwood; seed tree is not recommended. Clearcutting is best where sprouts from the stumps and roots of harvested trees and advance reproduction will combine to form an acceptable species mix in the new stand. Where advance reproduction is sparse, clearcutting may still be suitable if the seedbed is free of grass and herbs. Sprouts plus new seeds deposited by wind and/or water over a 2- to 3-year period usually result in an acceptable new stand of mostly light-seeded species. Shelterwood is best to perpetuate the heavy-seeded species that are growing in the overstory. However, it may take many years to develop good stands of oak reproduction due to infrequent seed crops and high seed losses to birds and animals. If the regeneration period is too long, you may have to release oaks from understory competition at the same time you remove the remaining overstory.

For uneven-age management, group and single tree selection can be used provided you can accept slower tree growth and a high proportion of relatively shade tolerant species. Group selection will allow some shade intolerant trees to develop but regeneration will be slower than under clearcutting. Single tree selection results in stands composed almost entirely of species with moderate to high shade tolerance. Examples are sweetgum, red and silver maple, green ash, hackberry, and American elm. Oaks establish in single tree openings but soon become

overtopped by other tree species. Although trees of sprout origin may grow rapidly during the first 5 years, they develop much more slowly in single tree openings than in clearcuts over 40 to 50 years.

Whatever way you open the stand for regeneration, it is important to remove all trees more than 1 inch d.b.h. to reduce competition to new seedlings and sprouts. Such a treatment is essential where there is a dense mid-story of low value species such as boxelder. You should leave small trees, regardless of species or quality, close to the boles of high-quality residuals around the edge of regeneration openings. The shade will reduce epicormic branching on residuals and maintain bole quality.

There is no good way to naturally regenerate stands of eastern cottonwood and black willow, although a few trees may establish following clearcutting. Existing natural stands have developed on new alluvium created by river flooding. Both species require bare mineral soil, full sunlight, and an almost complete lack of herbaceous competition, a combination rarely found in older natural stands. Recommendations are summarized in the following table:

SUMMARY TABLE

If you favor	And:	
	Adequate regeneration is already established (300+ trees/acre >18 inches tall)	Adequate regeneration is not established
	Then use:	Then use:
Oaks	Clearcut or Group selection	Shelterwood
Green ash, silver maple, American elm	Clearcut or Group selection or Single-tree selection	Shelterwood or Clearcut [1] [2]
Sweetgum	Clearcut	Clearcut [2]
Sycamore	Clearcut	Clearcut [1]

[1] Bare or litter-covered seedbed required; grass or a dense herbaceous cover is unsuitable.

[2] One hundred or more trees per acre between 2 and 12 inches d.b.h. will provide enough regeneration through coppice..

As both even-age and uneven-age stands develop they need periodic thinnings and perhaps even crop tree release to maintain vigorous growth and to favor the efficient production of desired species.

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CENTRAL HARDWOOD NOTES

Silvicultural Systems For Harvesting Mixed Hardwood Stands

Mixed stands that include oaks, yellow-poplar, black cherry, maples, white ash, basswood, birches, American beech, and other species are commonly found in the central hardwood forest. Depending on site quality and past stand treatment, overstory composition may range from nearly pure stands of oak or yellow-poplar to mixtures of 20 or more species.

Is There Enough Natural Reproduction?

In mixed hardwood stands, there are several sources of reproduction (see Note 3.01 Principles *of* Natural Regeneration) that collectively provide the potential to produce as many as 250,000 woody stems per acre. This is certainly a lot of reproduction. But sheer numbers are not enough; the species available and size of stems as related to competition are also important (see Note 3.02 *Assessing Regeneration Potential).*

A key point in using different silvicultural systems to harvest forest stands is the amount of light reaching the forest floor. Available light is related to intensity of cut. Species such as yellow-poplar and black cherry grow fast when exposed to adequate light. Conversely these shade intolerant species die in dense shade. Shade tolerant species such as beech and sugar maple can survive for many years under dense shade and will respond when given light and room to grow. So, to reproduce the mixed hardwoods you must control the establishment and development of shade intolerant and/or shade tolerant species. You can control species composition to some extent by using different cutting practices. Another key is the site quality which is an expression of geologic, climatic, and topographic characteristics of a stand.

Silvicultural Systems-What Are Your Options?

You have several silvicultural options in establishing and developing reproduction in mixed hardwood stands. In fact, the greater the number of species in the mixture the better your chances to regenerate desirable species. Almost any type of harvest practice used in mixed hardwood stands will regenerate some commercial species. The trick is to reproduce the species you want along with the others that will be favored by the harvest cutting practices you choose.

Silvical characteristics, available light, and site quality are the key factors that determine what tree species will succeed on your sites. Sometimes factors such as deer can have a major negative influence on reproduction and the choice of harvest methods to use.

Even-Age Method!+ Three Choices

Even-age methods reproduce a greater variety of species and a higher ratio of intolerant to tolerant species than uneven-age practices. Species that are intolerant to intermediate in shade tolerance are usually fast-growing, high-value species such as black cherry, black walnut, red oak, and white ash. Other fast growing species include yellow-poplar and basswood.

In stands where even-age silviculture is practiced, reproduction cuts are made at the end of each rotation. There are three regeneration cutting practices to consider in even-age management.

1. *Clearcutting*

- Clearcutting is done in mature and overmature stands where tree growth rates are slowing down and the current stand needs to be replaced with a new vigorous stand.
- Due to past stand treatment, clearcutting is also done in stands that are so badly degraded there is a need to start over.
- There is no optimum stand size. The stand should generally be confined to a single site quality and tree size class. A minimum of about 1/2 acre is needed to establish and develop most shade intolerant species.
- Normally all trees 2.0 inches d.b.h. and above are felled (see Note 3.04 *Treatments to Encourage Natural Reproduction).*
- Adequate advance regeneration must be present or species should have potential for seed being "stored" in the forest floor such as yellow-poplar (table 1).
- Both shade intolerant and shade tolerant species are reproduced but often intolerants dominate.
- Well-planned clearcuts in a forest provide variety in tree species and wildlife. Where clearcutting is done periodically on a large property, stands of different ages will contribute to diverse habitat and foster a variety of wildlife species.
- Clearcutting has more immediate impact on the forest than any other cutting practice. The greatest impact is the visual appearance of the cut area. Clearcuts do not look good for a few years after cutting.

Table 1 .-*Summary of several reproductive characteristics of 14 hardwood species (adapted from Kelly 1988)*

Species	Seedling shade tolerance	Minimum size acceptable advance growth	Seed dormancy
		Feet	*Years*
PIONEER SPECIES			
Yellow-poplar	Intolerant	—	> 3
Sweet birch	Tolerant	—	Several
Black locust	Intolerant	—	Several
MODERATE SHADE TOLERANCE			
Black cherry	Intolerant	0.5	> 3
Red maple	Tolerant	2.0	None[2]
White ash	Intermediate	2.0	> 3
Basswood	Tolerant	2.0	> 3
Red oak	Intermediate	4.5	Overwinter
White oak	Intermediate	4.5	None
Hickories	Intermediate		Overwinter[1]
Black walnut	Intolerant	—	
EXTREME SHADE TOLERANCE			
Sugar maple	Very tolerant	2.0'	Overwinter[3]
American beech	Very tolerant	2.0'	Overwinter
Eastern hemlock	Vet-v tolerant	2.0'	Overwinter

[1] Ideally should be sapling size (1 .O to 4.9 inches d.b.h.) to reach overstory in new stand.

[2] Majority germinate soon after falling, but some may remain dormant 1 year.

[3] Majority germinate the first spring after falling, but some may remain dormant 1 to 2 years.

2. shelterwood

- This method involves removing overstory trees in two or more cuttings within a period of about 20 years.
- In a mixed hardwood shelterwood, 20 to 30 percent of the basal area is generally removed at the first cut. Additional light cuts may be needed at 5- to 10-year intervals. When desirable advance reproduction is well established, the remaining overstory trees are removed in one final cut.
- Shelterwood is used to establish regeneration of desirable species where advanced regeneration is lacking.
- Shelterwood has the potential to reproduce heavy seeded, intermediate shade tolerant species such as oaks on good sites. However, this method has not consistently yielded good results and is still under study.
- Shelter-wood and clearcuts off en yield similar reproduction results in mixed hardwood stands.
- The residual trees left in a shelterwood cut can benefit from the increased growing space. Growth and value added to the residual trees may be worth more in the future than if the present stand were clearcut.

3. Seed Tree

A few seed trees per acre are left to reproduce the harvested stand. The seed tree method is seldom used or needed in mixed hardwoods. In most instances, regeneration comprising the new stand is already established or will become established in the first growing season after cutting regardless of the presence or absence of seed trees. Also, where seed trees are left in the stand, wind throw, sun scald, and loss of bole quality are problems. For some species, lumber values will decrease drastically by the time seed trees are harvested.

Uneven-Age Management-Two Choices

In uneven-age methods, both reproduction cutting and thinning are done together each time the stand is entered for harvesting. The stand is thinned to achieve a reasonably balanced distribution of size classes and openings in the overstory are small. So, shade tolerant species such as sugar maple, American beech, and red maple commonly dominate the reproduction. Noncommercial tolerant species such as dogwood, sourwood, and striped maple can also dominate the understory. These species create major problems to landowners interested in reproducing commercial timber species using uneven-age methods. There are two methods to consider in uneven-age management.

1. Single-Tree Selection

This method results in the least disturbance of the forest canopy. Usually one or two species dominate the reproduction and eventually a hardwood stand containing mixtures of tolerant and intolerant species will be replaced by a few tolerant commercial species such as sugar maple, American beech, or red maple.

- A high portion of shade tolerant tree and shrub species will be produced.
- In the future, wildlife habitat will be influenced by changes in tree species.
- Single-tree selection is commonly used where visual quality is a strong concern or recreational values are high.

2. Group Selection

Small, scattered clearcut openings in mixed hardwood stands can provide a mixture of desirable tolerant and intolerant species. Small openings, often 1/2 acre or less are made each time the stand is entered for harvesting. Also trees between the openings can be cut to achieve the chosen size class distribution to develop an uneven-aged stand.

- Select openings by looking for the more mature trees in the stand.
- Openings should be about 1/2-acre to establish and develop shade intolerant reproduction.
- Small openings don't detract from the esthetic quality of a stand.
- Wildlife habitat and diversity are good.
- Quality of trees bordering these small openings can be reduced by epicormic branching.
- If deer populations are high, reproduction in small openings may be browsed severely, even eliminated.
- Group selection is well suited to small woodlots where occasional cuts are desired.

Because mixed hardwoods generally contain a number of desirable species, these stands are often highly productive. While mixed species and the wide variation in silvical characteristics allow flexibility in applying silvicultural systems, management decisions are more complicated. Even-age management is often recommended to maintain mixed hardwoods of several species. Through this practice, both intolerant and tolerant species can be grown together. Because there are so many forest stands, site conditions, and management objectives there is no single silvicultural system that is best for managing mixed hardwood stands.

Reference

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CENTRAL HARDWOOD NOTES

Principles Of Natural Regeneration

To maximize chances of successful regeneration, carefully consider the following regeneration principles.

- Harvesting alone does not guarantee that the desired species will be established.
- The conditions required for the initial establishment and early growth of the desired species largely determine what regeneration method you should use and any supplemental treatments needed to enhance regeneration success.
- The species must be suited to the site.
- You should evaluate the regeneration potential of the desired species.

Regeneration Potential

The *regeneration* potential of a species or species group is the capacity of its various sources *of reproduction* to capture growing space when it becomes available. New growing spaces occur when canopy openings are created as a result of natural events or management practices such as harvest cuts. At any given time the regeneration potential of **a** stand depends on the presence of one or more sources of reproduction. These sources include:

- **Seed,** either from the current seed crop or seed stored in the forest floor.
- **Advance reproduction,** which is reproduction already in place in the form of seedlings, seedling-sprouts, root sprouts (suckers), and occasionally stump sprouts; stems are <2 inches d.b.h.
- **Stump sprouts** and **root sprouts,** not in place but potentially originating from the stumps or roots of standing overstory trees following disturbance (stems $\geq$2 inches d.b.h.). While most central hardwoods will produce stump sprouts, few species produce root sprouts.

Advance Reproduction is Important

Advance reproduction is the primary source of reproduction for most tree species in the central hardwood forest (table 1). For example, successful regeneration of oaks, hickories, and maples requires advance reproduction. For these species, seedling-sprouts are the primary reproduction growth form; they arise from the recurrent dieback of shoots of reproduction that originate as seedlings.

Table 1 .-*Sources of reproduction and shade tolerance of some species in central hardwood forests*

Species	Relative importance of reproduction source in relation to species regeneration potential'					Shade tolerance
	Seed from current seed crop	Seed stored in forest floor	Advance reproduction"	Stump sprouts'	Root sprouts (suckers) from cut trees	
Hardwoods						
American basswood			1	1	2	tolerant
American beech			1	3	2	very tolerant
American elm			1	3	2	intermediate
Bigtooth aspen	2		3	3	1	very intolerant
Black cherry		1	2	2		intolerant
Blackgum			1	2		intolerant
Black walnut	1		1	2		intolerant
Black willow	1			2	2	very intolerant
Butternut			1	2		intolerant
Eastern cottonwood	1			1	3	very intolerant
Eastern hophornbeam			1	2		very intolerant
Flowering dogwood			1	2		very intolerant
Green ash		1	1	2		intermediate
Hackberry			1	3		intermediate
Hickories			1	3		intolerant
Oaks			1	2		intermediate
Quaking aspen	2		3	3	1	very intolerant
Red maple			1	2		tolerant
Sassafras			1	2	1	intolerant
Silver maple			1	2		tolerant
Slippery elm			1	3	2	intermediate
Sugar maple			1	2		very intolerant
Sweetgum	1			1	1	intolerant
Sycamore	1		2	2		intolerant
White ash		1	1	2		intermediate
Yellow-poplar		1	2	2		intolerant
Conifers						
Eastern hemlock			1			very intolerant
Eastern redcedar	1		1			intolerant
Eastern white pine	1		1			intermediate
Pitch pine	1		1	2		intolerant
Shortleaf pine	1		1	3		intolerant
Virginia pine	1		1			intolerant

[a] 1 = primary source; 2 = potentially significant but not primary source; 3 = minor source. Relative importance of reproduction source is for sawtimber-size stands.

[b] Includes seedlings, seedling-sprouts, and in a few species root sprouts (i.e., species occurring in root sprouts column).

[c] Sprouts originating from stumps of trees ≥ 2 inches d.b.h.

Do Many Stems of Advance Reproduction Guarantee Regeneration Success?

Not by themselves. Where advance reproduction is the primary source of reproduction, the number, size, and distribution of stems of advance reproduction collectively determine regeneration potential. Size is important because larger stems have a greater likelihood of capturing growing space than smaller ones when the canopy opens. In some ecosystems, the number, size, and distribution of advance reproduction can be used to quantify regeneration potential (see Note *3.02 Assessing Regeneration Potential).*

Differences Among Species

The relative importance of a given reproduction source varies by species. For example, the primary reproduction source for yellow-poplar is seed stored in the forest floor. In contrast, reproduction of eastern cottonwood originates primarily from wind-dispersed seed from the current seed crop. And for most hardwoods, stump sprouts are a potentially important secondary or supplementary source of reproduction in even-aged stands. However, stump sprouting capacity varies widely by species, tree diameter, and age.

Differences Related to Site Quality

While most central hardwood species will grow on a wide range of sites, each species will regenerate and/or grow best over a more limited site range (see Note *4.01 The Importance of* Site *Quality).* Often, the relative abundance of the different sources of reproduction for a given species varies by site quality. For example, advance oak reproduction is off en absent or deficient under oak stands on good sites but may be abundant on medium and poor sites. Thus, abundant regeneration does not always equate with site conditions that are best for subsequent stand growth. Other factors such as competition and frequency of stump sprouting also are influenced by site quality.

Regeneration Methods

The diverse species and sites in the central hardwood region require a range of silvicultural options to regenerate the economically important species (see Note *2.04 Choosing a Silvicultural System).* Each of the major silvicultural systems can be used to regenerate one or more species common to the region; which one to use depends on management objectives and species' regeneration potentials.

Clearcutting

Clearcutting will produce new stands composed largely of the species existing as advance reproduction, those that reproduce from seed stored in the, litter, plus stump sprouts originating from trees in the parent stand. The greater the number of small diameter trees in the overstory, the greater the contribution of stump sprouts to the new stand. Consequently, stands thinned from below several times before final harvest will usually produce few stump sprouts. In any case, the composition of the new stand is predictable from the advance reproduction and overstory present at the time of final harvest.

Clearcutting also may be appropriate for regenerating certain light-seeded bottomland species such as eastern cottonwood, sycamore, and sweetgum. For these intolerant species, clearcutting provides the full sunlight necessary for the germination of seeds that may be wind-dispersed from adjacent stands.

Shelterwood

The shelterwood method may be an appropriate regeneration system where essential advance reproduction is lacking. It is often possible to increase the amount of advance reproduction through moderate reduction of overstory density with one or more shelterwood preparatory cuts. However, site preparation is sometimes necessary to assure regeneration success (see Note 3.04 Treatments *to Encourage Natural Regeneration).*

Seed Tree

In the central hardwood region, the seed tree method usually is restricted to regenerating pine (see Note 2.05 *Silvicultural Systems for Oak-Hickory and Oak-Pine).* It is not an effective method for regenerating species dependent upon advance reproduction or seed stored in the forest floor-which collectively comprise most of the central hardwood species.

Group Selection

The group selection method is applicable where the management objective is to create or maintain an uneven-age forest. The method has the potential for regenerating both tolerant and intolerant species. However, to maintain the uneven-age character of stands, the diameter of openings should not exceed 1 to 2 times the height of dominant trees.

In some parts of the region, sugar maple, red maple, American beech, and other tolerant species tend to replace less shade-tolerant species. The process occurs most rapidly on good sites. Thus, a frequent problem in managing uneven-age stands containing tolerant species is to maintain a desirable mixture of both tolerant species and less tolerant but more valuable species. The group selection method has the potential to maintain such mixtures.

Single Tree Selection

Where an uneven-age forest is the management objective, the single tree selection method will regenerate shade tolerant species such as sugar maple, red maple, and American beech. These species can grow into and dominate very small canopy openings. In contrast, intolerant or moderately tolerant species are unable to develop in the understory as advance reproduction and/or they are unable to successfully occupy the small canopy openings created by the single tree selection method.

References

Fowells, H.A., ed. 1965. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture, Forest Service. 762 p.

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CENTRAL HARDWOOD NOTES

Assessing Regeneration Potential

When a regeneration harvest cut is planned for even-aged stands or it is time to make another cut in uneven-aged stands, the first thing to do is assess the regeneration potential. Regeneration potential is the likelihood of being successful in reproducing desired species. You need an assessment to be reasonably sure that regeneration and management objectives can be met. In even-aged stands, an assessment will help determine which regeneration method to use. In uneven-aged stands it will help determine where to locate groups, which species are reproducing, and how the reproduction is growing.

An assessment answers the following questions:

1. What is the site quality?

   Is it suitable for the species desired or which other species will grow well on the site? (See Notes 4.01 The Importance of Site Quality, 4.02 Measuring Site *Qualify in the Central Hardwood Region,* and 4.03 *Forest Site Classification in the Interior Uplands.)* Site quality is also important because advance oak regeneration must be larger and/or more numerous on good sites than on poor sites to become established in the new stand or in openings.

2. What is the source of the reproduction of the species desired?

   Primary resources are seed, advance reproduction, stump or root sprouts or a combination of these sources. *(See* Note 3.01 *Principles of Natural Regeneration)*

3. If the source is advance reproduction, is the advance reproduction adequate to replace the current stand?

   Answering this question requires making an inventory that includes size, numbers, and distribution of the advance reproduction. In general, large advance reproduction stems of any species will grow faster and compete better than small stems. So, the larger an advance reproduction stem, the higher its potential to become dominant or codominant in the new stand.

4. How many sprouts can be expected from stumps of cut overstory trees of the desired species?

   An inventory by broad diameter classes and species must be made to answer this question. Except for some oaks, information is not available on stump sprouting frequency for important central hardwoods. Stumps of small or

young trees generally sprout more frequently than stumps from large or old trees. You can use this general relationship to get a rough estimate of the number of sprouts to expect.

5. If advance reproduction plus stump sprouting are not adequate, are new seedlings needed, and if so, are the desired species present in the overstory?

   If there are a few yellow-poplar and/or white ash overstory trees, you can expect new seedlings of these species to be present in the reproduction, especially on good sites. These seedlings will come from seed stored in the fitter, but there is no way to accurately estimate how many seedlings will result. In the eastern part of the central hardwoods area, numbers of new seedlings in experimental cuts have ranged from about 1,000 to more than 10,000 per acre for yellow-poplar and from about 300 to 2,000 per acre for white ash. While not all of these seedlings will survive and grow well enough to become part of the dominant stand, regeneration of desirable species is not a problem in mixed hardwoods.

6. How severe is the competition from unwanted species likely to be?

   We do not have techniques to estimate competition severity. However, when surveys show that advance reproduction plus stump sprouts of the desired species are adequate, and/or where yellow-poplar seedlings are expected, the desired species will be able to compete successfully if the regeneration method recommendations are followed (see Notes 2.05 Silvicultural Systems for Oak-*Hickory and Oak-Pine, 2.06 Silvicultural Systems for Bottom/and Hardwoods,* and *2.07 Silvicultural Systems for Harvesting Mixed Hardwood Stands).* Where new seedlings of oak or pine are needed, existing understories that contain largely unwanted species must be controlled. Follow the recommendations for the regeneration method that will be used.

If your assessment indicates there will be enough natural reproduction of desired species, the stand can be harvested. If there will be insufficient natural regeneration, the final harvest must be delayed until natural regeneration is adequate. There may be opportunities to supplement the natural regeneration with planted seedlings *(see* Note *3.05 Seeding and Planting Hardwoods).* The major considerations in evaluating regeneration potential for planted seedlings are choosing the right species for the site, the appropriate size seedlings to plant, seed source, and competition control.

Note 3.03 outlines *How to Assess the Oak Regeneration Potential in the Missouri Ozarks.* A similar procedure by Marquis et *al.* exists for hardwood stands in the Alleghenies. Both are complex and you should use them only with professional help or training. The Carvell publication listed in the References suggests ways to assess regeneration potential and leaves the choice up to the user.

For other areas definitive data for adequate amounts of the different kinds of reproduction are not generally available. Your best source for these kinds of recommendations are from local or regional silviculturists.

References

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CENTRAL HARDWOOD NOTES

How To Assess Oak Regeneration Potential In The Missouri Ozarks

The values in tables 1 and 2 apply specifically to oak stands in the Missouri Ozarks and may or may not apply outside this area. Unfortunately, similar values for oak do not exist for other geographic areas. Use the procedures and values cautiously in other areas. Consider them as approximations and compare them to values based on local experience and guidelines.

Table 1 .--*Stocking values for oak advance reproduction in the Missouri Ozarks*

Size of tallest tree per plot		Aspect and slope position of plot								
Height class (feet)	Ground diameter class	Southwest			Southeast and Northwest			Northeast		
		Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
	Inches	*Plot Stocking Value (SV)*[1]								
cl	All	1	1	0	1	2	0	1	1	0
	0.5(0.3-0.7)[2]	5	6	1	8	9	2	4	5	1
(1.123.0)	1.0(0.8+)	14	17	3	22	26	6	13	15	3
4	0.5(0.3-0.7)	10	11	2	15	18	4	8	10	2
(3.1-5.0)	1.0(0.8-1.2)	22	25	6	32	37	9	19	22	5
	1.5(1.3+)	37	42	11	51	56	18	34	38	10
	0.5(0.3-0.7)	19	22	5	28	32	8	16	19	4
(5.167.0)	1.0(0.8-1.2)	32	36	9	45	50	14	29	33	8
	1.5(1.3+)	45	50	15	59	65	23	41	46	13
	1.0(0.8-1.2)	44	49	14	59	64	22	40	45	12
(7189.0)	1.5(1.3-1.7)	54	59	19	68	73	28	49	54	17
	2.0(1.8+)	62	67	24	76	80	35	57	62	21
10+	1.0(0.8-1.2)	58	63	22	72	77	32	54	59	14
(9.1+)	1.5(1.3-1.7)	62	67	24	76	81	35	58	63	16
	2.0(1.8-2.2)	66	71	27	79	84	38	61	66	19
	2.5(2.3+)	69	74	29	82	86	41	64	69	21

Narrow ridge tops
Level areas (<15 percent slopes other than ridge tops and bottoms);
Bottoms

[1] Stocking Value (SV) is the contribution of a single stem to stand stocking at age 20.

[2] Ranges in parantheses.

Table Z.--*Expected proportion of stumps that will produce at /east one codominant or larger stem at age 20*

Species	Site index	D.b.h. class	Age of parent tree (years) 40	60	80	100	All ages
		Inches					
Black oak	50	2-5	0.36	0.34	0.32	0.30	—
		6-l 1	.13	.11	.10	.08	—
		12-16	.06	.05	.04	.03	—
		17+	—	.02	.02	.01	—
	60	2-5	.47	.45	.42	.40	—
		6-l 1	.16	.15	.13	.12	—
		12-16	.07	.06	.05	.04	—
		17+	—	.03	.02	.02	—
	70	2-5	.61	.59	.56	.54	—
		6-l 1	.21	.19	.17	.16	—
		12-16	.19	.08	.07	.06	—
		17+	—	.06	.04	.03	—
White oak	50	2-5	.47	.25	.12	.05	—
		6-l 1	.18	.10	.06	.03	—
		12-16	.06	.04	.03	.02	—
		17+	—	.02	.01	.01	—
	60	2-5	.63	.38	.19	.08	—
		6-l 1	.26	.16	.09	.05	—
		12-16	.09	.07	.05	.03	—
		17+	—	.03	.02	.02	—
	70	2-5	.81	.55	.31	.15	—
		6-l 1	.36	.25	.16	.09	—
		12-16	.15	.11	.08	.06	—
		17+	—	.05	.04	.04	—
Northern red oak	60+	2-5	.86	.86	.49	.49	—
		6-l 1	.86	.86	.46	.46	—
		12-16	.86	.86	.38	.38	—
		17+	—	.86	.24	.24	—
Scarlet oak[1]		2-5	—	—	—	—	0.46
		6-l 1	—	—	—	—	.96
		12-16	—	—	—	—	.46
		17+	—	—	—	—	.10

[1] Values by parent tree age are not available. Values given are means for sawtimber-size stands of various but unknown ages.

The values in tables 1 and 2 are based on a goal of having at least 30 percent stocking (approximately C-level, see Note 5.02 Stocking *Chart for Upland Central Hardwoods)* in dominant and codominant oaks when the new stand is about 20 years old.

Inventories of (a) the oak advance reproduction and (b) the overstory are required. Both inventories should be made at the same time (see example tally form). If the oak advance reproduction inventory shows insufficient oaks to replace the stand, the overstory inventory is used to determine whether or not stump sprouts from overstory oaks are numerous enough to make up for deficiencies in advance reproduction.

Here are the steps to make the assessment.

1. Tally all oaks 1.6 inches d.b.h. and larger by species and size classes on 10 or more l/20-acre overstory plots.
2. Determine the average age of dominant and codominant oaks and the site index; record this on the tally form. Also determine and record the average age of intermediate and suppressed oaks (lower story) that are 1.6 inches d.b.h. and larger. If intermediate and suppressed oaks are younger than the dominant and codominant trees, they will have a higher sprouting frequency.
3. Select the number of 1/735-acre plots (4.3 feet in radius) to use in the oak advance reproduction inventory from the following tabulation by stand size. Distribute them uniformly throughout the stand.

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

4. Measure the tallest stem of advance oak reproduction on each 1/735-acre plot and record on the form. Tally these stems by the 2-foot height classes and l/2-inch ground diameter classes used in table 1. A 6-inch caliper graduated in either tenth or quarter inches can be used to measure ground diameters. Measure only trees 1.5 inches d.b.h. or less; larger stems should be tallied as part of the overstory, even if below the main canopy. If no oak advance reproduction is present, record zero for height and ground diameter on the tally form.
5. Record on the oak tally form the aspect of each plot by quadrant (NE, SE, SW, or NW) and its slope position (upper, middle, or lower thirds). For slope position on level topography, use LE for slopes less than 15 percent, RI for ridge tops, and BO for bottoms, and use the stocking values for southeast/ northwest aspects (table 1).

6. Determine the stocking value (SV) for each plot from table 1 and record on the tally form. Then calculate the average SV and round off to the nearest whole number. If average SV is 30 or greater, oak advance reproduction is adequate; no further calculations are necessary and the stand can be harvested.
7. If the average SV is less than 30, oak advance reproduction is inadequate to reproduce the stand if it is cut. But the stand can still be regenerated if enough stumps of the overstory oak trees will sprout after they are cut to make up for the advance reproduction deficiency.

   To compute the contribution to reproduction stocking from expected stump sprouts:

   a. Assume that the overstory inventory provides the data on the example form for an 80-year-old stand on site index 60.
   b. Note that there are 26 black oaks 2 to 5 inches in diameter per acre. Multiply 26 by 0.42 (from table 2) to estimate how many of the 26 stumps are expected to produce codominant or dominant trees at age 20: 26 x 0.42 = 11 (rounded off), the expected number of stump sprouts per acre for 2- to 5-inch black oaks. Enter 11 at the bottom of the tally form.
   c. Similarly, estimate the expected number of stump sprouts for the other black oak size classes (one for the 6- to 11 -inch class, one for the 12- to 16-inch class, and zero for the 17+ inch class). All these classes sum to 13. Do the same for all oak species.
   d. Summing all oak species and all size classes gives a total of 45 expected stump sprouts per acre.

8. Go to table 3 and find the number of stump sprouts required in combination with advance reproduction stocking to meet minimum stocking requirements. The stocking value for this example is 25. Opposite 25 note that 37 stump sprouts are needed to make up the deficiency in advance reproduction.
9. The computed value 45 exceeds the needed value 37 so oak stump sprouts will make up for the deficiency in advance reproduction. Thus, the oak component of the new stand will be adequate and the old stand can be harvested.
10. If the number of expected stump sprouts does not compensate for advance reproduction deficiencies, harvesting should be delayed until adequate oak advance reproduction is established.

Table 3.--*Number of stump sprouts required to compensate for stocking deficiencies of advance reproduction*

Mean stocking value (SV) for 1/735-acre plots	Stump sprouts required
	Number per acre
> 30	0
29	8
28	15
27	23
26	30
25	37
24	45
23	52
22	59
21	67
20	74
19	81
18	89
17	96
16	103
15	111
14	118
13	125
12	133
11	140
10	148
9	155
8	162
7	170
6	177
5	184
4	192
3	199
2	206
1	214
0	221

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Example Tally Form for Recording Overstory Trees and Advance Reproduction

Date 9/12/83 Compartment 1 Stand 10 Site Index 60

Stand Age (Dominants) 80 Stand Age(Lower story) 80

Overstory (1/20-acre plots)							Advance Reproduction (1/735-acre plots)					
Sample Point Number	D.B.H. Class	Black Oak	White Oak	Scarlet Oak	N. Red Oak	Other spp.	Plot No.	Asp:	Slope Pos.	Ht.	Crnd. Dia.	SV
1	2-5						1	SE	LO	0	0	0
	6-11						2	SE	LO	10	2.0	3 9
	12-16						3	SE	LO	0	0	0
	17+						4	SE	LO	2	.5	2
2	2-5						5	SE	LO	2	.5	2
	6-11							SE	LO	0	0	0
	12-16						7	SE	LO	6	1.5	23
	17+						8	SE	LO	4	.5	6
3	2-5						9	SE	LO	0	1.5	28
	6-11						10	SE	LO	6	0	0
	12-16						11	SE	LO		.5	8
	17+						12	SE	LO	0	0	0
4	2-5						13	SE	LO	2	.5	2
	6-11						14	SE	MI	4	.5	18
	12-16						15	SE	MT	8	1.5	73
	17+						16	SE	MI	4	.5	18
5	2-5						17	SE	MI	8	1.5	73
	6-11						18	SE	MI	0	0	0
	12-16						19	SE	MI	4	1.0	37
	17+						20	SE	MI	1	—	2
6	2-5						21	SE	MI	8	1.0	64
	6-11						22	SE	NT	0	0	0
	12-16						23	SE	MI	6	1.5	65
	17+						24	SE	MI	6	1.5	56
7	2-5						25	SE	MI	8	1.5	73
	6-11						26	SE	MI	0	0	0
	12-16						27	SE	UP	10	2.0	79
	17+						28	SE	UP	0	0	0
8	2-5						29	SE	UP	0	0	0
	6-11						30	SE	UP	8	1.5	68
	12-16						31	St?	UP	1	—	1
	17+						32	SE	UP	10	a.0	179
9	2-5						33	SC	UP	0	0	c
	6-11						34	SE	UP	0	0	C
	12-16						35	SE	UP	6	1.5	59
	17+						36	SE	UP	0	0	0
10	2-5						37	SC	UP	0	0	c
	6-11						38	SE	UP	8	1.5	68
	12-16						30	SE	UP	6	1.5	59
	17+						40	SE	UP	1	—	1
Total No. Per Acre	2-5	26	60	s-4-	4	26	140	SV Mean				25
	6-11	8	12	2	f-	? %	48					
	12-16	18	8	4	2	14	46					
	17+	2	2	0	2	0	6					
	Total	54	82	30	12	62	240	Advance Reproduction Adequate?				NO
No. of Stump Spts. per Acre	2-5	II	II	II	2							
	6-11	1	1	2	2		Total Per Acre	Advance Reproduction + Stump Sprouts Adequate?				Yes
	12-16	1	0	a	1							
	17+	0	0	0	0							
	Total	13	12	IS	5		45					

North Central Forest Experiment Station 3.04

CENTRAL HARDWOOD NOTES

Treatments To Encourage Natural Regeneration

Hardwoods can be regenerated best by clearcuttings, shelterwood cutting, or group selection. Regardless of the method chosen, regeneration comes from three sources:

1. New seedlings.
2. Stump sprouts (from stems with groundline diameter greater than 2 inches).
3. Advance reproduction (stems or sprouts from stems less than 2 inches in diamater at groundline).

New seedlings are a viable source of regeneration only for yellow-poplar, some of the birches, and, in some cases, white ash, basswood, and black cherry. Very high seedling densities and relatively rapid juvenile growth are characteristic of these species. With adequate seed sources they can be regenerated by removing all of the existing overstory, including undesirable stems of all sizes, or by removing more than half of the overstory and controlling subcanopy stems as the initial cut in a shelterwood.

All hardwoods sprout, and stump sprouts can become desirable stems in new stands. For example, stump sprouts are off en an important source of oak regeneration on low-quality sites (see Note 3.03 *How to Assess Oak Regeneration* Potential in the *Missouri Ozarks).* For a mature stand, however, the potential contribution of stump sprouts to the next stand is finite and cannot be increased during the last 10 to 20 years of the rotation. Numbers of sprouts of undesirable species can be reduced by applying herbicides prior to overstory removal.

If you want to regenerate hardwoods other than yellow-poplar, birches, and in some cases white oak, basswood, and black cherry, and if stump sprout potential of these other species is inadequate, then advance reproduction must be present before the overstory of the existing stand is heavily cut. When advance reproduction of such species as oaks, hickories, ashes, and basswoods is present, you have the opportunity to maintain a component of these species in the next stand.

Except in areas with very high deer populations, advance reproduction of several species is usually present under mature hardwood stands. If the stand has not been disturbed for several decades, this advance reproduction is likely to be quite small and not capable of competing successfully when you remove the overstory. For most species, the larger the advance reproduction, the better its chance of becoming dominant or codominant in the next stand. Under fully-stocked stands, seedlings of commercially desirable species become established, live for a few years, and die. Only relatively shade-tolerant species are able to persist for extended periods and to increase in size. For example, red oak seedlings are intermediate in shade tolerance and can become established under dense stands

after good acorn crops. But 10 years after establishment only a few of these seedlings will have survived, and they will be very small. Clearly, some kind of disturbance is necessary to break this cycle of establishment and mortality, and to provide conditions that will permit small advance reproduction to grow.

Thinnings sometime allow large advance reproduction to develop. More often, however, thinnings merely allow shade-tolerant midstory trees to expand their crowns, with little or no development of advance reproduction. Thinnings, by definition, are not regeneration cuts, and should not be relied on to provide the large advance reproduction necessary to regenerate most species. Treatments to enhance the development of advance reproduction should be considered part of a shelterwood method, even though all of the regeneration developing after overstory removal may not come from advance reproduction.

Research to determine the treatments necessary to develop large advance reproduction of oaks, hickories, ashes, and basswood is continuing in several places. But two guidelines seem to be emerging:

1. Reduce stand stocking or basal area from below, leaving no gaps in the overstory.
2. Use herbicides to reduce basal area of tolerant, noncommercial species in the midstory and lower canopy.

These guidelines enhance the growth of small advance reproduction that is already established in the stand, but do not necessarily result in the establishment of new seedlings of the desired species.

If the reduction in stand stocking creates large canopy gaps, yellow-poplar, the birches, and black cherry can become established and grow, and will dominate the stand after overstory removal. If herbicides, rather than cutting, are used to reduce the stocking of the tolerant undesirables, these species will be prevented from recapturing growing space. Since this treatment enhances the growth of existing advance reproduction, you have to assess the advance reproduction prior to treatment (see Note 3.02 *Assessing Regeneration Potential).*

About 1,000 or more small stems per acre of advance reproduction of the desired species should be present on the site before stocking is reduced as described above. Probably 10 or more years will be required for the small advance reproduction to grow large enough to compete successfully when the overstory is removed. If fewer than 1,000 small advance stems of the desired species are present, you have three alternatives:

1. Change regeneration objectives.
2. Wait until advance reproduction of the desired species becomes established before applying the treatment.
3. Underplant oaks in conjunction with the treatment described above (see Note *3.06 Seeding and Planting Upland Oaks).*

You should assess regeneration potential before regenerating any mature hardwood stand. If oaks, hickories, ashes, or basswoods are among the species you want in the next stand, large advance reproduction of these species must be present. If large advance reproduction of these species is not present, you must manipulate the stand to enhance the growth of small advance reproduction of these species without allowing intolerant species to become established and gain a competitive advantage. The best way to accomplish this is through a reduction in stocking that includes applying herbicide to undesirable shade-tolerant stems in the midstory, but leaves the stocking of the main canopy high enough to prevent intolerant species from regenerating.

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CENTRAL HARDWOOD NOTES

Seeding And Planting Hardwoods

Objectives of Hardwood Planting

Objectives of forest plantings can include one or more of the following:

1. Produce high quality timber and improve stand composition
2. Improve wildlife habitat
3. Reforest land not suited for agriculture
4. Arrest soil and wind erosion
5. Enhance esthetics

Site Evaluation and Species Selection

Site quality is the most important factor in establishing hardwood plantings. Hardwoods grow best on deep, fertile, moist, but well-drained soils. These areas usually occur where top soil has accumulated along streams, on lower north and east slopes, and in coves. However, stream bottoms that contain excessive amounts of gravel or chert are poor sites because they are droughty.

Hardwood survival and growth are affected by how well soil properties and other site factors such as aspect and topography match the requirements for the desired tree species. Large planting sites usually embrace a range of site conditions and may require you to plant more than one species. In the past, most hardwood plantings failed because the soil was too thin, too tight, too coarse, or the competition too intense. Many sites will simply not support the species you want to plant. Do not waste time and money. Get help from local or regional experts on site evaluation and species choices.

Seeds or Seedlings?

Nursery-grown seedlings are usually better for regenerating a stand than direct seeding. The advantages of seedlings over seed include (1) a more uniform spacing for future maintenance, (2) ability to use pre-emergent herbicides for weed control, and (3) less site preparation.

The advantages of direct seeding include (1) development of undamaged roots and tops, (2) ease of handling and transporting seeds, and (3) lower costs. The major disadvantage of direct seeding is uncertain success due to poor germination and seed pilferage by rodents. Plant seed just before or during germination in the spring when other food is available, maintain exposed areas around the planting, and trap seed eaters to minimize seed pilferage. Do not use pre-emergent herbicides when direct seeding.

Collecting and Storing Seed

Collect seed from trees located near the planting site or no more than 200 miles south of the planting site. Collect only from the best formed and most vigorous trees growing in open stands; avoid isolated trees and trees with poor seed crops (see Note 2.02 Genetic *Principles).* In most cases, you should immediately air dry seeds in shallow layers to avoid damage from molds or overheating. Black walnuts and acorns should be immediately planted or placed in cold, moist storage.

Most hardwood seeds exhibit some form of dormancy which must be overcome by stratifying overwinter under moist, cold storage (34 to 40°F) or in outdoor pits. For further information on seed collection, handling and storage by species consult Seeds *of Woody* Plants in the *United States (see* References).

Preparing Sites, Controlling Weeds, Protecting, and Fertilizing

Site preparation is the second most important factor in establishing a hardwood planting. For best results, remove all vegetation from the planting site by plowing or tilling in the summer or fall before spring planting. If the planting site is a forest opening or is too steep or stoney to cultivate, control competing vegetation with herbicides. Consult your local extension forester, service forester, or county agent for specific recommendations and instructions when using herbicides. Read herbicide labels before purchase to be sure they are registered for the intended use and follow all precautions on the label.

Control competition for at least 2 years or until planted trees are at least 1 foot taller than competing vegetation. To reduce rodent damage, keep weeds and mulches away from base of ?ree seedlings. Use fences to protect your trees from grazing and trampling by livestock. Cultivate firelanes as needed to keep them free of weeds and grasses. Periodically inspect seedlings for insect and disease damage and initiate corrective action if needed. Fertilization is generally not recommended during plantation establishment.

Spacing and Number of Seedlings Needed Per Acre

Most hardwood plantings are spaced 8 to 12 feet between trees and 10 to 15 feet between rows. This allows farm equipment to mechanically control weeds and allows trees to reach about 5 inches d.b.h. before thinning. Keep trees at least 10 feet from fences and install 1 O-foot or wider firebreaks around and through your plantings.

To determine the number of seedlings to plant per acre, divide 43,560 by the product of the distance in feet between rows times the distance in feet between trees within rows.

Obtain Quality Planting Stock

Order planting stock in the fail from state-operated or private nurseries for spring pick up or delivery. Obtain order forms from your local extension forester, state service forester, or county agent for seedlings from state-operated nurseries. Try to obtain seedlings from local seed sources or from proven seed sources. Pick seedlings up directly from nursery, if possible.

Hardwood seedlings are usually sold as 1-O stock (1 year from seed). Plant larger diameter seedlings with well-branched, fibrous root systems. The best stock will average one-fourth inch or more in diameter at the ground line. Premium stock for black walnut, yellow-poplar, and cottonwood will average one-third to one-half inch. Order extra seedlings and discard the smallest 10 to 20 percent plus any diseased or damaged seedlings.

Care for Planting Stock

Plant seedlings as soon as possible after arrival. Protect stock from dessication due to sun and wind during temporary storage and delivery to the planting site. Bundled seedlings that overheat or dry out cannot be revived by soaking in water. Seedlings can be held in their original wrappings up to a week if kept moist in an area protected from sun, wind, and freezing temperatures. Heel-in seedlings in a protected area, if they cannot be planted within a week. Dig a trench a little deeper than the root systems and spread roots against the back of the trench. Cover roots completely with soil, tamped to eliminate air spaces. Water as needed to keep roots moist but not wet.

Planting Time

Plant seedlings in late winter or early spring after the frost is out of the ground and the soil is dry enough to work. Seedlings planted in late spring will survive but grow slowly. Seedlings may be fall planted south of 37°latitude north if soil moisture is adequate to initiate fall root growth. Hazards of fall planting include exposure to rodent damage and frost-heaving.

Planting Methods

Use the hole method to plant containerized stock and seedlings having large spreading root systems (fig. 1). Use a shovel, mattock, or power-driven auger to dig a hole deep and wide enough to spread the root system in a natural manner. Roots should never be curled, bunched, or twisted. Plant seedlings about an inch deeper than they grew in the nursery. Firmly pack soil around the roots to eliminate air pockets. Do not plant when snow is on the ground. When using a power-driven auger, break up the compacted side walls before filling the hole.

Use the slit method to plant seedlings having a prominent taproot (fig. 2). Make a vertical slit in the soil with a planting bar, dibble, or tile spade, insert the taproot into the slit, and then close the slit taking care to remove air pockets. Properly planted seedlings should be very difficult to pull up. Use planting bars with a 10-inch-or-longer wedge-shaped steel blade. On taproot species, do not prune taproots shorter than 8 inches. Keep seedling roots moist during the planting operation. Survival and early growth may be enhanced by soaking the seedlings in water for 1 to 2 hours before planting and by planting on cool, cloudy days.

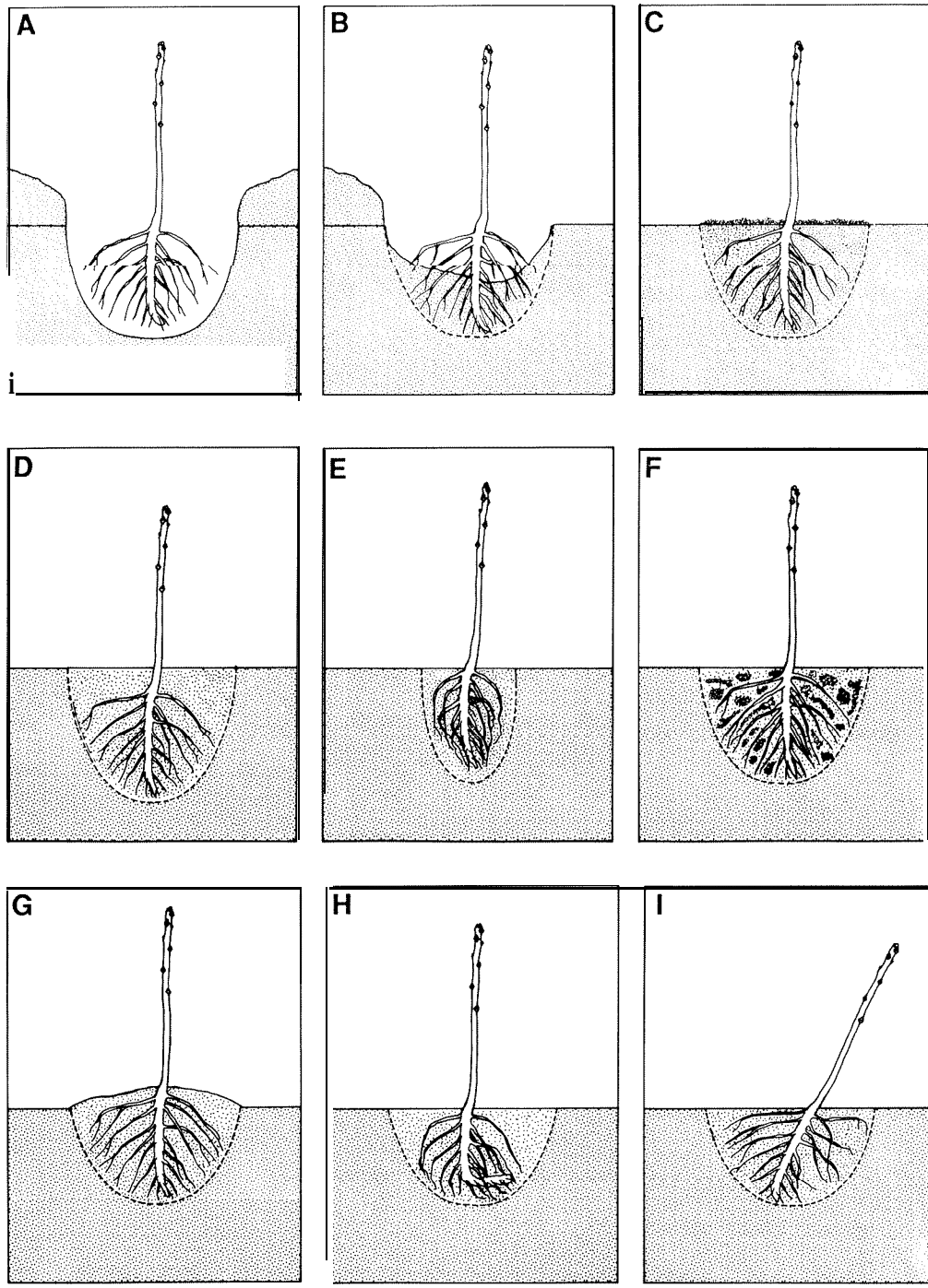

Figure 1 .-Hole planting

PROPER PLANTING
A. Dig hole slightly larger than the roots spread out.
B. Set seedling an inch deeper than in nursery. Partially fill hole and firm
C. Fill hole, firm, and add loose soil as mulch.

IMPROPER PLANTING
D. Hole too deep.
E. Compacted roots, hole too narrow.
F. Air pockets remain, organic debris in hole.
G. Exposed roots, hole too shallow.
H. "L"- or "J"-rooted, hole too shallow.
I Not vertical, hole too shallow.

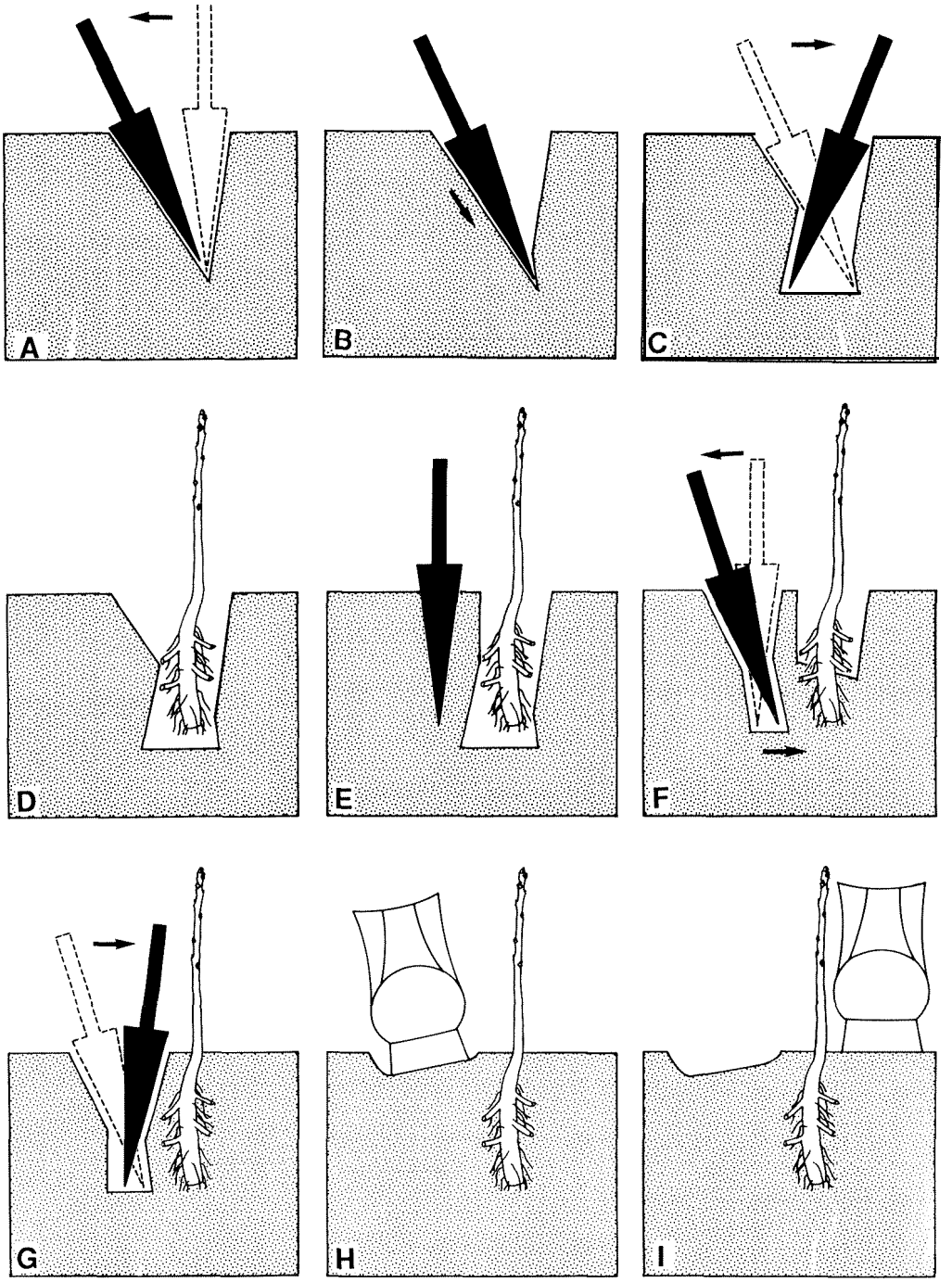

Figure 2.-Bar or tile spade planting.

A. Insert bar straight down and pull backward.
B. Push bar down at same angle to get a new bite.
C. Push bar to vertical position.
D. Remove bar and set seedling in hole at correct depth. (Root is schematically drawn. Prune taproots 8 to 10 inches long and lateral roots 3 inches long.)
E. Insert bar about 2" behind first hole.
F. Pull bar back to pack soil around lower roots.
G. Push bar forward to pack soil around upper roots.
H. Repeat steps E to G and close new hole with shoe heel.
I. Firm soil around seedling with foot.

When planting 3,000 or more seedlings on relatively level areas (slopes less than 20 percent) that are free of stones, consider using a tractor-drawn tree planter. If you do, make sure you set the planting depth deep enough to prevent L-shaped roots along the bottom of the slit. Follow the planter to straighten seedlings and to be sure the soil is firm around each seedling.

Reference

Schopmeyer, C. S. 1974. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service. 883 p.

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CENTRAL HARDWOOD NOTES

Seeding And Planting Upland Oaks

Oaks can be planted or seeded in uplands to: (1) afforest old fields, strip-mined areas, or other areas devoid of trees, and (2) supplement natural reproduction within existing forests. Planting is usually more successful than direct seeding. But even under good conditions survival and growth of planted oak has been considerably poorer than with conifers and other hardwoods.

Upland oaks grown in central hardwood nurseries include bur oak, white oak, black oak, scarlet oak, and northern red oak. Except for northern red oak, guidelines for planting upland oaks are not well established. On forested sites, the following steps for planting northern red oak under a shelterwood will give best results. Planting in clearcuts is not recommended.

How to Plant Northern Red Oak Under a Shelterwood

1. Underplant regeneration-deficient stands with at least 55 percent overstory stocking in trees 2 inches d.b.h. and larger based on the central hardwoods stocking chart *(see* Note 5.02 *Stocking Chart for Upland Central Hardwoods).* Plant only sites where the site index for northern red oak is 65 or better. Middle to lower north- and northeast-facing slopes are usually good northern red oak sites.
2. Determine how much planting is needed by first evaluating the existing natural oak regeneration potential of the stand. Use guides developed for that purpose if they are available for your specific geographic area (see Note 3.02 *Assessing Regeneration Potential).* If guides are not available for your area, you will have to rely on experience or extrapolation of guides for similar areas to evaluate the oak regeneration potential.
3. Reduce competition from woody plants less than 2 inches d.b.h. and/or other competitors by applying a herbicide *before* underplanting. Several registered herbicides are suitable for this purpose. To control woody vegetation, use 2,4-D + picloram (e.g., Tordon RTU[1]) or a similar herbicide with stem injection or cut stump applications during the dormant season *(see* Note 6.10 *Individual* Tree *Control).* During the growing season, herbicides such as glyphosphate (e.g., Roundup) can be applied to the foliage of unwanted vegetation. Use a low-pressure (e.g., less than 20 psi) hand sprayer if vegetation is less than 6 feet tall. Spray only unwanted vegetation and avoid drift or drip of the herbicide onto desirable advance regeneration.
4. Make a shelterwood cut and leave a well spaced overstory of about 55 percent stocking. If the overstory of the stand to be underplanted is only 55 to 65 percent stocked to start with, a cut is not necessary. If the trees to be eliminated in the shelterwood cut are unsalable, then steps 3 and 4 can be combined.

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[1] Use of trade names does not consitute endorsement by the USDA Forest Service.

5. Plant large l-0, 2-0, or l-l nursery stock: discard stock less than 3/8-inch in stem diameter 1 inch above the root collar. The larger the diameter the greater the chances for survival and acceptable height growth. Transplants or 2-O undercut seedlings are more likely to reach tree size than seedlings of the same diameter that have not been undercut or transplanted in the nursery. Undercut seedlings are root pruned in the nursery bed to produce branched root systems.

Estimate from table 1 the number of trees to plant per acre from the number of planted trees required to produce one "successful" tree. For example, with undercut 2-O stock averaging 7/16-inch in diameter, 2.1 seedlings must be planted to produce one successfully established seedling. Therefore, if 200 seedlings per acre are desired, 420 (2.1 x 200) seedlings should be planted.

Table 1 .-*Number of underplanted northern red oaks needed to obtain one successfully established tree*

Stem diameter 1 inch above the root collar (l/16 inch)	**Planted trees needed to obtain 1 successful tree**
	Number
1-O and 2-O seedlings (not undercut in nursery bed)	
4	9.1
5	5.9
6	4.3
7	3.4
8	2.9
9	2.6
10	2.4
2-O undercut seedlings and l-l transplants	
4	5.9
5	3.7
6	2.6
7	2.1
8	1.9
9	1.7
10	1.6

Plant in the spring. After the seedlings have been culled, prune the roots 8 inches below the root collar and prune the tops 8 inches above the root collar (fig. 1).

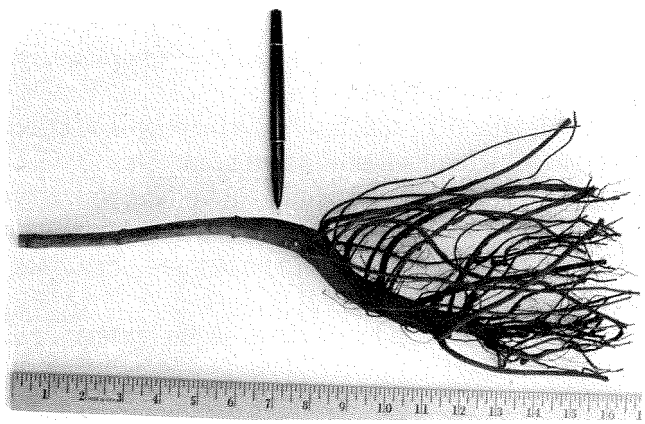

Figure 1 .-Northern red oak nursery stock ready for field planting should look like this 2-O undercut seedling. Roots and top have been pruned 8 inches below and 8 inches above the root collar, respectively.

6. Remove the shelterwood during the dormant season after three to six growing seasons. No special precautions are needed to protect planted trees from top breakage during logging because large, well-established stock will produce fast-growing, new sprouts from dormant buds near the root collar. If there are too many trees of undesirable species in the shelterwood, treat their stumps with an herbicide to prevent sprouting.

Underplanting Other Upland Oaks

Limited experience suggests that white oak also can be successfully underplanted in shelterwoods as described above. However, it may take 3 years to grow white oak nursery stock to the 3/8-inch diameter necessary for acceptable field performance. Guidelines for underplanting other upland oaks are lacking.

Afforestation by Planting

On old fields and other non-forested areas, control competing vegetation with an appropriate herbicide before planting. On dry sites such as upper slopes, south- or southwest-facing slopes, and ridge tops, plant drought-hardy species such as black, white, scarlet, or bur oak. Restrict planting of northern red oak to the better sites with deep soils. Spring plant with stock at least 3/16-inch in diameter. Top-prune stock greater than 30 inches tall and root prune as described for underplanting northern red oak. If site quality and growth rate of planted trees justifies intensive culture, *see* Note *3.05 Seeding and Planting Hardwoods.*

Plant drought-hardy species on strip-mined areas with soils between pH 4 and 7. If pH is near 7, plant bur oak-which is more tolerant of high pH than other upland oaks.

Direct Seeding

Direct seeding of upland oaks is not recommended because of the inconsistent results experienced over many years of trials. Rodent pilferage is a major problem. For those who want to continue the quest for better ways to establish oaks, the following suggestions are offered for small scale seeding trials:

1. Select red oak site index 65 or better sites in forest openings or other open areas that are at least 1/2-acre.
2. Get rid of brush, tops, and other vegetation and debris to reduce competition and eliminate the habitat of acorn predators.
3. Use quality seed with 75 percent or better germinative capacity.
4. Sow acorns 1 to 2 inches deep in spots in the fall as soon after natural seedfall as possible. Each spot should have three or four acorns sown about a foot apart.
5. Sow at least twice as many spots as the number of established seedlings desired.
6. Control weed competition as needed.

References

Johnson, P.S.; Dale, C.D.; Davidson, K.R.; Law, J.R. 1986. Planting northern red oak in the Missouri Ozarks: a prescription. Northern Journal of Applied Forestry 3: 66-68.

Johnson, R.L. 1981. Oak seeding-it can work. Southern Journal of Applied Forestry. 5: 28-33.

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CENTRAL HARDWOOD NOTES

Planting Bottomland Hardwoods

Diverse problems confront the forest manager when planting bottomland hardwoods. Bottomland vegetation types and sites are complex and differ markedly from uplands. There are different and more numerous hardwood species that grow faster in denser stands. Sites are subject to varying intensities and duration of flooding and the action of overflow river currents that deposit and erode soil. Added to these natural differences are the man-made influences of drainage ditches, borrow pits, levees, dams, dredging, and cultivation. Entirely different soils occur over very short distances. One or two feet in elevation often mean a change in suitable species. Therefore, the planter must consider each site a separate challenge and apply knowledge gained through careful examination and experience. The following information, offered to improve planting success with bottomland hardwoods, is based on experience in southeast Missouri and information available from recent research.

Site Evaluation

It can take you as long as a year to adequately evaluate and modify a site for planting with the right species. Standard soil maps are helpful but you should not rely on them entirely. Thorough soil probing of the planting site is necessary to detect changes that occurred after the maps were prepared. Collect and test soil samples to determine nutrient deficiencies. Soil testing is inexpensive and is especially important on sites that have been farmed and that are not subject to periodic flooding. investigate the flooding history including frequency, duration, season of occurrence, and the velocity and direction of overflows. Any areas that have active scouring or siltation should be noted.

The influence of soil organic matter content on planting success is not well understood. However, large amounts of decaying organic matter will make some nutrients unavailable for seedling growth and additional fertilizer may be needed to overcome deficiencies. In cultivated fields, find out if chemicals have been used to control weeds in the past to avoid chemical carryover which can harm planted seedlings.

Species Selection

You should make sure that the species selected for planting are suited to the site. Baker and Broadfoot (see References) developed a practical method of site evaluation to select cottonwood, green ash, hackberry, sugarberry, pecan, sweetgum, sycamore, yellow-poplar, and the oaks --cherrybark; Nuttall, swamp chestnut, water, and willow oak. Their method estimates the suitability of sites for these bottomland hardwood species by incorporating the physical conditions of the soil (factor 1), moisture availability during the growing season (factor 2), nutrient availability (factor 3), and aeration properties of the soil (factor 4), into a site

quality rating ("site index"). Each major factor consists of many soil and site properties that affect tree growth (table 1). Each soil factor is assumed to be responsible for a certain percentage of tree growth, with the proportion of growth accounted for by each factor being composed of contributions from each of its soil-site properties.

Table *1 .-Major soil factors and contributing soil-site properties*

(1) Physical condition	(2) Moisture availability	(3) Nutrient availability	(4) Aeration
Soil depth and pans	Water table	Geologic source	Structure
Texture	Pans	Past use	Swampiness
Compaction	Position	Percent organic matter	Mottling
Structure	Microsite	Top soil	Color
Past use	Structure	Soil age	
	Texture	pH	
	Flooding		
	Past use		

Harrington and Casson (see References) developed an interactive computer program (SITEQUAL) from the Baker and Broadfoot field guides. SITEQUAL calculates site index (SI) for all 14 species simultaneously and provides a breakdown of site index into component contributions by each factor. The major advantages of SITEQUAL are completeness and speed. Fourteen species are evaluated for a site rather than 3 or 4, and in less time. The user can also identify which of the four factors is at the least optimum level. For instance, although the total SI for cottonwood was still acceptable on a site cultivated for 30 years (table 2), nutrient availability (factor 3) received only 42 percent (11 out of 26) of its possible contribution points, indicating that fertilization might be used to improve growth. If the total SI is below a given level for a species, that site should be considered unsuitable unless soil conditions are improved. You should be thoroughly familiar with the Baker and Broadfoot publication before you use the SITEQUAL program.

Site Preparation

Before planting, most sites require clearing to permit the use of machinery such as harrows and disks. The exception is recently cultivated land. Fields with well-developed pans need to be subsoiled. Good hardwood sites are normally covered with dense vegetation of grasses, vines, and weeds which can be controlled by thorough disking. If machine planting is used, allow enough time between disking and planting for the ground to settle and firm.

Table 2.-*Major soil factors as components of site index for two species on ideal and cultivated sites*

Conditions	Species	Contribution of factors (1)	(2)	(3)	(4)	Total SI[1]
Ideal	Cottonwood	46	46	26	12	130
	Pecan	27	30	30	28	115
Cultivated	Cottonwood	31	35	11	12	89
	Pecan	17	22	21	28	88

[1] Maximum height growth in 30 years for cottonwood and 50 years for all other species.

While the minimum nutrient requirements are not known for most species and may vary with site conditions, major deficiencies should be corrected before planting. Apply a minimum of 120 pounds of nitrogen, 150 pounds of phosphorus, and 350 pounds of potassium per acre until better information is available. This treatment should suffice for several years. A pH level of 5.5 to 6.5 seems desirable for most hardwood species. It is better to delay correcting minor deficiencies for a few years to avoid stimulating unwanted competition.

Planting

Plant only large, healthy seedlings with root collar diameters of at least 1/4 inch and heights of over 18 inches. This usually means you will have to cull out the small seedlings. Also you may need to modify planting machines to accommodate large seedlings. Handle large planting stock carefully to avoid breaking the tops.

On firm soil, the seedlings should be planted with the root collar 1 inch below ground level. Seedlings should be planted deeper in loose soil to prevent root exposure when the soil settles. Prevent freezing, heating, or drying of the planting stock. Planting should be suspended if the temperature gets lower than 25 degrees F.

Keep rows straight with uniform spacing between rows to facilitate post-planting cultivation or spraying. Spacing is determined according to the species, cultural treatments and the end product. Most land managers use from 350 to 600 seedlings per acre.

Frequently you must deal with untrained, inexperienced planting crews. Under these circumstances, it is essential that you give personal supervision to storing, transporting, and handling planting stock as well as planting methods.

Plantation Care

Control of weeds, vines, and grasses is essential to establish hardwoods on bottomland sites. Hoeing, disking, and chemicals have all been tried. Disking is probably the most popular method, but a major disadvantage is that the ground must be dry enough to work. Often the land manager sees the vegetation overwhelm the seedlings during the early spring growth period while the ground is too wet to disk. When the ground is finally dry enough, the seedlings are hidden in the vegetation and some are destroyed during disking.

The land manager can select from a whole arsenal of chemicals to control unwanted vegetation. Overspraying while the seedlings are dormant shows some promise for effective control. Pre-emergent herbicides applied at the time of planting have had a beneficial effect on survival and growth of hybrid poplars.

Much research is now needed, but likely a mixture of chemicals targeted at the problem species will prove to be the most effective method. There are a number of important factors to consider when dealing with chemicals for weed control, including the tolerance of various tree species to specific chemicals. You need to consult local or regional experts to be sure treatments are effective, safe, and comply with appropriate regulations.

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CENTRAL HARDWOOD NOTES

Seeding And Planting Walnut

Aggressive black walnut plantation management will produce rapid growth, good form, and marketable products much faster than plantations allowed to grow without intensive culture.

Selecting Sites

Site quality must be the first consideration in deciding whether to plant walnut. Professional help is essential for this. In general, soils should be at least 36 inches deep, well-drained, and have good moisture-holding capacity. Fertile loams and sandy loams with high organic matter and pH from 6.5 to 7.2 are usually best. Bottomland soils often meet these requirements, but avoid bottoms with excessive flooding, poor internal drainage, and bedrock or gravel deposits close to the surface. Ridgetops, south- and west-facing slopes, and swampy areas usually are poor walnut sites. Some level upland fields may be suitable walnut sites if the soil is deep and internal drainage is good. A mottled appearance (alternating spots of gray and brown or orange color) indicates poor internal drainage.

Preparing the Site

This includes activities necessary to get the land ready to plant the trees. All perennial weeds, brush, or sprouts should be killed with herbicides the summer or fall before planting (table 1).

If soil pH is below 7.0, add lime before planting when it is most easily done. In general, if the pH is less than 6.0, apply 3 tons per acre; if 6.0 to 6.7 apply 2 tons per acre; and if 6.7 to 7.0 apply 1 ton per acre.

Sources of Seedlings

Most state forestry organizations maintain nurseries to provide seedlings for reforestation. Order at least 10 to 20 percent more trees than you need. Sort and plant only the larger seedlings with healthy root systems. If you decide to grow your own seedlings or direct seed:

1. Gather seed from the best-formed and fastest growing trees in your area (see Note 2.02 Genetic Principles).
2. Remove husks.
3. Keep nuts cool and moist at all times.
4. Store in cold moist stratification for 3 months (moist nuts in plastic bags in cold storage or in a well drained, outdoor pit will do).
5. Plant nuts 1 to 2 inches deep in the spring.
6. If you are direct seeding in the permanent plantation, cover each spot with a 1-foot square of 1 -inch mesh poultry netting to deter rodents. Stake the wire down and allow the seedling to grow through during the first growing season.

Table *1 .-Summary of black walnut management activities*

Activity	Date	Rate of application	Comments
Liming	Fall-Winter	Maintain pH between 6.5 and 7.2. Requires 2 tons per acre once every 3 to 4 years.	Incorporate or apply before planting. Use pulverized agricultural limestone only.
Pruning	Feb.-April	Annually after trees are 2 years old.[1]	Maintain a central stem. Side branch pruning should begin when trees reach 6 to 8 feet tall.
Fertilizing	April	100 to 200 lbs. per acre of urea or 400 to 800 lbs per acre of 12-1 2-l 2 every other year, starting after age 3.	Broadcast over entire area just before rain or incorporate. Do not fertilize the growing season of outplanting.
Controlling weeds	March-April	Surflan 75W[2] at 2-2/3 to 5-1/3 lbs per treated acre.	Surflan kills germinating weed seeds so must be applied early. Will not harm walnut seedlings.
Controlling weeds	May-June	Roundup[2] at 2 quarts per acre in 25 gallons of water per treated acre.	Roundup must be directed so that it is not applied to young bark or green foliage. Leave weed or legume strips 4 to 6 feet wide between rows. Strips could be mowed occasionally. After trees are 20 feet tall, weed control can be discontinued or greatly reduced. Tall fescue and goldenrod should be eradicated from all plantings.

[1] Beineke, W.F. 1982. Corrective pruning of black walnut for timber form. FNR-76. West Lafayette, IN: Purdue University Cooperative Extension Service. 7 p.

[2] The use of trade names does not constitute endorsement of the products by the USDA Forest Service. Be sure to read and follow all directions when using herbicides.

7. After the leaves fall, remove the wire netting.
8. If planting nuts in a nursery bed, roll poultry netting over the planted seeds and remove wire in the fall. Seedlings should be transplanted to their permanent location the following spring.

Establishing Plantations

Planting Season.-Plant bare-root walnut seedlings from March through early May, after danger of late freezes. You can direct seed either in the fall or spring; however, spring planting with stratified seed reduces the hazard of rodent pilferage.

Layout and Spacing.-Recommended spacing for walnut plantations varies from 12 x 12 feet (300 trees per acre) to 40 x 10 feet (108 trees per acre) depending on intercropping and thinning schedules. Rows must be perfectly straight in at least one direction to facilitate weed control and other cultural operations.

Planting.-Bare-root seedlings can be planted with a planting bar, auger, tree planting machine, or shovel. Walnut seedlings often require root pruning before planting. Prune long lateral roots that will not fit in the hole without curling or a taproot too long for the planting hole. Do not prune taproots to less than 8 inches.

Plant seedlings at the same depth or slightly deeper than they grew in the nursery. This spot can be recognized as a color change between the stem and root just above the swollen taproot. Keep seedlings cool and moist and out of direct sun when transporting, storing, and planting.

Multicropping.-Multicropping or "agroforestry" is planting two or more crops on the same site. Co-mingling species provides several advantages in walnut plantings. For example, crops of wheat, corn, hay, Christmas trees, or ornamental shrub crops provide income early in the life of the plantation. Black locust, autumn olive, vetch, and European alder add atmospheric nitrogen to the soil and trees and tall shrubs improve the form of the walnut bole through side-branch competition and early natural pruning.

Controlling Weeds

Without weed control black walnut plantations invariably fail or grow too slowly. Three methods of weed control are available to most growers: herbicides, cultivation, and mulches.

Herbicides are safe, effective, and the most popular method of controlling weeds in walnut plantations (table 1).

Cultivating is an acceptable alternative to herbicides but will be needed several times during each growing season. Do not cultivate more deeply than 2 inches because many walnut feeder roots are in the upper soil layers. Also you must keep machinery from injuring the base of the trees.

Black plastic or organic mulches such as leaves, hay, straw, bark, chips, sawdust, may be used to control weeds. Generally, if you have more than a few trees, obtaining enough materials and applying it is not cost effective.

Mowing.-Mowing is not effective weed control and is mostly cosmetic. Weeds resprout using moisture and nutrients. In numerous plantations, mowing has done much more harm than good by causing serious tree wounds.

Pruning

Next to weed control, pruning is the most important cultural activity needed during the establishment period to improve the quality and future value of your black walnut plantation (table 1). For more complete information on the subject see Note *6.09 Pruning Central Hardwoods.*

Fertilizing

Under no circumstances should seedlings be fertilized the year of planting. Most studies show that fertilizing walnut provides little growth improvement. On very good sites nutrient levels are probably adequate for optimum walnut growth, at least while the trees are young. Optimum nutrient levels for black walnut are unknown. The nutrient most often at low levels is nitrogen, and some additional nitrogen might be considered on some sites if optimum growth is desired (table 1).

Problems

Like all hardwoods, planted walnuts must be protected from domestic livestock. Deer browsing and rubbing are also a serious problem in walnut plantations. Small soap bars attached to trees and Ropel, a commercial repellent, have been reasonably effective deterrents.

Most disease and insect problems in black walnut cause cosmetic damage and some growth loss but seldom kill trees. Walnut shoot moth larvae feed on expanding shoots, and various caterpillars feed on leaves. Ambrosia beetles with their companion fusarium fungus sometimes kill small trees to the ground but they usually resprout. Scale insects occasionally kill back the tops of trees. Unless defoliation occurs very early in the season, leaf diseases cause little damage. If you encounter serious pest problems you should contact local or regional experts.

The walnut caterpillar eats the leaves of the black walnut but seldom does serious harm (Philip Marshall)

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CENTRAL HARDWOOD NOTES

Planting Yellow-Poplar, White Ash, Black Cherry, And Black Locust

Hardwood plantations that include yellow-poplar, white ash, black cherry, and black locust can be established on upland sites in the central hardwoods region *(see* Note 3.06 Seeding *and Planting Up/and Oaks,* and Note 3.08 *Seeding and Planting Walnut).* Even though hardwoods are more difficult to establish than conifers, there are good reasons to plant them. Yellow-poplar, white ash, and black cherry can provide valuable lumber and veneer, and black locust is still prized for fence posts because it resists rot. Yellow-poplar, white ash, and black locust can be planted and expected to grow on old fields or in forest openings and clearings that have at least moderate fertility. As a rule, all four species should be planted rather than direct seeded. None of these species is likely to survive if planted under existing tree crowns. Except for black locust, plantations should be free of competing vegetation the first few years after planting.

Here are the basic guidelines for establishing plantations on upland sites:

1. Sites should be moderately productive whether they are old fields or forest openings. Ranked from high to low according to the need for fertility are yellow-poplar, black cherry, white ash, and black locust.
2. Prepare the site before planting. This may include mowing (brush hogging), tilling, and/or application of herbicides for weed and sprout control.
3. Carefully plant large, sturdy, healthy stock at least onequarter inch in diameter at the ground line for black cherry, white ash, and black locust. Yellow-poplar should be at least one-third inch.
4. Control weeds and sprouts for 2 to 4 years, depending on competition and tree growth. See exception for black locust.
5. Take appropriate action to control cattle, deer, rabbit, and/or mice damage.

Selecting Sites

Yellow-poplar, white ash, and black cherry grow best on deep, moist, but well drained soils. There should be at least 18 inches of soil above a hard pan or other impermeable material. Sites inherently poor or impoverished by past practices should not be planted with site demanding hardwoods. You can improve border-line soil by planting legume crops and fertilizing, or even planting black locust, which fixes nitrogen in the soil. If grass is sparse and not vigorous, the site quality is likely too poor to support these species. In hilly country, the coves, stream bottoms, and the north and east lower slopes are generally moister and consequently better for good tree growth. On questionable sites, consult local or regional experts.

Black locust is more suitable than the other species on poor or old-field sites. It fixes nitrogen in the soil, tolerates drier sites, and consequently may survive and grow satisfactorily on the south and west facing slopes. If the site is too severe, even black locust may not produce a crop.

Preparing and Maintaining Sites

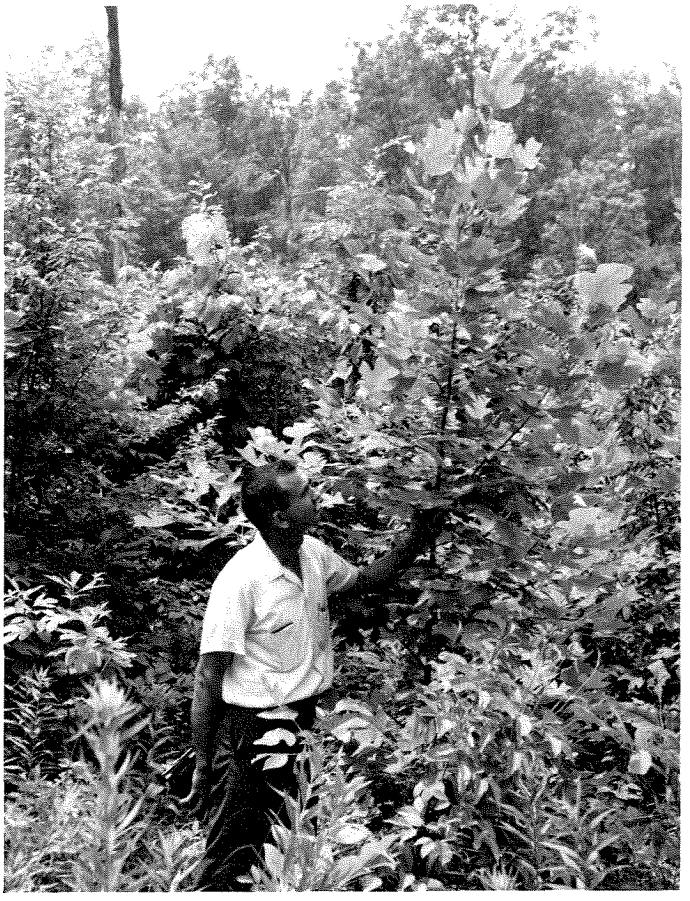
You have to prepare the site and control weeds if you want to establish yellow poplar and white ash. Control weeds by mowing and/or using herbicides unless there is a dense stand of grass occupying the site. Where grass is dense and vigorous, plow and disc. You may need to follow up treatment with pre-emergent weed control chemicals. It is not necessary to control weeds over the entire plantation area. You can treat 2- to 4-foot strips in the tree rows or you can treat a 2- to 4-foot-diameter spot around each tree.

Each tree species has its own herbicide tolerance level that varies with soil texture and organic content. Take care to protect people, animals, and the environment when using chemicals to control weeds, brush, and grass. Refer to publications, product labels, and local experts for specific application instructions and regulations.

Black cherry has not been widely planted on either forest or old-field sites in the central hardwoods region. However, in Pennsylvania tests, black cherry has been grown by planting large seedlings (20 inches tall) in scalped areas and fertilizing with nitrogen and phosphorus.

Black locust will generally become established when planted on unprepared sites unless competition is extreme. Like all crops, black locust will do better with some site preparation, weed control, and/or fertilization, but of the four species, it needs the least care. It grows rapidly and will occupy most sites in a few years.

(For additional essential information on site preparation, planting stock selection, and care and planting methods *see* Note 3.05 Seeding *and Planting Hardwoods).*



Five-year-old yellow-poplar

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CENTRAL HARDWOOD NOTES

Seeding And Planting Pines

Pines that occur naturally in parts of the region, as well as those that do not, have been introduced throughout. Pines usually produce greater volumes of wood faster than hardwoods, but in many parts of the region there is no market for pine stumpage or logs. Aside from wood production, pines are established for Christmas trees, windbreaks, landscaping, erosion control, and habitat diversity. Often a rotation of pine will build up a poor old field site so that it will once again support quality hardwoods.

Climate, Site, **Seed Source, and Species Compatability**

Pines grow on a variety of sites but do best where the climate is similar to the climate of their natural range. So you should plant red pine and jack pine in the northern part of the central hardwood region; eastern white pine in the eastern part; and shortleaf, loblolly, and Virginia pines in the southern part. Scotch pine, a native of Europe, has been successfully planted in much of the region for Christmas tree production only.

Pines do best on moderate to well drained, acidic soils of coarse texture. Soils less than 18 inches deep over a fragipan should not be planted with pines.

On poorly drained soils use loblolly in the south, white pine in the north. On such sites shortleaf pine is prone to littleleaf disease. Don't attempt to establish pines at all on soils that stay wet or are subject to periodic flooding. Do not regenerate pines for wood production on sites less than black oak site index 45. They may survive, but will not grow fast enough to pay management costs in a reasonable time. Sites with site indices exceeding 65 will grow good hardwoods and will provide severe competition to pines, so generally you should restrict pine planting to sites ranging from 45 to 65.

Unless other species have performed well on eroded areas and mine spoils, plant shortleaf or Virginia pine in the south and jack pine in the north. Except in the extreme southern part of the central hardwood region, winter burn is common on loblolly and shortleaf. Loblolly grows faster than shortleaf on better sites but shortleaf or more northern species should be used where winters are cold, droughty or subject to ice storms. Don't plant eastern white pine in the western part of the region where seasonal droughts are common. Do not plant jack and red pine in the southern part of the region.

Geographic variations.-Growth can be affected by geographic origin of the seed. So get seedlings from seed collected from latitudes similar to the planting site. This is a good rule even within the natural range of the species. If the soil is shallow and accompanied by limestone outcrops, consider planting eastern redcedar.

Reforestation Techniques

Direct seeding.-In the central hardwoods area, many direct seedings have failed. Seeding should be limited to shortleaf pine within its natural range either on large areas following wildfires or where terrain or soils are too difficult to plant. For broadcast seeding, prepare the site so that at least 65 percent of the area has less than one inch of duff or loosened leaf litter above mineral soil. If possible, leave some debris for shade to reduce moisture loss. Broadcast application requires about 1/2 pound of high quality seed per acre. Consider seeding strips, rows (furrows) or spots, to reduce the amount of seed needed, to improve spacing, and to reduce site preparation costs. About 1,000 spots can be seeded with 2 to 3 ounces of seed per acre, 4 to 8 seeds per spot. Sow bird and rodent repellent treated seed unstratified between December and February or stratified from March 1 to April 15.

Planting.--Machine or hand planting controls stocking better than seeding does and may reduce the need for precommercial thinning and make harvesting easier. It is also more practical to plant expensive, genetically-improved seedlings than to plant improved seed. For locations with saw log markets only, use 12 x 12 foot spacing for white pine and 8 x 10 or 10 x 10 feet for all other pines. On better sites consider mixed stands of pine and hardwood. Where there is a small roundwood market or where quick crown cover is needed, use 8 x 8 foot spacing or less.

Site Preparation

Both survival and growth of pine seedlings are improved by reducing the amount of competing vegetation. Hardwood sprouts and herbaceous growth may be controlled by fire, machinery, approved chemicals or a combination of these methods.

Use fire in combination with chemicals, as sprouting may intensify after fire. Burning is usually used with direct seeding rather than planting. Before planting old fields, kill herbaceous growth with herbicides. Use a mix which includes a pre-emergent herbicide to kill germinating seeds of annual weeds as well as established plants. Apply the herbicide in spots or strips. This reduces the costs, herbicides used, and erosion. Strips 4 feet wide or spots 4 feet in diameter provide adequate control.

Ripping can enhance soil aeration and root development, concentrate fine-textured soil, and make hand planting easier. In the fall before planting, rip on the contour to a depth of 15 to 24 inches (fig. 1).

A

B

C

Figure I.--(A) Planting site has been "ripped" and treated with herbicide in the spring, one full year before being planted. (B) On this planting site the rows were first ripped and then "banded" with the herbicide *Roundup*[1], applied in mid-August. (C) Planted seedling. Note that grass is allowed to grow between rows to reduce the effects of drying winds and too much direct sun in the summer. Grass should be mowed in the fall to discourage damage by mice and rabbits during winter. (Lois Schmollinger)

'The use of trade names does not constitute endorsement of the products by the USDA Forest Service.

Special Practices

Planting stock.-Although bareroot nursery seedlings are commonly planted, container-grown stock can improve survival and growth on sites difficult to regenerate, extend the planting season, and possibly reduce the need for site preparation. You can improve survival of bareroot seedlings by dipping them in a commercially available antidesiccant. If available, use genetically improved planting stock to improve growth, vigor, and disease resistance.

underplanting.-Shortleaf pine and eastern white pine have been successfully underplanted when sites were adequately prepared and the seedlings were released at the proper time. The advantages are better seedling survival in dry years, easier hand planting, less soil disturbance, and less competition from sprouts and annual weeds. Kill all stems 1 to 8 inches d.b.h. with herbicide before you plant, or at least in the same growing season. Plant white pine slightly denser than normal and shortleaf pine on normal spacing. Shortleaf seedlings damaged by logging will sprout. Remove the overstory within 1 to 3 years.

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CENTRAL HARDWOOD NOTES

The Importance of Site Quality

Yield and quality of central hardwoods depend greatly on the site. So, first off you should determine the site quality of your land for a variety of tree species. This information will allow you to compare yield and value so you can favor the species best suited for each site. Knowing site quality will help you determine what levels of management intensity and investment your land will support.

There are several advantages to intensive management on productive sites:

- Good sites can yield more at a higher quality, especially for high value species such as white and red oak, black walnut, black cherry, and white ash.
- Good sites generally require shorter rotations thus reducing interest costs on long-term forestry investments.
- Good sites may produce a better return on investments in silvicultural practices such as thinning, pruning, fertilization, and drainage.
- Good sites typically are more diverse in woody and herbaceous understory plants and produce more food and habitat for wildlife.

It is also essential to know the capability of poor sites to prescribe the proper kinds and levels of management.

Site quality for central hardwoods is usually expressed as site index-the height of the dominant and codominant trees at an index age, usuatly 50 years. Site index for many central hardwoods can be estimated directly using site index curves or tables and species comparisons. Indirect site index estimates are obtained from soil site relationships, soil surveys, or site classification systems. Methods for direct and indirect site index estimation are discussed in detail in Note 4.02 *Measuring Site Index in the Central Hardwood Region.*

Central hardwoods cover a large geographical area with great differences in climate, topography, and soil. These differences may cause considerable variation in site quality. Most central hardwood species respond similarly to the same favorable site conditions, although the importance of any one site factor or combination of factors may vary among species.

Soil properties most often correlated with site quality are surface soil thickness, total soil depth, and surface and subsoil textures. The surface soil, or “A” horizon, is generally considered the layer most favorable for fine root development and absorption of nutrients and moisture. The relationship between surface soil thickness and site quality is often curvilinear. Where surface soils are thin, small increases in surface soil thickness can cause large increases in site quality.

The best hardwood sites are usually on medium-textured soils. Texture and stone content affect available moisture, nutrient levels, internal drainage, and aeration. Coarse-textured soils generally are of lower site quality because soil moisture holding capacity and nutrient levels are limited. Medium-textured soils are good sites because they have adequate available moisture and nutrients, good structure, internal drainage, and aeration which favor root development. Fine-textured soils generally have adequate soil moisture and nutrients, but are often poorer sites because they commonly have clay subsoils that impede internal drainage, aeration, and root development.

Topographic variables often associated with site quality are: aspect, slope position, slope gradient, slope shape, and elevation. The best hardwood sites are generally north- and east-facing, gently sloping, concave or lower slope positions. The poorest sites are on narrow ridge tops or south- and west-facing, steep, convex upper slopes. Topographic features are often closely associated with soil depth, soil profile development, amounts of available soil moisture and nutrients, and microclimate. In hilly and mountainous terrain, topographic features have the strongest relationships with site quality. On more level terrain, site quality is influenced more by soil properties.

Any estimates of site quality, whether from direct tree measurements or indirect estimates based on soil and topographic features, are only "point" observations of variable conditions in the landscape. Because the land manager deals with large areas, point site quality estimates-to be useful-must be translated into a site classification applicable to larger areas.

A site classification system should be relatively simple, practical, and applicable to all sizes and classes of ownership. The scale and intensity of classification should be appropriate to the management objectives.

Recent physiographic or ecological site classifications have been developed for the Interior Uplands of east-central United States (see Note 4.03 Forest Site Classification in the interior Uplands) and the Mark Twain and Monongahela National Forests. A multifactor site classification system is presently being developed for the southern Appalachian Region.

These physiographic or ecological site classification systems stratify the landscape in a hierarchy according to physiography, geology, soils, topography, and vegetation. The basic management units, landtypes (or ecological landtypes), are visually identifiable areas that have similar soil and productivity because of similar climatic and geologic processes. Landtypes are described in terms of geographic setting, soils, parent material, soil depth, soil moisture, drainage, and most common or potential climax vegetation. Landtypes are also rated for potential competition, seedling survival, erosion potential, and other site-related factors that may

affect forest management operations. Each landtype is evaluated in terms of productivity (site index or volume growth) for selected species and rates species desirability for timber production.

Land units identified in these classification systems have ecological significance for a wide range of forest-related resources and their potential uses. Site classification systems allow you as a resource manager to determine the capability of the site right in the woods and are essential to provide an ecologically based, practical framework for forest management planning and forest practices.

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CENTRAL HARDWOOD NOTES

Measuring Site Index In The Central Hardwood Region

Site index is the average height of dominant and codominant trees growing in well-stocked, even-aged stands at a given age called "index age." Fifty years is the most commonly used index age in upland hardwoods. Sometimes 25 or 30 years are used for short-rotation bottomland hardwoods. Site index is widely used to indicate site quality because it correlates well with site productivity, is easily measured, and within limits is not affected by stand stocking. You can measure site index either directly or indirectly. It is important to be able to determine site productivity when deciding on biological treatments and levels of economic investments *(see* Note 4.01 *The Importance of Site Quality).*

Direct Measurement of Site Index

Site index is determined directly by measuring the heights and ages of sample trees and then estimating tree heights at the index age from a table or set of curves.

To measure the site index of a well-stocked, even-aged stand:

1. Delineate a stand of uniform site quality.
2. Select 5 to 10 sample trees evenly distributed over the area that best represent average site productivity. Sample trees should be of the same species if possible, and should be:
   - Healthy dominant or codominant trees
   - Straight, vertical, single-stemmed trees (multiple-stemmed trees and those with acute-angle forks are acceptable if others are not available)
   - Trees that have never been suppressed
   - Trees that have not been significantly damaged by fire, grazing, insects, disease, wind, ice, or lightning
   - Trees that do not differ in age by more than 10 years from other trees in the stand.
3. Measure tree heights with a measuring pole or altimeter, clinometer, or similar optical device.
4. Determine tree ages from increment cores, stand records, or stump ring counts. Take increment cores at breast height and add 2 to 5 years to obtain total age. The site index curve publication should indicate the proper number of years to add. Count the rings carefully using a hand lens if necessary, because each l-year error can cause a 1- to 2-foot error in site index. Examine each core or stump and reject trees that have been suppressed at any time. Heights and ages are most easily determined when a cutting is being made, where heights can be measured on felled trees and ages determined from stump ring counts.

5. Use site index curves or tables appropriate for the species and physiographic region. This is important because species often differ from each other in rates and patterns of height growth among different regions. The Carmean, Hahn, and Jacobs publication (1989) contains most site index curves available in the central hardwood region. Service foresters or extension foresters can usually advise you on the best curves to use for specific applications. The curves included at the end of this Note (figs. l-4) are regional curves for four upland oaks in the unglaciated portion of the Ohio Valley and southern Missouri (Carmean 1971).
6. If you cannot get enough sample trees of a single species, convert site indexes of the different species to the equivalent site index of one species with locally developed site index comparison charts or graphs. Conversions are essential because the site indexes often differ among species. For example, in Missouri a black oak site index of 63 feet is equivalent to a scarlet oak site index of 66 feet, and a white oak site index of 60 feet. Because of these differences, site indexes should always be listed by species: for example, white oak site index 58 feet, or black oak site index 67 feet.
7. When the site indexes of all sample trees have been determined and, if necessary, converted to a common species, average all the values to obtain the mean site index of the area.

Indirect Measurement of Site Index

Direct measurement of site index is best, but if suitable sample trees are not available, you can often estimate site index indirectly. Indirect methods used in eastern forests include indicator species, growth intercept, ecological site classification, and soil-site relations. The use of understory indicator species to estimate site quality does not work well in the central hardwood region. And the growth intercept method is only applicable in young stands of species such as eastern white pine that form a single whorl of branches each year. Several ecological site classification systems have been developed recently in the central hardwood region. These systems give average site indexes, by species, for specific physiographic regions and subregions based on landform or landtype, aspect, and soils. One of these systems is described in Note 4.03 Forest *Site Classification in the Interior Uplands.*

In the soil-site relations method, site index and several easily measured soil and topographic factors are correlated mathematically. A variation of this method has been developed for bottomland hardwoods in which various site factors are assigned numerical values, and the sum of these values equals the site index.

Soil and topographic factors often included in soil-site correlations for upland forests are surface soil depth, total soil depth, soil texture, aspect, slope position, and gradient. Factors often included for bottomland areas are elevation, drainage, water table depth, and soil texture.

To use the soil-site method, first delineate an area that is generally uniform for the soil and topographic variables in the equation. Select several sample points throughout the area, and measure the relevant soil and topographic factors at each point. Calculate the site index at each point, and average the sample point site indexes to obtain the mean site index of the area. The number of sample points necessary to achieve a given level of precision can be estimated after the site indexes of several sample points have been determined. If the first sample points vary widely, take more samples. If they do not vary, your sample is probably adequate.

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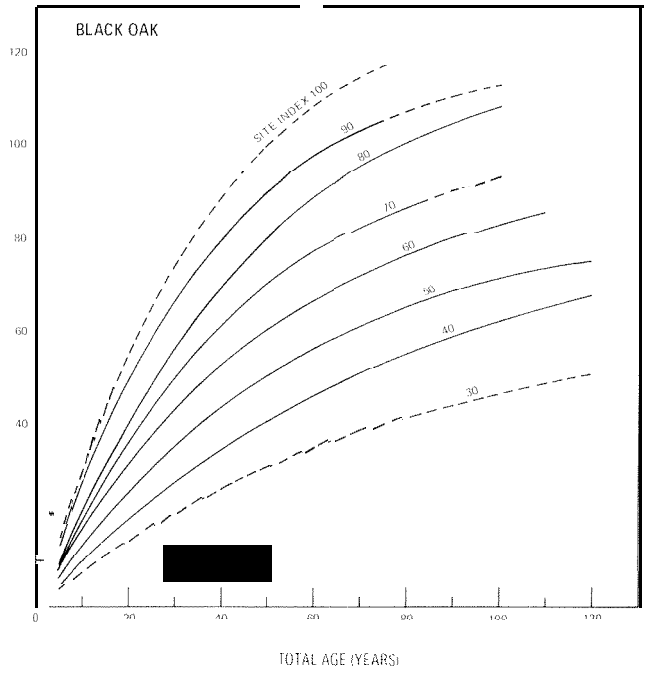

Figure 1 .-Site index curves for black oak in the Central States. Based on trees located in the unglaciated portions of southeastern Ohio, eastern Kentucky, southern Indiana, southern Illinois, and southern Missouri.

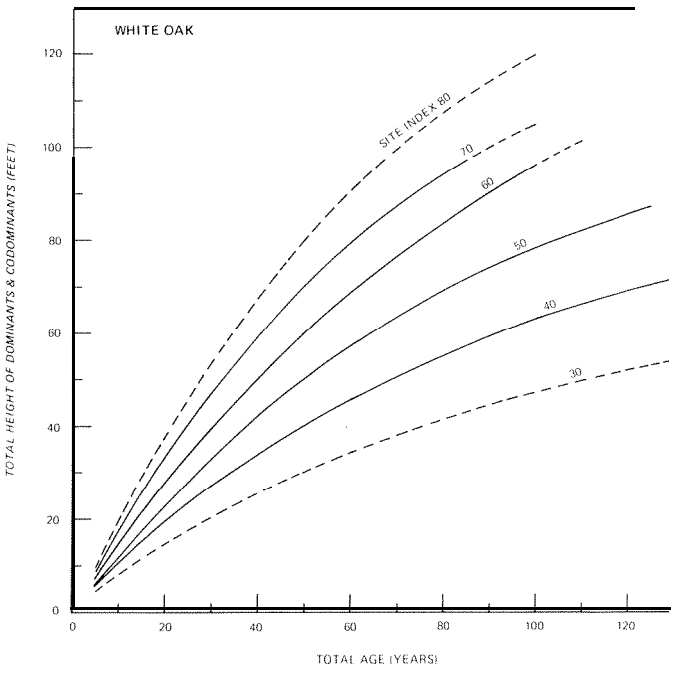

Figure 2.-Site index curves for white oak in the Central States. Based on trees located in the unglaciated portions of southeastern Ohio, eastern Kentucky, southern Indiana, southern Illinois, and southern Missouri.

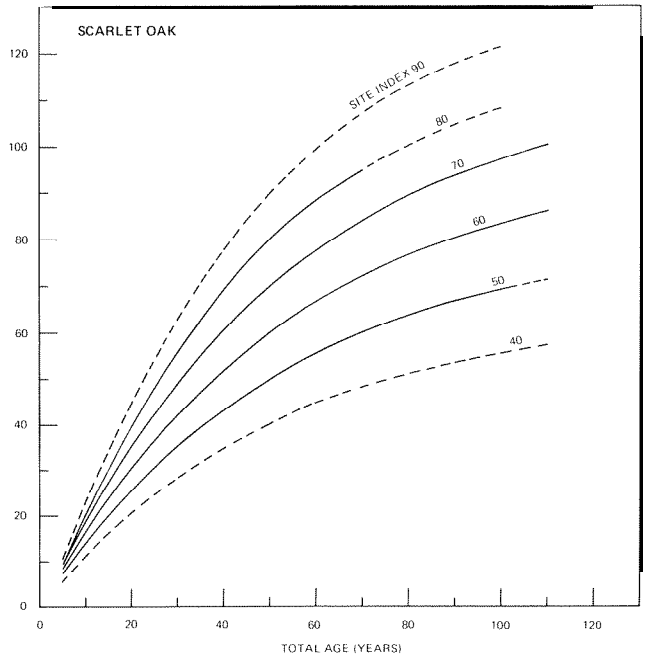

Figure 3.-Site index curves for scarlet oak in the Central States, Based on trees located in the unglaciated portions of southeastern Ohio, eastern Kentucky, southern Illinois, and southern Missouri.

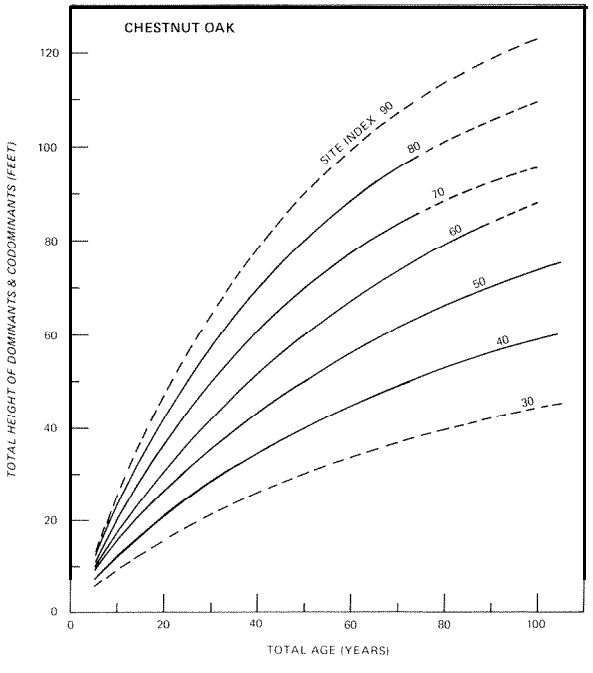

Figure 4.-Site index curves for chestnut oak in the Central States. Based on trees located in the unglaciated portions of southeastern Ohio, eastern Kentucky, and southern Indiana.

North Central Forest Experiment Station 4.03

CENTRAL HARDWOOD NOTES

Forest Site Classification In The Interior Uplands

Introduction

Classification and evaluation of forest sites is an essential step in managing central hardwood forests. In Note 4.01, The Importance of Site Quality, the usefulness of land classification systems was discussed. The present Note describes one of those systems in more detail. It is an easy-to-use system developed for the Cumberland Plateau and Highland Rim-Pennyroyal physiographic provinces in Alabama, Tennessee, Georgia, Kentucky, and Virginia. Although the system applies only to a limited portion of the central hardwood forest, the concepts used to develop the system are probably applicable to the entire area. Potential users must first obtain copies of the publication listed at the end of this Note.

In this system the landscape is stratified according to physiography, climate, geology, soils, topography, and vegetation. Macroclimate does not vary much across both provinces, but microclimate varies because of local relief. Existing vegetation is of minor importance because, generally, today's forests often do not indicate site potential and present stand boundaries may or may not coincide with site boundaries.

Five-Level System

The system has five levels. Physiographic province is the largest and least detailed level. Landtype is the smallest and most detailed level, and is considered the basic unit of land for management. Intermediate levels are region, subregion, and landtype association. The Cumberland Plateau was divided into four regions and the Rim was divided into two regions. A separate guide was published for each of these six regions (see References).

Although nearly 200 landtypes were identified and described-95 on the Plateau and 98 on the Rim, most tracts of land smaller than 500 acres seldom contain more than 12 landtypes. landtype names are composed of two or more of the following descriptors: topographic-e.g. broad upland, ridge, slope, or streambottom; geologic-e.g. sandstone or limestone; aspect-north or south; or soil drainage-good or poor.

Standard Format of the Guides

A standard format for describing the landtypes was developed to enable users of the system to recognize landtypes. Each landtype is described in terms of nine elements-geographic *setting, dominant soils, bedrock, depth to bedrock, surface soil texture, internal soil drainage, relative soil water supply, soil fertility, and vegetation.* The landtype used in the example (table 1) is Landtype 1, Broad Undulating Sandstone Uplands on the Mid-Cumberland Plateau.

Table 1 *.-Forest management interpretations for Landtype 1: Broad Undulating Sandstone Uplands on the Mid-Cumberland Plateau.*

PRODUCTIVITY

Species	Site index		Average annual growth cubic feet per acre	
	Natural stands	Old-field plantations	Natural stands	Old-field plantations
	age 50	*age 25*	*age 50*	*age35and40*
E. white pine	**75**	**52**	**126**	**145**
Shortleaf pine	**65**	**45**	**131**	**102**
Loblolly pine	**75**	**50**	**114**	**117**
Virginia pine	**70**		**92**	
E. red cedar	**30**			
Upland oaks	**60**		**43**	
Yellow-poplar	**85**		**80**	

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate	Slight	Slight	Slight	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	E. red cedar
Shortleaf pine	White oak	Post oak
Loblolly pine	Chestnut oak	Sassafras
Virginia pine	Black oak	Serviceberry
Yellow-poplar	S. red oak	Black locust
	Scarlet oak	American holly
	Sweetgum	Red maple
	Black cherry	Blackgum
	Dogwood	
	Sourwood	
	Persimmon	

Following each landtype description are forest management interpretations. Each landtype is evaluated for productivity (site index and mean annual cubic growth) and desirability (most desirable, acceptable, and least desirable) of selected conifers and hardwoods for timber production. In addition, each landtype is rated (slight, moderate, or severe) for five soil or site-related problems-plant competition, seedling mortality, equipment limitation, erosion hazard, and windthrow hazard-that can affect forest management operations (table 1).

Application

To use the system, you must first determine the physiographic province and region in which your forest land lies from the map in figure 1. Send for that guidebook (see References). After you get the guidebook, here is how the system works:

1. Determine the subregion and landtype association where your land occurs using the guidebook.

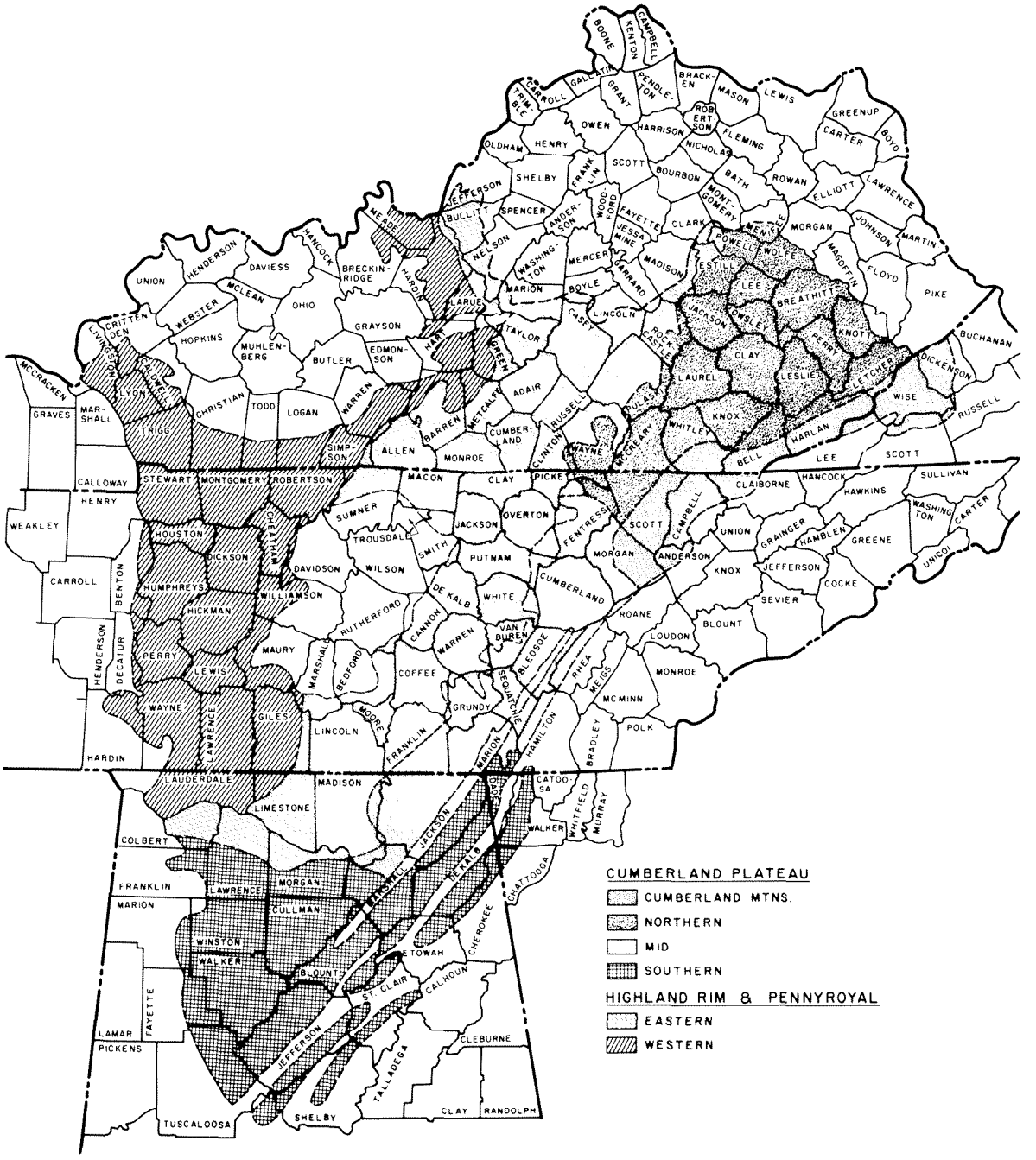

Figure 1 .-Locator map showing physiographic provinces and regions. (See References and order guidebook for your area.)

2. Determine which landtypes may occur on the tract in question using the summary of landtypes and the individual landtype descriptions.
3. Read the description of each landtype and decide which of the possible landtypes actually occur on the tract in question. This step can usually be done at the desk if the user is familiar with the tract. A field reconnaissance will be necessary if you are unfamiliar with the tract. Landscape drawings are included in each guidebook to assist you in determining where the individual landtypes occur on the landscape. (For an example see fig. 2.)

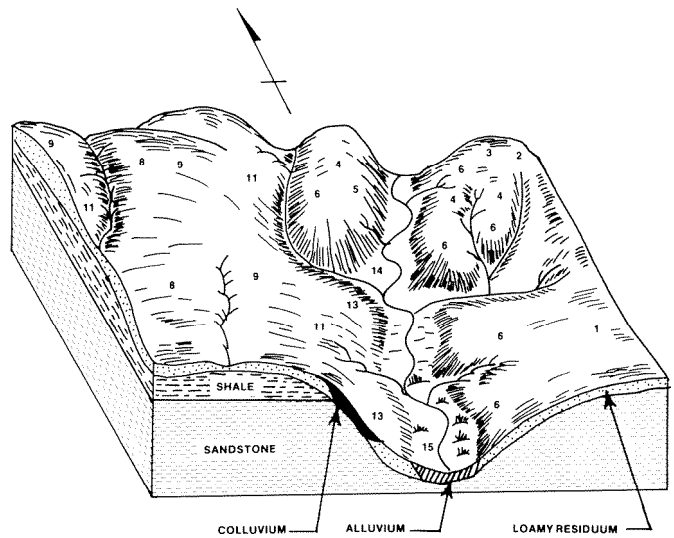

Figure 2.-Landtypes characteristic of the weakly and moderately dissected portions of the surface of the Mid-Cumberland Plateau. Landtypes (numbers) in the legend are described in General Technical Report SO-38.

4. Refer to the accompanying tables of interpretations for each landtype to determine species productivity, species desirability, and severity of management problems (example, table 1). You may wish to modify these timber production oriented interpretations where other land uses are a primary consideration.
5. Make a landtype map using a topographic map or aerial photo for the base. You can do this at the desk if you are familiar with the tract, or in the field if you are unfamiliar with the tract. Determine the acreage of each landtype.

Continuous forest inventory or other inventory systems can easily be linked with this site classification system to obtain information on acreage, stocking, composition, and growth of forests by landtypes. Once productivity data are available on a specific tract, they should be substituted for the regional values.

For additional information or copies of the individual regional site classification guides, write the Southern Forest Experiment Station, USDA Forest Service, U.S. Postal Service Bldg., 701 Loyola Avenue, New Orleans, LA 70113.

References

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CENTRAL HARDWOOD NOTES

Introduction To Forest Growth And Yield

Forests are dynamic communities that are constantly changing. To the casual observer, only the most obvious change, such as the death of a tree, may be discernible. However, other changes are continually occurring. Trees grow in both height and diameter. This is termed survivor growth Ingrowth occurs when a tree's diameter grows larger than an arbitrarily specified lower size limit. Collectively, mortality survivor growth and ingrowth are designated as the components of forest growth. They are usually expressed on an annual basis and in units of merchantable wood volume.

A term very closely related to forest growth is forest yield. It is the sum of annual changes in the growth components. Thus, yield is the net volume of wood present in the forest at any given age while growth is the change in wood volume in a given year.

When you consider the concepts of forest growth and yield, some important questions are:

1. Why are growth and yield important to both the forester and the landowner?
2. How do you estimate growth and yield?
3. What factors affect forest growth?
4. Can growth be modified?

Importance of Growth and Yield

To manage a business, an organization, our personal finances or even a forest, we need to measure our ability to achieve a specific goal. For example, in managing our personal finances we may want to accumulate a certain amount of capital at the end of a given period. The annual interest or return corresponds to how fast our investment increases in value. We may express this increase in actual dollars or as a percentage increase which will let us compare alternative investment opportunities. The same concept may be used in managing a forest. The annual growth corresponds to interest income and may be expressed as either the absolute or percentage increase in wood volume. In both illustrations, the yield or net amount present at the end of a given period is represented by the summation of the annual increases added to the initial amount with which we began. The only difference is the units to express the principal-dollars versus wood volume.

From the foregoing analogy, it is easy to understand why growth is called "the lifeblood of the forest." The dynamic processes of mortality, survivor growth, and ingrowth are the record of changes in the forest resource. Both the forester and the landowner can use estimates of these changes or "growth" to evaluate their

management activities and forestry investments. In planning forestry operations, estimates of future wood volume that will accumulate frdm alternative management practices are absolutely essential. Growth and yield data are the sole source of these predicted values.

A service forester explaining management alternatives to a landowner.

Estimation of Growth and Yield

Growth estimates may be obtained for individual trees or for the entire forest. If your objective is to evaluate the quantity of various products that can be obtained from a mixture of species that comprise your forest, then an individual tree approach is ideal. On the other hand, if your interest is just to evaluate the total increase in volume, then a stand level approach would be appropriate.

An individual tree approach can be as simple as recording successive annual bole circumference measurements. This is exactly the process used by foresters. All trees are periodically remeasured on permanent plots established throughout a forest. These data are used to develop equations that describe the growth of individual trees in relation to their surroundings. An example of this approach is TWIGS, a computer program to "grow" a list of individual trees. The use of TWIGS is described in Note 5.10 Growth *and Yield Models for Central Hardwoods.*

The growth of individual trees can be collectively summarized to obtain yield tables. A yield table contains the net volume per acre for a given species, age, and site index. Some yield tables may also use stand density as an additional variable. In the past, the majority of yield information was provided in tabular form; however, today it is often expressed as a mathematical equation. This is convenient for calculating growth estimates and for including yield estimates in computer programs. A stocking chart is included in Note 5.02 Stocking Chart for *Upland Central Hardwoods.*

Factors Affecting Growth

There are many complex and interrelated factors that influence the quantity, quality, and distribution of growth in a forest stand. Some of the more important factors are:

site quality	environmental conditions
stand age	species composition
stand stocking	stand density

Site quality refers to the capacity of the soil at a given location to produce a crop of trees. Characteristics such as soil depth, nutrient and moisture content, and soil structure significantly relate to tree growth. All trees do not respond the same on a given site. Each species has its own physiological requirements and responds uniquely to a given site. Environmental and climatological factors strongly relate and interact with the soil conditions. The majority of site and environmental factors are not easily changed. A fundamental management practice is to prudently match species' requirements with site characteristics.

Individual trees as well as whole stands have characteristic growth patterns that depend on age. For very young trees, growth is slow. This is followed by a period of very rapid increase that gradually tapers off and ultimately declines in old trees. Stand growth follows a similar pattern. While the growth pattern may be similar for all species, the quantity of growth will vary by species and site. Age and site quality are the primary variables used to estimate growth and yield.

Stocking and *density* are terms to describe the extent to which the productive capacity of an area is being realized. A stand may be characterized as overstocked, understocked, or fully stocked. These terms imply a subjective indication of the number of trees that produces optimum growth. Stand density, a way of quantifying stem crowding, may be expressed as square feet of basal area, degree of crown closure, volume of wood or number of trees. Very dense stands grow at reduced rates while low density stands do not achieve the full productive potential of the site. Acceptable growth may be obtainable somewhere within a

wide range of stocking and density levels but it is often difficult to recognize the proper levels. Stocking charts that relate basal area, average diameter, and number of trees to stocking percentages are valuable aids to determine if a stand is attaining its potential. Upland oak stocking charts are included in Note 6.06 *Thinning Even-Aged, Upland Oak Stands..*

Modifying Growth

For a given site, species mixture, and stand condition, there is a finite amount of growth that can occur. One management option may be to leave the stand grow and develop according to natural competition. An alternative may be to consider modifying the stand through such cultural operations as thinning or timber stand improvement. Such treatments should consider species composition, spacing between trees, tree size, tree quality, and the space available for tree crown development. The decision to remove individual trees should be made to provide residual trees with optimum growing space. So, the site's full growth potential is concentrated on fewer, faster growing, better quality trees, which lowers competition among remaining stems and reduces the mortality component of growth. Growth and yield equations that reflect such cultural treatments enable the forester and landowner to consider the consequences of alternative management opportunities. Illustrations of this concept are given in several Notes that follow.

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CENTRAL HARDWOOD NOTES

Stocking Chart For Upland Central Hardwoods

The upland hardwoods stocking chart, introduced by Gingrich in 1967, has become one of the forest manager's most useful tools. The chart allows you to determine the condition of the present stand in relation to a stocking standard. The stocking of a stand is extremely helpful in prescribing various silvicultural treatments such as intermediate thinnings, improvement cuts, or regeneration cuts.

After determining the number of trees per acre and the basal area per acre, you can read the percent stocking directly from the graph (fig. 1). Percent stocking tells us how completely a particular stand is occupying its area relative to these charts, and also how much of the stand may be removed without wasting growing space. Stocking charts can help make other management decisions besides timber harvesting, regeneration, or thinnings. They are particularly useful for wildlife and watershed management decisions when appropriate standards are available for comparison.

The A line on the chart was developed from stands of average maximum density, and the B line was developed from open-grown trees. Upland hardwood stands can be grown over a wide range of percent stocking and still use all the growing space. Total basal area growth *per acre* of surviving trees will be about equal for stands of similar site and species composition falling between the A and B lines on figure 1. However, diameter growth of *individual trees* will vary greatly within this density range; the slowest rates occur near the A line, then continue to increase as percent stocking is lowered *(see* Note 5.03 *Estimating Oak Growth and Yield).*

The chart is easy to use as long as you know the *basal area per acre* and the *number of trees per acre.* Both these variables can be readily obtained in the field with a wedge prism and a tree count. The point where the number of trees per acre intersects the basal area per acre represents the present stand conditions. For example, from your stand tally you find 600 trees per acre and 80 square feet of basal area. Then from figure 1 the point of intersection indicates your stand has a mean diameter of about 5 inches and is approximately 90 percent stocked. When the tree tally is recorded by species and size class it provides extremely useful information for prescribing silvicultural treatments. For example, a simple classification system where trees are tallied by acceptable or unacceptable growing stock and cull, based on species, quality, and size class, can help the manager decide whether the stand is worth managing or whether it should be replaced now with a thrifty new stand. Also a simple classification of stand stocking by size classes such as saplings, poles, small sawtimber, and large sawtimber is helpful in making the appropriate prescription.

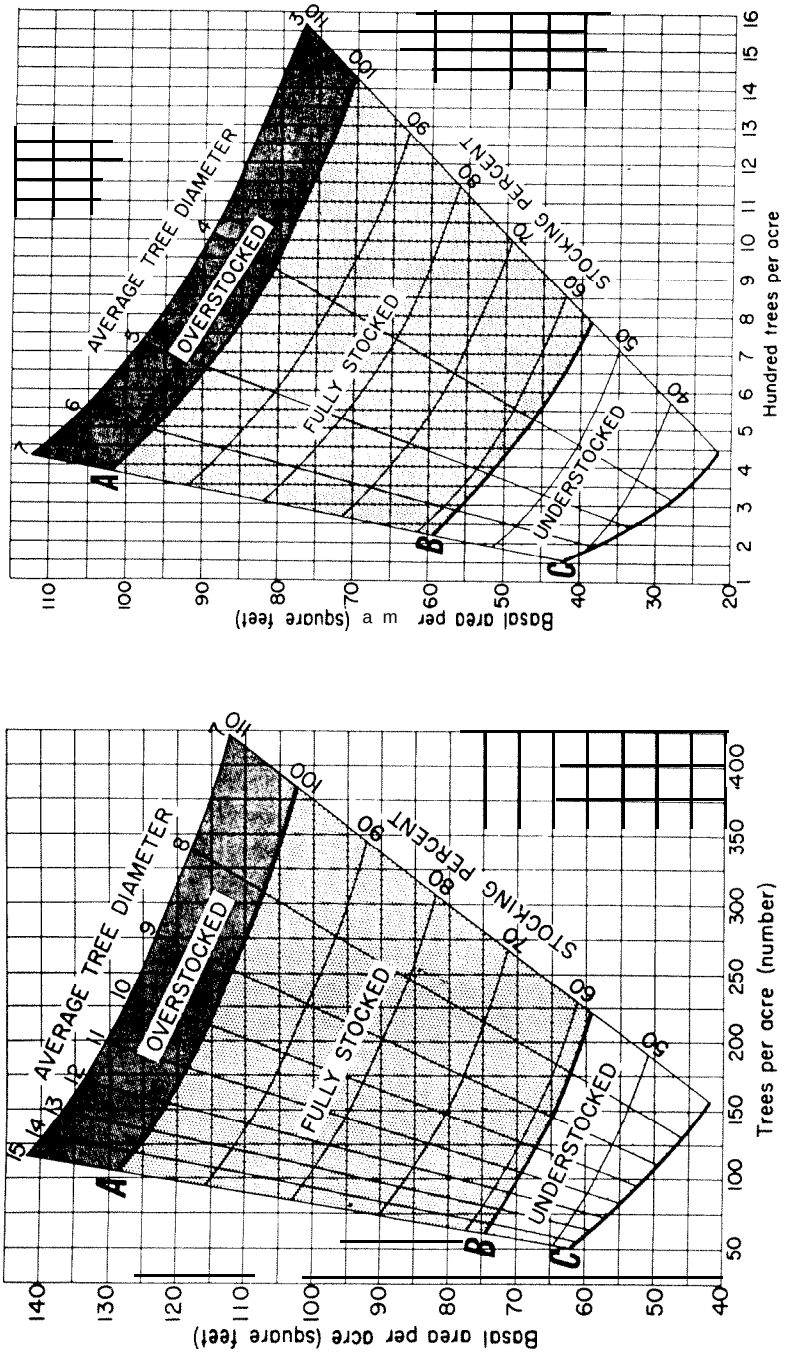

Figure 1 .-Stocking chart for upland central hardwoods. (Gingrich 1967)

Stands with stocking around 100 percent (A-level) are near the average maximum density and are overstocked for timber management purposes. Individual trees grow slowly and natural mortality is high, primarily among small trees. A thinning would benefit such stands, increasing growth on the bigger, higher quality, and more valuable residual trees. A light thinning would reduce the percent stocking to about 80 percent; a moderate thinning to about 60 percent; and a heavy thinning to about 40 percent.

At the B-level, when all trees are uniformly spaced over the area, each tree presumably has all the growing space it can use (fig. 1). So at densities below B-level some growing space is not occupied by timber producing trees and total stand production will be reduced. Moreover, extensive branching may reduce the quality of residual trees, and reproduction and brush develop in a heavy understory. The B-level (or slightly below) continues to be the recommended thinning level for many upland hardwood stands.

Stands below the C line are understocked. The C line indicates the stocking necessary for a stand to reach the 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. If a stand is much below C-level it is severely understocked and in most cases the general recommendation would be to regenerate that stand now rather than continue to waste growing space for another 15 years or longer.

Stocking charts (or equations) for other species are becoming available. In addition to the chart for the upland oaks, there are now charts for yellow-poplar, black cherry, sugar maple, and the northern hardwood species (maple-beech-birch). However, work continues on the development of stocking charts for the truly mixed-species stands that we encounter in the central hardwood region.

Reference

Gingrich, Samuel F. 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the central states. Forest Science. 13: 38-52.

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CENTRAL HARDWOOD NOTES

Estimating Oak Growth and Yield

Yields from upland oak stands vary widely from stand to stand due to differences in age, site quality, species composition, and stand structure. Cutting history and other past disturbances such as grazing or fire also affect yields.

The old normal yield tables for upland oaks based on unmanaged stands are no longer suitable for modern timber management. Today's managers need information on how yields vary in relation to relative stand density and species composition. They also need to know how the yields may be altered by various thinning strategies or other timber management practices. This information is available through stand models.

Managed Stand Yield Models

Growth and yield predictions in the upland oak timber type have been available for managed stands for several years. Most stand models use equations that relate stand age, site, relative stand density, or other attributes to stand growth and yield expressed in basal area, cords, or board feet. Yields from these models are based on long-term measurements of permanent growth plots. Predictions are derived from data representing a wide range of site, age, and density conditions from both thinned and unthinned stands. When these equations are used in computer programs to simulate stand growth they provide an extremely useful tool (see Note 5.10 Growth and Yield *Models for* Central *Hardwoods).* Managers can use these computer models to answer questions such as:

How do stands respond to various thinning treatments?
What is the best age to thin?
How much volume should I cut or leave?
How long should I wait for a second or subsequent cutting?
How long should the rotation age be?
How do I determine the relative productivity between sites or age classes?

Individual Tree Growth and Yield Models

Individual tree growth and yield models are newer and provide more detailed information than stand models. Models like TWIGS or OAKSIM for the upland oaks (see Note 5.10 Growth *and Yield Models for* Central *Hardwoods)* keep track of the growth and mortality of individual trees in a stand. Using tree size and species, managers can more accurately assign tree grade or quality to determine tree and stand market values. Individual tree models are used to answer the same questions as before on the timing, intensity, and frequency of thinning, but they can provide greater reliability than stand models. The growth and yield predictions presented here and the management recommendations given in Note 6.06 *Thinning Even-aged Upland* Oak *Stands,* are based in part on the individual tree growth model-OAKSIM.

Upland Oak Yields

Figure 1 illustrates typical yields for even-aged unmanaged upland oak stands from 30 to 90 years old on fair, average, and excellent sites (site index 50, 65, and 80). We assume that unthinned stands are very well stocked; about 80 percent of the average maximum density presented in normal yield tables. Yields, especially the board foot volume, are substantially more on the better sites. Usually there are more trees on the poor sites at a given age but they are smaller, so it takes longer to reach merchantable size. On excellent sites some trees start reaching merchantable sawtimber size (12 inches d.b.h.) as early as 35 years while on poorer sites it may take 50 or 60 years. The graphs in figure 1 indicate that both site and age are important factors that influence the yield from typical unthinned upland oak stands.

Species composition has a large influence on stand yields. The yields in figure 1 are based on stands with more of the slower growing white oak than the faster growing black, scarlet, or northern red oak. For a given age and site, stands that are predominantly black oak or red oak would have considerably higher yields than shown in figure 1.

Relative stand density is another important factor that influences yield. If your stand does not have as much basal area for a given age and site shown in figure 1 a, then your yields should be reduced proportionately. For example, on an average site, at age 60 we would expect about 85 square feet of basal area and a yield of almost 2,500 cubic feet (fig. la, lc). If your stand has 50 square feet of basal area (60 percent of expected), then your total yield (in cubic feet) would be about 60 percent of 2,500 cubic feet or only about 1,500 cubic feet.

Growth of Managed (Thinned) Upland Oak Stands

The forest manager can manipulate relative stand density by various thinning regimes and strongly influence growth and yield. Because net growth of the residual stand increases after thinning, the total yield from thinned stands usually exceeds the yield of unmanaged stands. Commercial thinnings usually can be made as early as age 30 and continued to age 90. Such practices will substantially increase net growth of the residual stand.

The periodic annual growth estimates in table 1 reveal some important trends regarding upland oaks. Young stands produce more annual cubic volume growth than older stands. For a given age, thinning to 40 percent stocking produces more net growth than thinning to 60 percent; and 60 percent residual density produces more growth than unthinned stands.

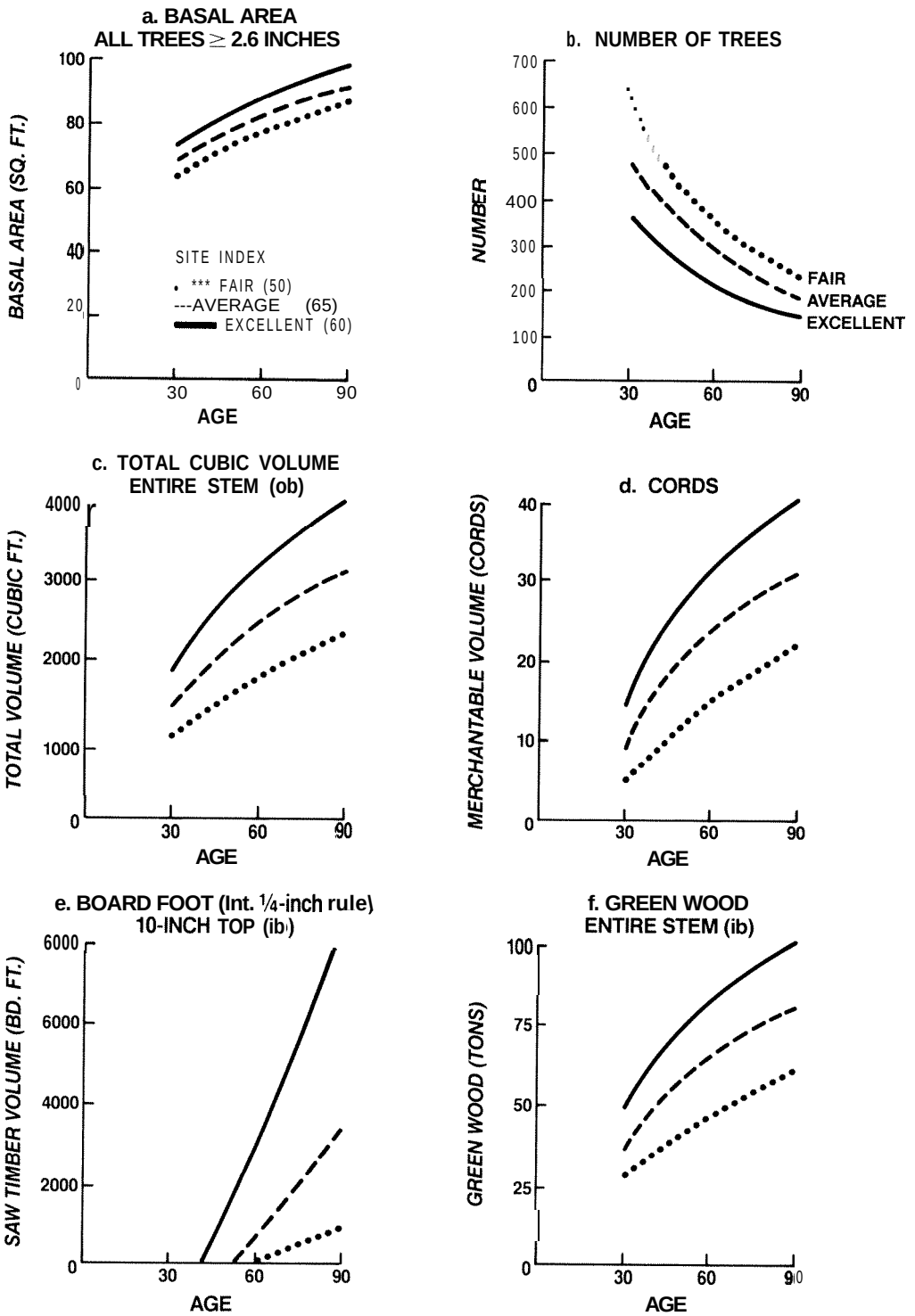

Figure 1 .-Yields of typically stocked unmanaged upland oak stands.

Table 1 .--Comparison of periodic annualgrowth for thinned versus unthinned oak stands on average sites

Stand age (Years)	Stand attribute	Unthinned		Thinned			
				60 percent stocked		40 percent stocked	
		Net	Gross	Net	Gross	Net	Gross
30	Basal area, square feet	1.8	2.7	2.3	2.6	2.5	2.5
	Total cubic feet	66	81	72	79	73	74
	Merchantable cubic feet	63	66	62	65	65	65
	Green wood. tons	1.7	2.2	1.9	2.0	1.9	2.0
60	Basal area, square feet	1.0	1.7	1.5	1.7	1.6	1.6
	Total cubic feet	51	67	60	66	64	65
	Merchantable cubic feet	49	58	53	56	54	54
	Green wood, tons	1.4	1.8	1.6	1.7	1.7	1.7
	Board foot volume	95	95	105	105	135	135
90	Basal area, square feet	0.8	1.4	1.1	1.4	1.3	1.3
	Total cubic feet	42	58	51	58	53	53
	Merchantable cubic feet	40	49	45	50	45	45
	Green wood, tons	1.1	1.5	1.3	1.5	1.4	1.4
	Board foot volume	183	188	219	219	250	250

Natural Mortality in Oak Stands

Mortality, the difference between net and gross growth, increases with residual stocking (table 1). When stands are thinned to 60 percent or less stocking, mortality is slight. In unthinned stands mortality can approach 40 percent of the basal area growth potential. Most mortality in young stands is confined to small trees that usually are too small to be merchantable. Mortality of merchantable size trees is not significant until stands become older. Even at age 90 sawtimber mortality is slight. In unthinned stands only a few trees reach sawtimber size by age 90, whereas in stands regularly thinned to 40 or 60 percent stocking many trees are large enough for sawtimber. Growth estimates in table 1 apply to typical oak stands on average sites-site index 65. Growth estimates vary with site by approximately the same percentage differences given for the yield estimates in figure 1.

Individual Tree Growth

Total stand growth is only one factor managers should consider when evaluating management options. Growth of individual trees is also important, especially the 50 to 80 largest trees per acre that constitute the final harvest.

The largest 80 crop trees per acre respond to the same factors as total stand growth (fig. 2). In addition to the stocking and age effects shown in figure 2, diameter growth also varies with site quality and species. In upland oak stands the black oak group (northern red, black, and scarlet oak) grow faster than the white oak group (white, chestnut, swamp white, post, burr, and chinkapin). Associated species such as hickory, beech, blackgum, and sugar maple grow slower than yellow-poplar, ash, aspen, black cherry, black walnut, and elm. Diameter growth is less affected than stand volume growth due to site differences; even so, a 1 O-point change in site index may alter diameter growth 10 to 15 percent.

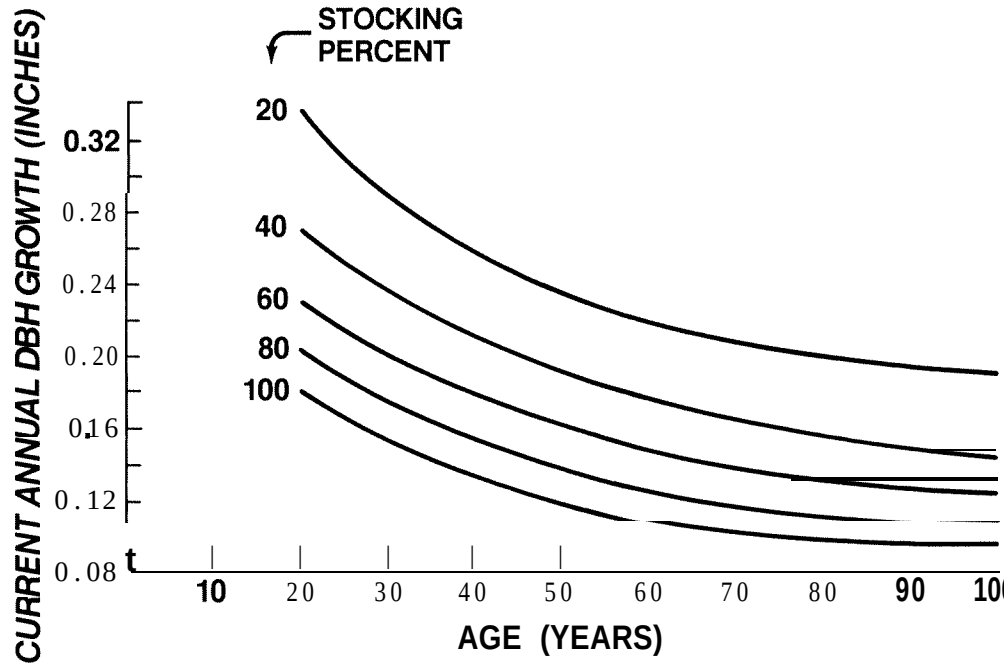

Figure 2.-Current annual diameter growth of largest 80 trees per acre by age and stocking percent.

As shown in figure 2, individual tree diameter growth increases as relative stand stocking decreases. However, with stocking below 40 percent there are too few trees to occupy the site fully and total stand growth is reduced. A more serious problem with low stocking is the potential for quality loss. Many tree species, especially white oak, develop epicormic branches when stocking is reduced below about 50 percent. You should select crop trees with vigorous, well-developed crowns, having a dominant or strong codominant crown position. Most importantly, crop trees should be free from small epicormic branches or bud clusters. Such trees can be readily identified for removal by the careful tree marker.

Within acceptable stocking levels diameter growth on the largest 80 trees per acre can be increased substantially-at least 75 to 80 percent over unthinned young stands. Growth on the largest 80 trees per acre may be less than 20 percent of the total stand growth at age 30, but in well-managed older stands all the potential growth should be concentrated on as few as 50 to 80 trees per acre.

By thinning throughout the rotation, you can concentrate growth potential on these few crop trees and produce bigger and more valuable trees at the final harvest.

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Also, see References in Note 6.06 *Thinning Even-aged Upland Oak Stands.*

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CENTRAL HARDWOOD NOTES

Estimating Growth And Yield Of Mixed Stands

A mixed stand is defined as one in which no single species comprises more than 80 percent of the stocking. The growth estimation methods described below can be used not only in mixed stands but in almost any stand, regardless of species composition, age structure, or size structure. The methods described are necessary to accommodate the complex species mixtures and irregular size distributions characteristic of many central hardwood stands. These same methods can also be used in pure or even-aged stands, although they will not always be best for those stands.

Two methods to estimate growth of mixed stands are (1) stand table projection, and (2) individual-tree-based simulation models. To use either method you need to sample the number of trees per acre by species and size. Information on tree quality may also be desirable for better value estimates. You can collect these kinds of information using any of the common forest sampling schemes designed to tally tree characteristics. For stand table projection this information is summarized into **a** stand table by species, and diameter class. For individual-tree-based simulation systems the sample information is entered as a list of the sampled trees, including species, diameter, quality class, and number of trees per acre represented by each sample tree.

Stand Table Projection

One of the oldest and simplest ways to project the growth and yield of mixed-species stands is by stand table projection. This technique is described in detail in most forest mensuration texts. Stand table projection begins and ends with a stand table showing the number of trees by species and diameter class. Future stand tables are predicted by estimating the number of trees of each species moving to different diameter classes for each projection period (usually a decade). The projected stand table can be used to estimate growth and future volumes by species and size classes.

To use traditional stand table projection you must (1) estimate periodic diameter growth by species and diameter class, (2) estimate periodic survival rates by species, (3) estimate periodic ingrowth, and (4) have a local volume table. These estimates are used to "move" the initial stand table to a future condition, species by species and diameter class by diameter class. Estimates for (1), (2), and (3) can be obtained from continuous forest inventory (CFI) plots or from increment cores taken at the time the initial stand table is developed. In general, these projections are excellent short term estimates because the best indicator of how trees will grow in the near future is how they grew in the recent past. Stand table projection generally works well for understocked or uneven-aged stands. However, stand table projection is not appropriate for all situations. In young, dense

stands with high ingrowth or in dense or overmature stands with high mortality, stand table projection is usually not appropriate because ingrowth and mortality estimates are imprecise under those conditions. Also, stand table projection does not account for changes in tree height or form, and these can have a significant effect on volume changes. This is particularly true in long term projections for well stocked, even-aged stands. It is not advisable to make stand table projections of longer than 20 years.

The biggest drawback to stand table projection is that for most applications foresters and landowners are unwilling or unable to take the large number of increment cores or to maintain CFI plots needed to estimate local growth, survival, and ingrowth. A prudent compromise is to use as many site-specific growth and survival observations as possible and, if necessary, supplement them with regional estimates from sources such as those listed under References.

Although you can project stand table data manually, personal computer programs like YIELD-MS provide easy-to-use stand table projection algorithms. They also provide excellent ways to enter and edit data and to prepare summaries of projected stand conditions. YIELD-MS can provide much more than traditional stand table projection. YIELD-MS includes options for economic evaluation of management alternatives, and includes default values for diameter growth and survival rates for many species in the central hardwood region. These rates can be used in lieu of local estimates or, preferably, used to supplement locally collected growth and survival information. With YIELD-MS it is particularly easy to select one of several different sets of regional growth and mortality rates, to incorporate locally observed rates, or to combine the two sources of information. One option in YIELD-MS is to generate growth and survival rate estimates from the mathematical models in the OAKSIM simulator (see Note 5.10 Growth and *Yield Models for Central Hardwoods).*

Individual-Tree Models

Individual-tree models are an extension of stand table projection with two important distinctions. First, individual-tree models require no prior aggregation of the individual tree inventory data describing the stand conditions. The projection begins and ends with a list of the individual trees sampled during a stand inventory. Growth and survival of each tree is projected, and the projected conditions for individual trees can be summarized and reported by combinations of species and/or size classes. The second important distinction is that individual tree projection systems include models that estimate diameter growth and survival rates for most important species, taking into account tree size and competition from surrounding trees. So you don't need increment cores or CFI plots before you can apply the models. However, information on local growth and survival rates can be quite valuable to assess model accuracy.

For the central hardwood region, the Central States variant of TWIGS is currently the most readily available individual-tree-based simulation system for mixed stands. TWIGS operates on common personal computers, it is easy to use, and it includes options for economic analysis of simulated management alternatives. TWIGS includes individual-tree growth and yield models for the species groups listed below. The models are applicable in Indiana, Illinois, and Missouri. A Lake States variant of TWIGS includes mathematical models for species and conditions in Minnesota, Wisconsin, and Michigan.

Species Groups for Central States TWIGS

White oak	Hickory	Black tupelo
Northern red oak	Ash	Other upland oaks
Scarlet oak	Black walnut	Other upland hdwds.
Black oak	Elm	Other lowland oaks
Blackjack oak	Sugar maple	Other lowland hdwds
Post oak	Silver maple	Noncommercial spp.
Chinkapin oak	Yellow-poplar	Eastern redcedar

TWIGS is generally applicable to pure or mixed forest types of any age or size distribution, provided the majority of the stand is in trees 1 inch d.b.h. or larger. Projections of longer than 30 years are not advisable. The models are based on tree growth and survival data from Indiana, Illinois, and Missouri, and predict regional averages. Actual growth for a particular stand may be higher or lower than the prediction. Data for local growth and survival rates should be compared to model predictions in order to evaluate model accuracy. Also, good data on local rates of diameter growth or survival can be used to adjust the models. The TWIGS models do not currently predict ingrowth, but user-supplied ingrowth estimates can be included in TWIGS projections.

One of the best uses for TWIGS is to compare management alternatives for specific stands. (Small, consistent overpredictions or underpredictions of growth do not generally affect the relative ranking of management alternatives.) Other uses include updating past forest inventories or projecting inventories into the future.

Example

The following example illustrates how you can apply either stand table projection or an individual-tree projection system to stand data in southern Indiana. The uneven-aged stand includes 6 species and has a site index of 85 for yellow poplar. For the 30 years from 1987 to 2017, the volume was predicted to increase from 950 to 5,170 board feet per acre while the number of trees decreased from 550 to 290 per acre (fig. 1). The estimated change for individual species can be followed in addition to total stand change. The species dynamics are illustrated in figure 2 which shows the distribution of basal area by species and 5-inch diameter classes for 1987 and 2017. In this example it is evident that basal area for maple,

American beech, and yellow-poplar increase at a faster rate than the other species, and elm basal area actually decreases. Additional simulation runs could be made for this stand to compare the predicted outcomes of different cutting alternatives, including comparison of the financial return of each of those alternatives.

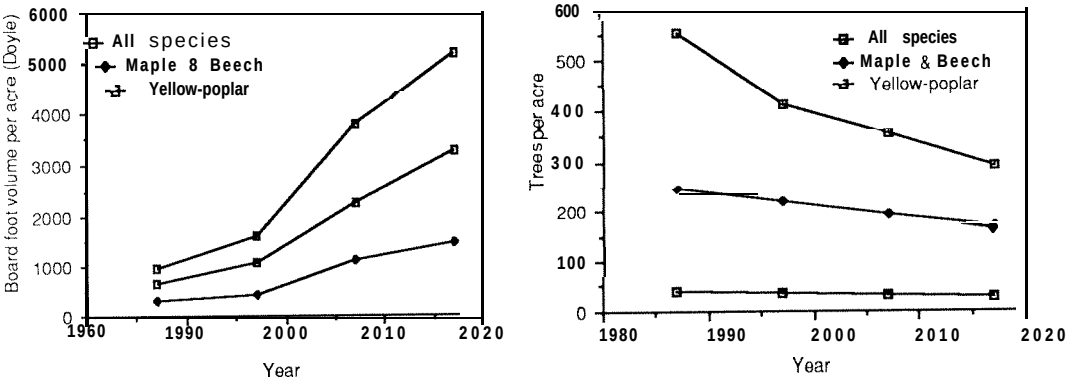

Figure 1 .-Change in volume and trees per acre between 1987 and 2017 for a mixed stand with six species. Changes for maple, beech, and yellow-poplar are shown individually.

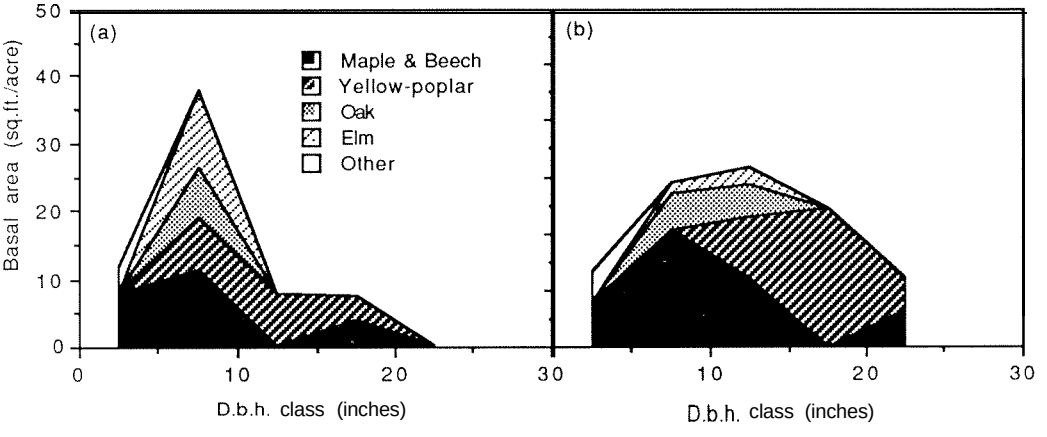

Figure 2.—Comparison of basal area by species and size class for a stand in 1987 (a) and as it is predicted for the year 2017 (b).

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For more information about:	Contact	Minimum system configuration
YIELD-MS	Todd Hepp Tennessee Valley Authority Forestry Building Norris, TN 37828 (615) 494-9800	PC with MS/DOS 2.0 or higher 320K memory Two 5.25 inch disk drives Hard disk, math coprocessor, printer, and graphics monitor recommended
TWIGS	North Central Forest Exp.Stn. 1992 Folwell Avenue St. Paul, MN 55108 (612) 649-5173 or FTS 777-5 173	PC with MS/DOS 2.1 or higher 384K memory One 5.25 inch disk drive Second disk drive, printer and graphics monitor recommended

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CENTRAL HARDWOOD NOTES

Estimating Bottomland Hardwood Growth And Yield

Most bottomland hardwoods grow on very productive sites-site index 70 or more. A fully stocked immature stand (table 1, fig. 1) requires tending throughout its life. The goal is to attain a stand of approximately 50 high quality trees of commercial species per acre at maturity. Releasing these crop trees can result in the cumulative yield of 2,000-4,000 board feet per acre and 30-35 cords of poletimber and topwood from the thinnings before the final harvest.

Table 1 .-Stocking guide for maintaining maximum growth on good sites

Average d.b.h.	A-level (maximum stocking)	B-level (minimum stocking)
	Number of trees	
6	475	202
10	202	112
14	112	71
18	71	49
22	49	36
26	36	27

A well managed, fully stocked, mature stand will yield from 15,000 to 18,000 board feet per acre (International l/4-inch rule) and 5 to 6 cords of topwood from the harvest cut (table 2). You should clearcut for the final harvest. This not only efficiently removes all products, but creates the opening necessary to establish a new stand of intolerant species.

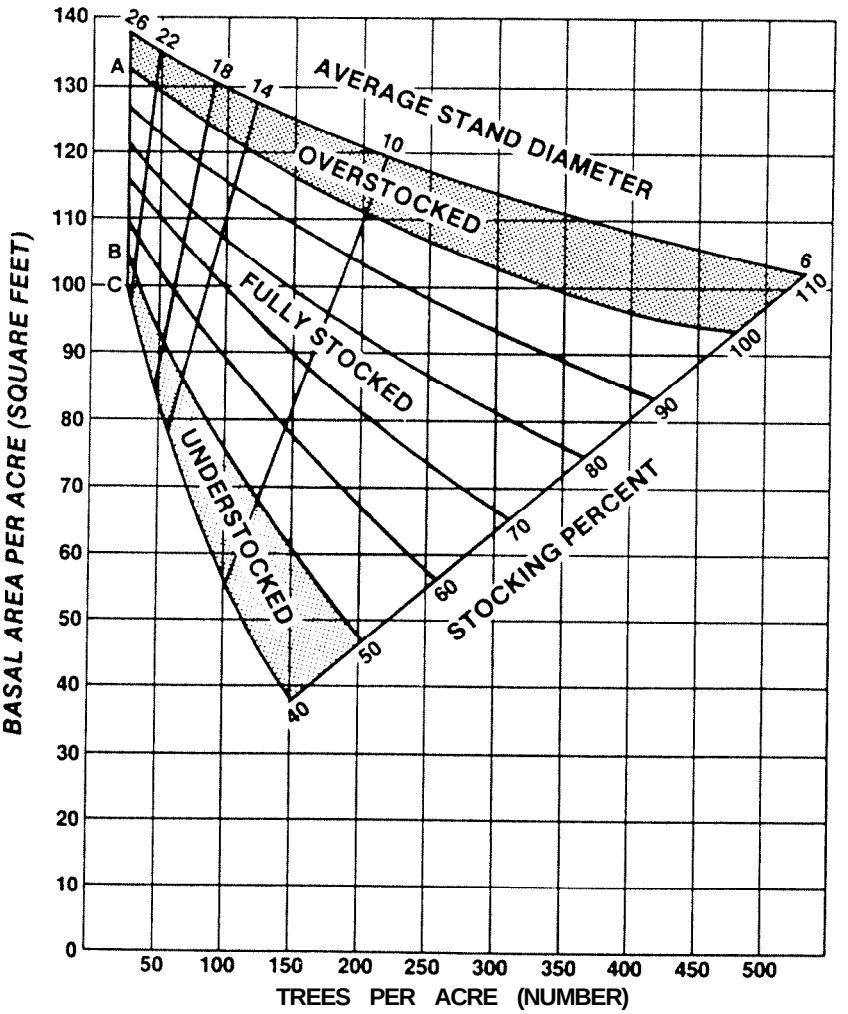

Figure 1 -Stocking guide for bottomland hardwoods.

Table *2.-Cumulative yields per acre for well-managed stands on good sites*

Average d.b.h.	Sawtimber		Poletimber	Topwood
	Standing crop	Previous thinnings		
	- - - - - - - - *Board feet* - - - - - -		- - - - - - *Cords* - - - - - - -	
6	0	0	5.3	0
10	0	0	11.8	0
14	5,196	0	18.8	6.8
18	10,623	0	18.8	12.7
22	14,699	1,705	18.8	18.2
26	18,243	3,876	18.8	23.2

Eastern cottonwood is an important component and cannot be maintained without management or natural disturbance. Eastern cottonwood is included in the Central States version of the computer software called The Woodsman's *Ideal Growth* Projection System (TWIGS). A condensed output from a sample TWIGS run for a pure cottonwood stand, age 20 years, is given in table 3. The stand site index was given as 80 and stand age as 20 years. In addition to projecting growth, TWIGS aids you by providing management and economic analysis.

Table *3.-Eastern cottonwood growth projection from TWIGS* [1]

	1985 (age 20)	1995	Mortality
No. trees/acre	200	168	3.2
BA/acre	109.4	129.5	18.1
Ave d.b.h.	10	11.8	—

[1] To obtain TWIGS, write or call: Forest Resources System Institute
201 North Pine Street, Suite 24
Florence, AL 35630
(205) 767-0250

References

Myers, C.C.; Buchman, R.G. 1984. Manager's handbook for elm-ash-cottonwood in the North Central States. Gen. Tech. Rep. NC-98. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 11 p.

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CENTRAL HARDWOOD NOTES

Estimating Yellow-Poplar Growth And Yield

Yellow-poplar grows in essentially pure, even-aged stands, so you can make growth and yield estimates from relatively few stand characteristics. The tables and models described here require only measures of stand age, stand basal area in trees 4.5 inches and larger, and site index. They were developed by remeasuring (at 5-year intervals over a 20-year period) many stands having a wide range in age and site index and thinned to varying basal areas.

Pure yellow-poplar stand on an excellent site.

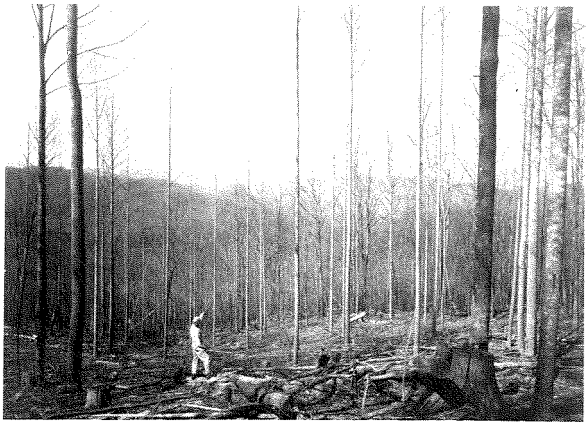
Table 1 shows yields for a range of sites and ages that you can expect in unthinned fully-stocked stands. The large influence of site quality on yield is particularly striking. Increases with stand age are also very significant. You should note that the yields shown are near the maximum expected. If your particular stand has areas that are unstocked, for example, you must reduce yield estimates accordingly. Simply reduce yield estimates proportional to stocking reduction. Consider a stand on site 100 at age 40 that averages only 100 square feet of basal area per acre, which is 80 percent of expected stocking. Yields might be expected to be only 80 percent of those shown in table 1.

Table 2 shows yields for stands thinned under one of the many possible combinations of residual basal area and age at thinning. In this example, the stands were thinned at ages 40 and 60 to the residual basal areas shown and then projected to age 80. The thinning regime shown was picked to keep board-foot yields near the maximum possible while increasing growth of individual trees moderately. Heavier thinnings would increase individual tree size more rapidly and shorten rotation length, but total yields could be reduced.

Table *1 --Unthinned stand yields*

Age and site index[1]	Basal area	Volume	Volume	Average tree diameter
	Square feet	*Cubic feet* [2]	*Board feet* [3]	*Inches* [4]
		40 years		
Site 80	105	3,138	2,354	8.0
Site 100	125	4,544	9,769	9.5
Site 120	145	6,286	20,804	11.2
		60 years		
Site 80	145	5,106	11,430	10.1
Site 100	170	7,400	25,879	12.1
Site 120	200	10,405	46,225	14.5
		80 years		
Site 80	170	6,575	19,579	11.5
Site 100	200	9,569	38,935	13.8
Site 120	220	12,466	60,661	16.2

'Estimated height of dominant and codominant trees at age 50.
[2]Volume in trees 4.5 inches d.b.h. and larger.
[3]International 1/4-inch rule for trees 11 .O inches d.b.h. and larger.
Quadratic mean stand diameter.



A thinned stand can provide early income.

Table 2.-Stand yields with sequential thinnings at ages 40 and 60, and final harvest at age 80

Age, site index, and time of tally[1]	Stand characteristics			Average tree diameter[4]
	Basal area	Cubic volume[2]	Board volume[3]	
	Square feet	Cubic feet	Board feel	Inches
AGE 40				
Site 80				
Before harvest	105	3,138	2,362	8.0
After harvest	70	2,182	2,362	9.3
Harvested	35	956	0	6.5
Site 100				
Before harvest	125	4,544	9,769	9.5
After harvest	90	3,454	9,769	11.5
Harvested	35	1,090	0	7.0
Site 120				
Before harvest	145	6,284	20,786	11.2
After harvest	110	5,053	20,011	14.2
Harvested	35	1,231	775	7.6
AGE 60				
Site 80				
Before harvest	99	3,666	9,001	11.0
After harvest	80	3,037	8,796	11.9
Harvested	19	629	205	8.7
Site 100				
Before harvest	128	5,948	22,606	13.7
After harvest	100	4,773	19,681	15.0
Harvested	28	1,175	2,925	11.1
Site 120				
Before harvest	160	9,062	41,918	17.1
After harvest	120	6,989	33,770	18.7
Harvested	40	2.073	8.148	14.1
AGE 80				
Site 80	118	4,949	19,190	14.5
Site 100	139	7,358	34,133	17.6
Site 120	160	10,185	53,093	21.6
TOTAL YIELD[5]				
Site 80	172	6,534	19,395	
Site 100	202	9,623	37,058	
Site 120	235	13,489	62,016	

[1]Estimated height of dominant and codominant trees at age 50.
[2]Volume in trees 4.5 inches d.b.h. and larger.
[3]International 1/4-inch rule for trees 11 .O inches d.b.h. and larger.
[4]Quadratic mean stand diameter.
[5]Total of harvests at ages 40, 60, and 80 years.

Board-foot yields are not likely to be increased substantially by any thinning regime, but board-foot growth is near maximum over a wide range of densities. So you have considerable leeway to reduce stocking to accelerate diameter growth and achieve quality goals with shorter rotations without sacrificing volume yield. As a rule of thumb, after about age 40, basal areas that approximate stand site index will maximize board-foot volume growth while producing trees that will be fifty percent larger than trees in unthinned stands.

Another advantage of thinning is that it allows early income. For example, on site index 120 an unthinned stand yields 60,661 board feet at rotation age 80. A thinned stand has a total yield of 62,016 board feet over the rotation, but produces income from about 8,000 board feet by age 60. The tables and models given under References allow you to examine the results of many thinning regimes. In addition to stand-level yields, the models allow you to generate tree diameter distributions, so you can predict thinning effects on yields by size class. The yield models can help you decide when to begin thinning, as well as the frequency, intensity, and timing of subsequent thinnings. The models can help you set the proper rotation length and to see how this varies with site quality. By comparing many thinning regimes, you can select the one that best suits your needs.

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CENTRAL HARDWOOD NOTES

Estimating Black Walnut Plantation Growth And Yield

Growth and yield of plantation grown black walnut depends upon the site productivity and management practices such as vegetation control and thinning. Growth and yield information for all the various combinations of sites and management practices is not available; however, there is some information from unmanaged plantations which provides reasonable estimates. The following graphs relate directly to plantations established with site preparation and weed control the first 2 or 3 years, but no additional management.

Site Index

The first step in estimating growth and/or yield is to determine site productivity. For existing plantations, the age and the average height of the dominant/codominant trees are used to estimate site index (fig. 1). Site index (SI) is expressed as the height in feet at 50 years. For example, the SI for a 25-year-old plantation with an average dominant/codominant tree height of 50 feet is equal to 70. For areas without trees, available information on the soil profile and on tree growth in adjacent areas can help you make a general estimate of relative productivity from low (SI 40) to high (SI 80).

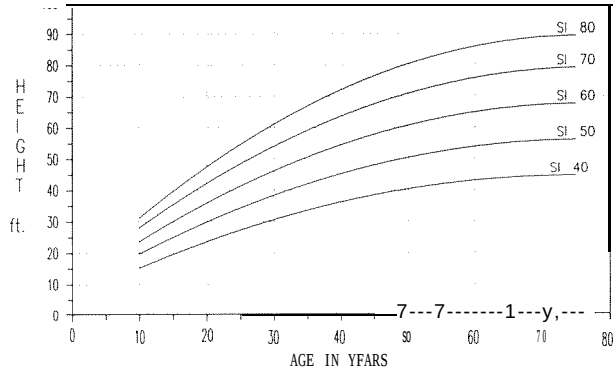

Figure 1 .-Site index determination for black walnut plantations.

Growth and yield estimates on a per acre basis can be obtained directly from a series of graphs for plantations established at an original spacing equivalent to 10 by 10 feet, and indirectly for other spacings as described. While number of trees (fig. 2) decline through natural mortality over time, the yield estimates apply strictly to stands without silvicultural thinning.

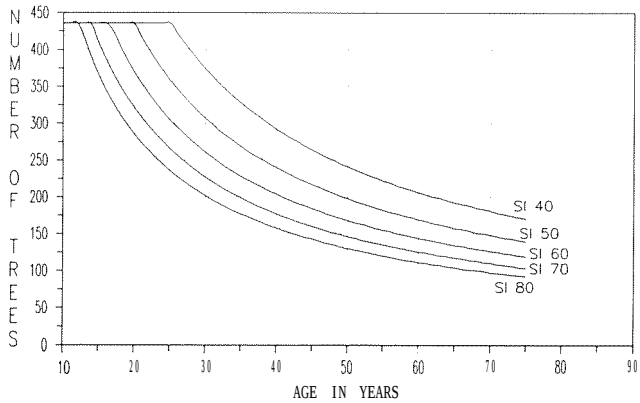

Figure P.-Numbers of trees per acre by age and site index.

Basal Area Growth and Volume Growth

You can use figure 3 to estimate basal area growth by site index for different time periods. For example, the basal area growth of all trees for a plantation with an SI = 60 is estimated to be about 11 square feet between the ages of 30 and 40 years. This estimate is obtained by subtracting the total basal area at age 30 (about 81 square feet) from the total basal area at age 40 (about 92 square feet). You can use figure 4 to estimate volume for different sites at various ages. By age 75, the Doyle rule board foot volume for the same stand above is about 7,300 board feet per acre for trees at least 11 inches in d.b.h.

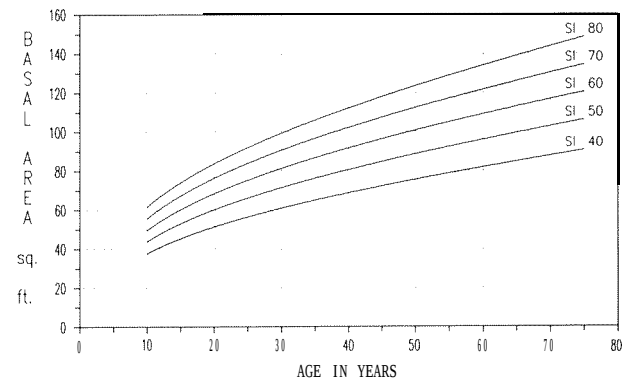

Figure 3.-Basal area per acre by age and site index.

Additional management activities, especially thinning, will change the growth and yields from those shown in the graphs. The primary effects of additional management beyond the establishment period are to reduce the time to obtain a given yield, or to redistribute the yield from many, small trees to fewer, large trees. Although you cannot use the graphs directly in these cases, they can be used in conjunction with other information to develop growth and yield estimates.

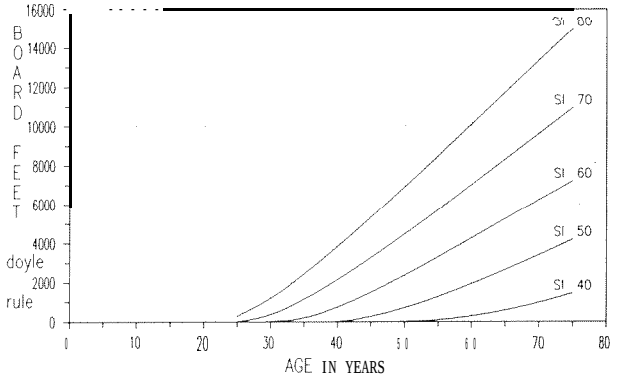

Figure 4.-Board foot volumes, Doyle Rule, per acre by age and site index.

For example, if past management such as weed and understory control or fertilization has increased the growth rate, and the measured basal area is 81 square feet at age 25 for a plantation with an SI = 60, the trees have grown 20 percent faster than without management. This conclusion is drawn by noting from figure 3 that an unmanaged plantation on SI = 60 would have a basal area of 81 square feet at age 30, and that the age difference of 5 years is 20 percent of the actual age (30 years - 25 years/25 years = 20 percent).

If continued management keeps the trees growing 20 percent faster for the rest of the rotation, then you can expect to produce 7,300 board feet on SI = 60 sooner than age 75 (fig. 4). Obtain the actual age by solving the following equation: 25 years/30 years = X years/75 years. In this example, 7,300 board feet can be produced in 63 years.

The management activity that affects individual tree growth most is periodic thinning. Although total yield per acre at final harvest is usually less in thinned stands, the value yields can often be increased by accumulating the growth on fewer, but larger trees. The levels of stocking for the unthinned stands used to develop the graphs were considerably higher than desirable for rapid individual tree growth.

Crown Competition Factor

Crown competition factor (CCF) can be used to determine the level of stocking (fig. 5). At CCF = 100, the plantation fully occupies the site, and each tree can grow at about its maximum rate. As the stocking level rises above CCF = 100, individual tree growth will be progressively less. In general, the diameter growth will be reduced about 4 percent for each 10 CCF units above 100 (see Note 6.05 Silvicultural Treatments in Immature Stands for additional discussion of stocking).

For example, the average tree size in unthinned stands on site index 60 increased from 10.5 inches to 11.8 inches between ages 50 and 60 (fig. 6), while the CCF was about 200 (fig. 5) as determined from the number of trees (fig. 2) and basal

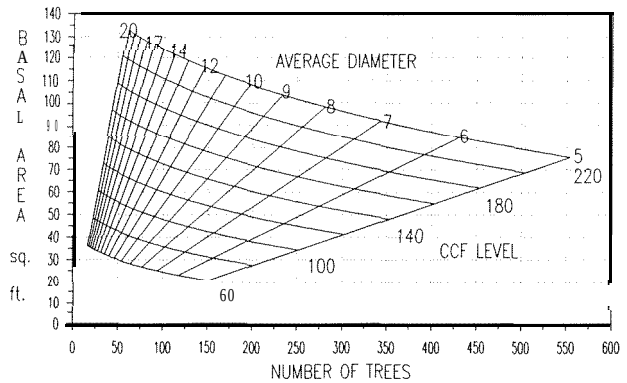

Figure 5.—Black walnut stocking chart.

area (fig. 3) S I= 60. If a stocking level of CCF = 100 had been maintained through periodic thinnings, the average tree size would have increased by 2.2 inches, rather than 1.3, during the same period. This conclusion is drawn by noting that at a stocking level of CCF = 200, growth would be about 40 percent less than at CCF = 100. Thus, growth from figure 6: 1.3 inches/l - 0.40 = 2.2 inches.

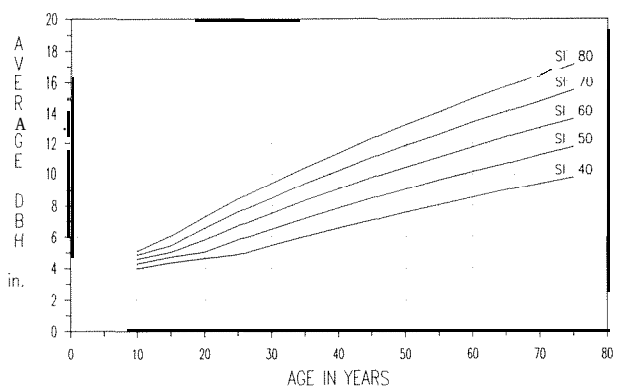

Figure 6.-Average diameter by age and site index.

Black walnut trees are very responsive and the growth and yield can be altered significantly by management. Although the graphs are derived from generally unmanaged plantations, they can provide reasonable estimates for managed plantations if adjustments are made for effects of treatments as shown in the preceding examples. As is true of all such growth and yield estimates, when periodic measurements are available they should be compared with the tabular values and the appropriate adjustments made to customize the graphic value to local conditions.

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CENTRAL HARDWOOD NOTES

Estimating Pine Growth And Yield

Although hardwoods comprise the bulk of the volume in the central hardwood forest, pines are locally important in the oak-pine association, pine types, and plantations. The two principal pine species are shortleaf pine and eastern white pine. Shortleaf occurs primarily in the southern parts of the central hardwood forest: white pine is found in the northern and eastern parts of the region.

Users of growth and yield models should understand how they were developed and what kind of data were used. This knowledge will help you make better investment decisions, but remember that yield is only one of the many criteria. Here are some points to consider:

- Reliable yield estimates for thinned stands must come from permanent plots that have been thinned to different densities and periodically remeasured. This information is the most useful but it is scarce.
- Because growth and yield studies are expensive, models are sometimes derived from inventory data. These models may underestimate what can be produced in managed stands.
- Some growth and yield models are developed from temporary plots.
- For natural even-aged stands, yields are presented by age and site index classes; plantation yields are given by age, site index, and planting density.
- Yields are usually for unthinned stands; if so, do not apply them to thinned stands.
- Past history and origin of the stand can influence yields. For example, most plantation information is for old-field stands; but many plantations are now being established on cutover sites. Yields from cutover sites may be less than that from old-fields because of greater vegetation competition. Or, plantation yields may be higher than comparable natural stands because of earlier stocking and spacing control.
- Growth and yield information is most reliable when used to choose a management regime. Models predict average growth and yield, what is produced in a specific stand may be higher or lower.
- Yield estimates outside the data range are less reliable than those within.

With these cautions in mind, let us look at some yields.

Shortleaf Pine

Plantations

The only available example of yields from unthinned plantations on old-fields shows that site index has a profound effect on yield (table 1). The yield at age 30 with an initial planting density of 750 trees per acre is more than two times greater for a good site versus a poor site. Mean annual increment peaks between 25 and 30 years for average and good sites but has not yet culminated by age 30 for poor sites. Planting more trees results in more merchantable cubic-foot yield. At age 30, doubling the trees planted from 750 to 1,500 per acre increases yield from 11 percent on poor sites to 19 percent on good sites.

Table *1 .-Merchantable cubic-foot and green weight yields' for old-field shortleaf pine plantations in Tennessee, Alabama, and Georgia Highlands*

Age (from seed)	Trees planted (per acre)			
	750	1,000	1,250	1,500
	Cubic feet (green tons) per acre			
	POOR SITE'			
15	383 (12)	343 (11)	290 (9)	247 (8)
20	865 (27)	855 (26)	819 (25)	806 (25)
25	1,334 (41)	1,368 (42)	1,405 43)	1,409 (43)
30	1,771 (55)	1,847 (57)	1,881 58)	1,974 (61)
	AVERAGE SITE[3]			
15	850 (26)	835 (26)	792 (24)	752 (23)
20	1,573 (48)	1,671 (51)	1,712 (53)	1,725 (53)
25	2,245 (69)	2,386 (74)	2,490 (77)	2,610 (80)
30	2,745 (85)	2,955 (91)	3,077 (95)	3,277 (101)
	GOOD SITE[4]			
15	1,401 (43)	1,463 (45)	1,466 (45)	1,522 (47)
20	2,377 (73)	2,571 (79)	2,711 (84)	2,830 (87)
25	3,152 (97)	3,422 (105)	3,637 (112)	3,826 (118)
30	3,686 (114)	3,915 (121)	4,171 (129)	4,402 (136)

[1] Solid wood volume from a 6-inch stump to a 4-inch top, d.o.b. Green weights are to same merchantability standards and were derived by using ratio of 61.618 pounds per cubic foot of solid wood.

[2] Poor site-site index 40 feet (base age 25).

[3] Average site-site index 50 feet (base age 25).

[4] Good site-site index 60 feet (base age 25).

The higher the planting density the smaller the stem diameter and the longer it takes for trees to reach sawtimber size. Notice that board-foot yields at a given age decrease with increased planting density (table 2). To accelerate sawtimber production, you should sacrifice some total cubic yield and plant fewer trees, so planting costs should also be less. You should probably choose a rotation longer than 30 years for sawtimber. Notice that site quality affects sawtimber yields (table 2) more than cubic-volume production (table 1).

Table 2.-Board-foot yields' (International 1/4-inch rule) for old-field unthinned shortleaf pine plantations at age 30 in Goergia, Tennessee, and Alabama Highlands

Trees planted (per acre)	Site quality[2]		
	Poor	Average	Good
	Board feet per acre		
750	247	2,398	7,738
1,000	99	1,227	5,385
1,250	49	686	3,939
1,500	—	356	2,933

[1] Trees 9.6 inches d.b.h. and larger from a 0.5foot stump to an 8-inch top, d.o.b. Using stand tables from Smalley and Bailey (1974), tree volumes were calculated from equations found in the following: Rockwood, D.L.; Arvanitis, L.G.; Hodgins P.E. 1980. Southern pine volume equations and associated conversion factors for southwest Georgia. FL Agric. Exp. Stn. Bull. 813. Gainesville, FL: Florida Agricultural Experiment Station. 49 p.

[2] Poor site is site index 40 feet; average site, 50 feet; and good site, 60 feet (all base age 25).

Natural Stands

Extensive natural stands of shortleaf are found in the central hardwood forest, particularly in Arkansas. The yields for even-aged stands (table 3) were from permanent plot inventory data and show that the stands were not managed intensively. More intensively managed stands with aggressive hardwood control will produce larger yields.

Table 3.-Board-foot (International 1/4-inch rule) and green weight yields' for extensively managed natural even-aged shortleaf pine stands in the Interior Highlands of Arkansas

Age (years)	Site quality[2]		
	Poor	Average	Good
	Board feet (green tons) per acre		
30	1,048 (6)	2,711 (16)	6,042 (35)
40	4,473 (26)	6,495 (37)	10,092 (56)
50	7,207 (41)	9,443 (53)	13,220 (72)
60	8,609 (49)	10,966 (61)	14,940 (81)

[1] Yields are solid wood in trees 8.6 inches d.b.h. and larger from a l-foot stump to a 7-inch top, d.o.b. Green weights were derived by using the ratio of 61.618 pounds per cubic foot of solid wood.

[2] Poor site is 50 feet site index (base age 50), the medium site is 60 feet, and the good site is 70 feet.

Table 3 does not contain yields at different density levels because the same thinning strategy was employed. Assuming that the poor, average, and good sites have 120, 130, and 140 square feet of basal area, respectively, at age 30, the stands are thinned back to 80 square feet at ages 30, 40, and 50; cut back to a seed tree at age 55; and harvest cut at age 60. The yields at each age and site represent thinnings plus the standing volume. Yields become larger with increasing site quality and advancing age. The mean annual increments at age 60 are 143, 183, and 249 board feet for the poor, average, and good sites, respectively.

Another alternative is uneven-aged management. Uneven-aged stands on average sites usually grow about 2 square feet of basal area per acre per year. You must choose both the number of trees by diameter class to leave and a cutting cycle. These two factors are interdependent. (For further details on growth and yield for uneven-aged shortleaf pine stands, consult the appropriate publication in the References.)

White Pine

In the southern part of its range, white pine is not subject to severe insect and disease attack as farther north. It also grows faster than most of its associates there. However, growth and yield models for this part of the range are scarce, and the best data are for unthinned old-field plantations.

The yields from Ohio are impressive (table 4). Wide spacings result in higher sawtimber yields for young stands. But by age 50, board-foot volume is slightly more with close spacing; the trees are smaller, but there are more of them. Mean annual increment peaks on good sites between 40 and 50 years, but it is still increasing at age 50 for average sites.

Yields for the southern Appalachians are in table 5.

Table *4.-Yields of unthinned old-field white pine plantations in Ohio*

Age	Initial spacing (trees per acre)			
	6X6 ft (1,210)	7X7 ft (889)	8X8 ft (681)	9x9 ft (538)
	Board feet per acre[1] (green tons)[2] per acre			
	AVERAGE SITE[3]			
20	— (59)	134 (58)	1,215 (56)	**1,774 (54)**
30	12,744 (95)	13,128 (93)	13,277 **(91)**	**13,142 (90)**
40	22,192 (118)	22,090 (117)	21,818 (115)	21,355 (113)
50	29,609 (135)	29,264 (133)	28,778 (131)	28,136 (130)
	GOOD SITE[4]			
20	4,145 (79)	6,130 (77)	7,454 (74)	8,165 (71)
30	20,908 (132)	21,391 (130)	21,586 (127)	21,474 (125)
40	31,598 (169)	31,512 (166)	31,240 (164)	30,762 (162)
50	**39,741 (194)**	**39,387 (192)**	38,882 **(189)**	**38,212 (188)**

[1] international 1/4-inch rule from a 1-foot stump to an E-inch top, d.i.b.
[2] Tons of wood (excluding bark and branches) from a 1-foot stump to a 2-inch top, d.i.b.
[3] Average site is site index 70 feet (base age 35).
[4] Good site is site index 90 (base age 35).

Table *5.-Merchantable cubic-foot yields' for unthinned old-field white pine plantations in the southern Appalachians*

Age	Initial spacing (trees per acre)			
	6X6 ft (1,210)	8X8 ft (681)	10x10 ft (435)	12X12 ft (302)
	Cubic feet per acre			
	AVERAGE SITE[2]			
10	360	327	313	305
20	2,985	2,844	2,782	2,749
30	5,157	4,995	4,920	4,882
	GOOD SITE[3]			
10	630	572	547	534
20	5,222	4,975	4,866	4,807
30	9,018	8,734	8,604	8,537

[1] Volume, outside bark, for trees 3 inches d.b.h. and larger from a 6-inch stump to a 3-inch top, d.o.b.
[2] Average site is site index 55 feet (base age 25).
[3] Good site is site index 70 (base age 25).

Oak-pine

There have been no growth and yield studies aimed specifically at the oak-pine type, in which shortleaf is a component. Should you want to simulate yields from this type, a software package called TWIGS is available (see References).

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CENTRAL HARDWOOD NOTES

Short-Rotation Plantations

Why Short Rotations?

Short-rotation plantations offer several advantages over longer, more traditional rotations. They enhance the natural productivity of better sites and of tree species with rapid juvenile growth. Returns on investment are realized in a shorter period and the risk of loss is reduced compared with long term investments. Production of wood and fiber can be maximized by intensifying cultural treatments near a processing site, lessening transportation costs.

Disadvantages of short-rotation plantations are similar to those of other intensive silvicultural systems. Costs of establishment are high because of the need for intensive site preparation, thorough weed control, and fertilization.

What exactly do we mean by short-rotation? Three possible short-rotation lengths for central hardwoods are:

- 5 to 10 years - Short-rotation intensive culture (biomass)
- 10 to 20 years - Short-rotation (for pulpwood)
- 20 to 40 years - Short-rotation (for sawtimber)

Material from short-rotation forests can be used for a variety of purposes including:

- Supplemental source of cellulose for the pulp and paper industry
- Reconstituted or solid core stock for furniture and paneling
- Chips and flakes for the fiberboard industry
- Feed stock for organic chemicals; cellulose for conversion to coke, ethylene glycol, ketones and alcohols; extractives, oils and gums
- Firewood
- Energy feed stocks for municipal and industry uses
- Fence posts
- Pallets

Species suitable for short-rotation intensive culture (biomass) plantings in the central hardwood region exhibit rapid, early growth on good sites and respond to fertilization-particularly nitrogen fertilizers. Short-rotation tree species are adaptable to a wide range of sites and reproduce by coppice or sprouting from the stump. This ability to sprout or coppice is critical for biomass plantations. Tree species that have these two characteristics in the central hardwood forest region include sycamore, eastern cottonwood, hybrid poplars of proven worth, bigtooth aspen, river birch, sweetgum, silver maple, black locust, willows, and European alder.

Site Selection

Soil Conservation Service drainage classes can be used as a general guide to site selection, but keep in mind that species will vary in their adaptability to poorly or excessively drained conditions:

Drainage class	Potential growth (Tons/acre/year)	Species favored'
Excessive	2-3.5	8
Somewhat excessive	2.5-4.5	1,2,8,10
Well	4.5-I 2.0	I-10
Somewhat poorly	4.5-I 2.0	I-10
Poorly	5.0-8.0	5,6,9
Very poorly	3.0-4.0	5,9

' 1 -Sycamore
2-Cottonwood
3-Bigtooth aspen
4-Hybrid poplar
5-River birch
6-Sweetgum
7-Silber maple
8-Black locust
9-Black willow
10-European alder

Sites most suitable for short-rotation plantations are fertile, moist but well drained, with soil pH ranging from 5.2 to 7.0 and an adequate rooting depth.

Site Preparation and Weed Control

Good site preparation improves soil aeration, helps control weed competition and some pests, and can improve accessibility. On old fields or cleared land, tillage is recommended. You should plow (including subsoiling if necessary) and disk before planting. In short-rotation forestry either mechanical or chemical weed control is necessary for 1 or 2 years to establish the original planting. Weed control for the coppice plantation may not be needed at all, or only needed for the first year. You can use a legume cover crop to control weeds and increase nitrogen fertility. If you do not till, either “broadcast” herbicides or apply them in bands or strips. However, more chances of rodent damage are likely to occur when herbicides are applied in strips.

On cut-over lands and in brushy areas, logging debris and existing vegetation should be chopped and burned or windrowed and burned. Afterwards you may find it necessary to use herbicides to control woody sprouts. Tillage is beneficial but may be omitted if impcactice

Planting Stock

Bareroot seedlings, containerized seedlings, and unrooted or rooted cuttings can be used depending on the tree species selected, the planting season, and the site quality. For example, unrooted cuttings of eastern cottonwood would be planted at

the start of the growing season when soils are likely to remain moist during root initiation. Plant only those selections, clones, or seedlings from sources appropriate to the locale and site. Plant either by hand using a planting bar or punch dibble, or by machine, but in all cases plant high quality stock.

Planting Density

The spacing you should use depends on your (or the owner's) objectives, the tree species or clone, the rotation length, and the desired sizes and uses of the end product. Some examples of planting densities are listed below:

Management objectives	Spacing (Feet)	Approximate number of trees/acre	Remarks
Chips	3x3 to 6x6	4,800 to 1,200	5- to 1 O-year rotation
Cordwood (pulp and fuelwood)	6x9 to 9x12	800 to 400	10- to 20-year rotation. Will need thinning.
Cordwood and logs	10x10 to 12x12	435 to 300	Up to 40-year rotation for logs. Thin closer spacings for cordwood.
Intercrops and mixed plantings	9x24 to 18x36	200 to 67	Manage trees for cordwood or logs. Crops, including herbaceous legumes, nitrogen-fixing or other trees can be planted between rows.

Post-Establishment Management

After planting, weed control is *critical.* Use chemical or mechanical methods; periodically mow or till in older stands to help control vines and give a manicured look to the plantation. Cut vines on crop trees if necessary.

Thin after the canopy closes. Thin by taking out a row at a time; or thin based on the diameter of the potential crop trees (see preceding tabulation).

Fertilization requirements vary with sites and tree species. Fertilize any time from the second or third year up to 3 to 5 years before harvest. Ideally, fertilization rates should be based on chemical analyses of soil and plant foliage. In the central hardwood region, trees respond the most to nitrogen, followed by phosphorus and potassium. In some cases, thorough weed control increases early growth as much as nitrogen fertilization with or without weed control does. A wide variety of formulations, rates of application, and methods of application may be appropriate to a given site. The upper limit of nitrogen uptake by a rapidly-growing plantation of hardwoods may approach 80 pounds per acre per year in the central hardwood region. The more productive the site the longer fertilization can be delayed.

The use of nitrogen-fixing ground covers, shrubs or trees (such as black locust and European alder) may add enough nitrogen to the soil to eliminate the need for fertilization. Such species can also be used to increase the growth of trees planted with them and to diversify cropping. For example, alfalfa hay or black locust fenceposts can be produced along with a crop tree. Alternatively, Christmas trees or agronomic crops can be interplanted to provide income early in the forest rotation.

Generally, only one or two coppice rotations for biomass are feasible; production drops with more rotations. Coppice growth is not usually acceptable for sawtimber production. To obtain coppice you should harvest in the winter when the root system carbohydrate reserves, which support initial coppice growth, are at a high level. Stump heights of about 6 inches are often adequate to support coppice, and juvenile trees sprout more readily than mature trees. So you should use coppicing with the short-rotation biomass plantings.

Closely monitor plantations for insect and disease problems because dense plantings of single species are more susceptible then widely spaced, multi-species plantations.

Table 1 lists reported production of short-rotation plantations in the central hardwood region.

Table 1.-*Production of short-rotation plantations in the central hardwood region*

Common name	Location	Spacing	Rotation	Annual yield
		Feet	*Years*	*Tons/acre*
Hybrid poplar	Western Kentucky Ohio Valley	2 x 3	4	5.0
Sycamore	Western Kentucky Ohio Valley	2 x 3	4	3.8
European alder	Western Kentucky Ohio Valley	2 x 3	4	3.2
River birch	Western Kentucky Ohio Valley	2 x 3	4	3.8
Silver maple	Kansas	Variable	2	3.0
Black locust	Kansas	Variable	6	3.2
Sycamore	Mississippi Delta	6 x 4	2	3.2
Sycamore'	Mississippi Delta	6 x 4	4	10.7
Sycamore	Southern Illinois	0.7 x 0.7 to 1.8 x 2.3	2	3.6
Sycamore	Southern Illinois	0.7 x 0.7 to 1.8 x 2.3	4	4.5
Black locust	Southern Illinois	0.7 x 0.7 to 1.8 x 2.3	2	5.2
Black locust	Southern Illinois	0.7 x 0.7 to 1.8 x 2.3	3	5.2
Black locust	Indiana	6 x 3	3	10.9
Black locust	Indiana	6 x 3	5	10.3
Sycamore'	Mississippi	3.8 x 4.5	4	6.4
Populus	Lake States	6 x 6	5	7.1
Populus[1]	Lake States	6 x 6	5	8.2
Black locust	Central Great Plains	7.5 x 7.5	6	10.2
Black locust'	Central Great Plains	7.5 x 7.5	6	12.0
Eastern cottonwood	Mississippi River Floodplain	6 x 6	5	8.9
Eastern cottonwood	Mississippi River Floodplain	6 x 6	5	10.7

[1] **Coppice stands from sprouts**

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CENTRAL HARDWOOD NOTES

Growth And Yield Models For Central Hardwoods

Over the last 20 years computers have become an efficient tool to estimate growth and yield. Computerized yield estimates vary from simple approximation or interpolation of traditional normal yield tables to highly sophisticated programs that simulate the growth and yield of each individual tree.

Types of Models

Growth and yield models are generally stand models or individual tree models. The main distinction between stand models and individual tree models is in the type of information needed to build the models and the detail of output they produce. Only stand data are needed to use stand models, whereas individual tree measurements are needed to use individual tree models. Stand models produce only aggregated stand estimates while tree models produce estimates for each tree in the stand. Some models, such as diameter distribution models or stand-table projection models produce a level of detail intermediate between whole stand and individual tree models. In table 1 we classify the models available for the central hardwood forest according to the resolution of detail they generate in projections.

Stand models compute future growth and yield using a few simple stand variables supplied by the user, such as stand age, site index, basal area per acre, and number of trees per acre. Output from these models predicts total stand growth and yield per acre in such terms as cubic-foot volume, basal area, board feet, number of trees, or tons of biomass. For many purposes average yields per acre are sufficient. Stand models are easy to use, require minimal input data, and operate very economically on hand-held or micro-computers.

Stand-tab/e projection models are more complex. Diameter distribution models, for example, are basically stand models with a useful feature that allows whole stand growth and yield to be distributed or allocated to each diameter class. These models compute growth and yield by user-specified species groups and size classes. Stand table projection models usually require you to specify appropriate growth rates by species and size class. They provide reliable yields for short projection periods, especially if the growth and mortality rates you supply are developed specifically for the projected stand. Projections longer than 15 to 20 years may have considerable error, unless growth and mortality rates are appropriately adjusted. With stand table projection models or diameter distribution techniques individual trees are not identified by species or d.b.h. class.

Table 1.-*Growth and yield models for the central hardwood region. Affiliation of contact person and expected application of model is shown.*

Model	Contact	Affiliation[1]	Hardware[2]	Application	Reference
		STAND LEVEL			
GROAK	Arlyn Perkey	NAS&PF	1	Upland oaks	Perkey (1986) Dale (1972)
———[3]	Harold Burkhart	VPI&SU	2	Yellow-poplar	Knoebel *et al.* (1986)
GROWPINE[4]	Arlyn Perkey	NAS&PF	2	White pine (Ohio plantations)	Perkey (in press)
		STAND-TABLE PROJECTION			
SILVAH	Dave Marquis	NEFES	2	Allegheny hardwoods (cherry, maple, oak)	Marquis (1986)
TIMPIS[5]	John Moser	Purdue Univ.	3	Mixed central hardwoods	Unpublished
		INDIVIDUAL TREE			
COPPICE	Paul Johnson	NCFES	2	Red oak stump sprouts (WI)	Johnson and Rogers (1984)
G-HAT	Harold Burkhart	VPI & su	2	Appalachian mixed hardwood stands	Harrison et *al. (1986)*
OAKSIM	Don Hilt	NEFES	2	Upland oaks	Hilt (1985a, b)
TWIGS[6] (Central States and Lake States)	Steve Shifley	NCFES	2	Mixed species stands (Central and Lake states)	Belcher (1982) Shifley (1987)
NE TWIGS (Northeastern States)	Don Hilt Richard Teck	NEFES	2	Mixed species stands (Northeast)	Hilt *eta/. (1987)*
SE TWIGS[4] (Southeastern States)	Ralph Meldahl	Auburn Univ.	2	Southeastern forest stands	Unpublished
		CONSOLIDATED			
ERGYS[4]	Tom Gullett	NCFES	2	——[7]	Gullett (1986)
YIELD	Todd Hepp	TVA	2	[8]	Hepp (1982)
YIELD-MS	Todd Hepp	TVA	2	[9]	Hepp (1986)

[1] NA S&PF-Northeastern Area, State and Private Forestry, Broomall, PA.
NEFES-Northeastern Forest Experiment Station, Broomall, PA.
NCFES-North Central Forest Experiment Station, St. Paul, MN.
TVA-Tennessee Valley Authority, Norris, TN.
VPI 7 SU-Virginia Institute and State University, Blacksburg, VA.

[2] Hardware: 1 = pocket computer or larger, 2 = micro- or larger, 3 = mini or mainframe.

[3] This model has no specific name (acronym). While it is based on stand level, projections, diameter distribution methods are used to obtain the number of trees in each diameter class.

[4] In development.

[5] Write for most recent cost information.

[6] Currently being distributed for a fee by the Forest Resources Systems Institute (FORS), 201 N. Pine Street, Suite 24, Florence, AL 35630. (205) 767-0250.

[7] ERGYS includes GROAK, SILVAH, OAKSIM, TWIGS and other models for the northeastern United States.

[8] YIELD includes GROAK, a yellow-poplar model, and other models for southern pines.

[9] YIELD-MS uses diameter growth and mortality rates from G-HAT, OAKSIM, SILVAH, and TWIGS. Also has option for using local growth rates.

Individual free *models* provide you with the greatest detail, but require more input data such as a tree list by species and diameter. Most require a micro- or larger computer to operate. You can generate a list of trees by species and size for any time during the projection period. This level of detail allows you to assign a tree grade or quality class to each tree and provides a framework to compute tree and stand dollar values for economic evaluations. Such models provide a powerful tool to evaluate various silvicultural treatments and to develop management guidelines.

Consolidated models like ERGYS (Eastern Region Growth and Yield Simulators), a user-friendly micro-computer program, are also available. YIELD-MS also incorporates several individual models, applicable to different species or regions, into a convenient and useful system. Such systems bring together many individual models into one user-friendly system and have special appeal to users dealing with many species, timber types, or broad regional areas.

Uses of Growth Models

You can use growth and yield models to:

- Evaluate the effect of various silvicultural prescriptions.
- Perform economic analyses of alternative management prescriptions.
- Forecast changes in timber supplies for large ownerships, as well as the timber supply outlook at local, regional, state, and national levels.

For some purposes aggregated stand data are adequate, such as the administrative use of models to aid in policy issues or in planning programs to deal with future timber resources on a state or national level. You need more detailed information on tree species and size in models used to evaluate the economics of applying various silvicultural treatments to a specific woodlot.

Keep in mind that virtually all growth and yield models are best suited to compare alternatives or answer ‘what if?” questions to help you select density levels, thinning intervals, rotation lengths, etc. While they are generally not well suited to predicting actual growth of a specific stand, they can be used with caution. Growth of actual stands is best estimated by an adequate inventory system.

Choosing a Model

Consider several factors before you choose a particular model:

- Select a model that can utilize the type of hardware or computer available to you.
- Select a model that uses the input data you have, or can obtain easily.
- Select a model that gives clear, concise output information in a form that is easy to apply in your work situation.
- Choose a model that has been developed for the same species or species groups in your area. Obviously, do not use a model developed for stands with 80 percent oak when your stand has a mixture of 20 percent oak and 80 percent yellow-poplar.

- Select a model that has been developed for your geographical area. For mixed oak stands in Ohio or Kentucky favor the OAKSIM model, but from Indiana to Missouri and Iowa consider Central States TWIGS model.
- Consider the availability of the program, ease of use, and cost of computing.

For example, if you only need stand estimates for your Ohio upland oak forest and your only hardware is a pocket computer, then the GROAK program is a logical choice. If you have a mainframe computer available and need greater detail about the species and size classes, then choose the OAKSIM model. Or if your stand is located in Missouri, or contains an uneven-aged mixture of species, then the Central States TWIGS model might be your best choice.

New models are becoming available quite rapidly. Current information regarding computer applications and software used in management of natural resources are listed in the Software Directory compiled by FORS (Forest Resources Systems Institute, see footnote 6 to table 1). FORS serves as a useful clearinghouse for available software, providing information about computer hardware requirements, software requirements, name and address of vendor, and price of system and options if appropriate.

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CENTRAL HARDWOOD NOTES

Principles Of Managing Stands

Forest stands are managed to achieve some combination of desired products or values. These products or values may include income and tangible benefits from timber production or fees for hunting rights and other recreational activities. The values may be intangible, such as the enjoyment of seeing wildlife or flowering plants, or the simple satisfaction of knowing that there is an area undisturbed by human activities.

Defining Your Objectives

With such a diversity of benefits possible, it is extremely important that you as a forest land owner or manager clearly define your objectives before you make any decisions on how to manage the land. For some objectives, management may be very intensive, with frequent cuttings and other procedures that substantially affect the forest character. For other objectives, proper management may involve doing nothing more than providing minimum protection against fire, insects, and diseases.

Once you define your objectives, an overall silvicultural (management) system can be selected. This system defines the combination of cutting methods and cultural practices to be used. It determines the amount of area regenerated each year and the size of the regeneration openings, which in turn establishes the distribution of tree sizes, ages, and species over the area. *This manipulation of the* vegetative cover is *the* primary tool of *the forester* ; it affects esthetics, visual and biological diversity, wildlife habitat, water yields, plant and animal species composition, tree growth, economic returns, and many other forest attributes. Associated cultural practices, such as the use of herbicides, fertilization, and site preparation, are tools that increase the effectiveness of cutting practices to obtain the desired vegetation.

The basic unit of management for regulating the forest vegetation is the stand. Stands are areas of relatively uniform site and forest conditions. They vary in size according to: management goals, the size of the overall forest, and the practical considerations of harvesting and applying silvicultural practices. Stand size usually ranges from 5 to 100 acres, but smaller and larger areas are sometimes used. The overall management plan is implemented by applying silvicultural practices in an ordered sequence to individual stands.

Developing Stand Prescriptions

The extreme variation found within the central hardwood forests calls for a systematic process to develop stand prescriptions. Your first step is to inventory site and vegetation. Then you should analyze these data to evaluate the stand's stage of maturity, potential for future growth, ability to regenerate, condition of

wildlife habitat, and similar factors. After you consider alternatives for the particular site and stand, you should develop a prescription to move this stand toward the overall goals for the property, taking into account the resources available to implement chosen actions.

Stand Management Goals

Some of the more important stand management goals are:

1. Establish regeneration. For long-term forest development, establishing desirable regeneration is one of the most critical management tasks. Harvested trees and trees with low potential value should be replaced with desirable species suited to the site and goals of the landowner.
2. *Control* species. Species composition determines the value produced, in terms of timber value, food and habitat value for wildlife, and scenic value. Species composition also determines growth potential since certain species grow faster than others.
3. *Control density.* Stand growth and yield and timing of yield are determined in large measure by stand density. In dense stands, individual trees grow slowly, harvests are delayed, economic returns are reduced, and trees with poor vigor are more susceptible to insect and disease damage. Such stands offer little vegetative cover or food for ground nesting birds or browsing animals. In stands that are too open, total yields may be reduced and individual tree quality is often poor because of bole branches and other defects. Mast and fruit production for wildlife may be very low in open stands.
4. Reduce losses to *insects, diseases, and* fire. The best way to reduce insect and disease losses is through timely application of silvicultural treatments. Providing adequate growing space, maintaining desirable species mixtures, and creating fire lanes are examples of management actions you can take to reduce losses.
5. *Enhance nontimber* value. The quality and quantity of nontimber benefits can be positively affected by stand management practices. Dead snags and den trees can be protected to increase the number of cavity-nesting birds and animals, minimum disturbance zones can be identified, and harvest cuts can be distributed in time and space to assure consistent wildlife habitat. Nontimber values can often be enhanced with little or no loss of timber production.

Achieving Stand Management Goals

You achieve goals through regeneration cuttings and intermediate stand management practices. The regeneration cuttings determine the potential stand production as well as the organization of the vegetative cover over the whole forest. Through the regeneration practices you establish the potential for the property to provide the long-term goals of the owner/manager.

Intermediate management practices, (sometimes called forest improvement practices), are applied to ensure the survival and increase the growth of desired species, to reduce the time to harvest, to improve the quality of future harvests, to improve tree vigor, to enhance wildlife food or cover, etc. In the managed forest,

the extent of these practices determines how much of the potential established by regeneration practices will be realized. Previously mismanaged forests can be made more productive through timely application of intermediate management practices.

Regeneration Considerations

It is usually not difficult to obtain natural regeneration in central hardwood forests. New tree seedlings will usually become established after any type of harvesting or natural stand disturbance, except where dense understories of undesirable trees, shrubs, and herbaceous species are present. On the other hand, establishing a particular species can be difficult.

Dense understories of undesirable vegetation will prevent establishment of desirable tree species. Newly germinated tree seedlings cannot compete with established vegetation for light, soil moisture, and nutrients. If undesirable understory vegetation is too dense, control measures may be needed. Herbicides provide the most efficient and effective means of control, but uprooting of woody vegetation with the blade of a tractor or during logging may also be effective.

The cutting method selected for regeneration has a major impact on the species regenerated. A key silvical characteristic is shade tolerance, the capacity of a species to survive and grow in shade. Very tolerant species will survive in deep shade, whereas very intolerant species require full sunlight. There are many species with intermediate shade tolerance. Generally, the more shade-tolerant species can become established beneath the canopies of the intolerant species and will replace them in undisturbed stands. But the most intolerant species will not develop in the shade of other trees.

There are five commonly-used regeneration cutting methods: individual tree selection, group selection, shelterwood, seed tree, and clearcut. Each is an orderly procedure to harvest mature stands and to create microclimates favorable to the desired species or, conversely, unfavorable to unwanted species. The methods differ in the amount of canopy removed and the resulting degree of exposure of the forest floor to sunlight. Essentially, each method simulates various kinds of natural disturbances. All regeneration methods can be used in central hardwood forests.

With the individual tree selection method, relatively few trees are harvested at one time, resulting in continuous shade on the forest floor. So it is useful only for tolerant and very tolerant tree species such as sugar maple and beech. Since very valuable, less tolerant species such as red and white oak, black walnut, black cherry, and others cannot be regenerated by this method, it is seldom recommended for timber production. However, selection forests appear natural and relatively undisturbed and often are preferred where esthetic and recreation values are highest. Their interspersed crown levels also provide excellent habitat

for nongame birds. On the other hand, they generally provide poor habitat for ground dwelling birds and animals because plants in this stratum are not very diverse.

Methods other than single-tree selection are necessary to regenerate less tolerant species. Group selection cutting, with openings ranging from 1/3 to 2 acres in size, can be used to secure reproduction of desired, less tolerant species such as red oaks, white ash, green ash, black cherry, cucumbertree, red maple, and-to some extent-yellow-poplar. The proportions of valuable species may be less with group selection than obtained with shelterwood and clearcutting, but they are substantially higher than with single-tree selection. The mosaics of various size trees and variety of shrub and herbaceous species also provide excellent habitat for a wide variety of wildlife.

Epicormic branching on border trees with poor crowns may cause quality defects in group selection forests. Group and patch selection are seldom used for managing large properties because yield regulation and cultural practice applications are inefficient compared to other methods. However, group selection provides a useful compromise for landowners who want vegetative and wildlife diversity, but object to larger clearings.

Shelterwood and clearcutting methods are well suited to central hardwood forest types, where the most valuable species tend to be shade intolerant. The choice between the two cutting methods is based primarily on presence of advance regeneration of appropriate size, and wildlife, water, and esthetic objectives for each particular tract. Shelterwood cutting is useful in the oak-hickory type when oak advance regeneration is not adequate in size or numbers. Clearcutting requires fewer returns to the stand for cutting (“entries”) and is less costly to administer than the shelterwood cuttings, so it is the preferred method when advance seedling regeneration is adequate. When shelterwood cutting is used, the number, intensity and sequence of cuts, intervals between cuts, and supplementary treatments applied must be carefully tailored to stand conditions and species present.

Clearcutting also produces more browse and forage for wildlife species such as deer than shelterwood cutting. However, browse is available over a longer period of time under a shelterwood. Clearcutting is the only cutting method that will produce a water increase large enough to justify cutting for this purpose. This is likely to be a serious consideration only on municipal watersheds.

Many forest users object to clearcuts and shelterwoods because of their appearance during the years immediately after cutting. Attempts to minimize slash and soil disturbance and limits on size of openings and their proximity to older ones help reduce visual impacts; even so, these cuts remain unsightly to many people As a consequence, clearcutting and shelterwood cutting are the least suitable in areas where recreation or visual goals are primary.

There is no universal "best" regeneration method. Each method meets specific requirements and owners will have different objectives and different levels of resources available to meet those objectives. Since most landowners have varying objectives, several or *all* methods are off en appropriate for the same property.

Intermediate Stand Management

Intermediate cuttings may be necessary to enhance the development of existing stands to meet the overall goals for the property. Some trees are cut or killed to ensure survival and growth of more desirable trees. Intermediate harvests may be commercial but often an investment is required because of tree size or value, or local market constraints. More specific information on intermediate management practices is found in the Notes that follow.

In central hardwood forests, stands are often harvested through some form of "high grading" or cutting only the most valuable trees. When timber production is a management goal, intermediate cuttings must be considered for high graded stands. In these stands high value species and large diameter trees have been cut, leaving low value species and poor quality trees to occupy growing space, and to regenerate the next stand. This is still the most prevalent harvesting method on nonindustrial private forest lands.

Abundant reproduction usually develops beneath relatively open canopies of high graded stands, followed by suppression of the reproduction as the overstory expands. As a result of the suppression, the reproduction slows in growth and begins dying. The less tolerant species die first and many remaining stems develop poor form from bending toward crown openings. Ideally, the undesirable overstory should be cut or killed before it begins to suppress the desirable reproduction. Such release cuttings are effective if applied within 5 to 15 years, depending on overstory density. Usually all overstory trees should be cut or killed in one operation, but some trees might be left for longer periods. For example, trees that are undesirable for timber production may be highly desirable for wildlife habitat if they contain nesting cavities, perch sites, and produce mast or fruit.

There are millions of acres of older high graded stands in the eastern United States that have not had release cuttings. Invariably, undesirable growing stock greatly outnumbers desirable growing stock. But there are sufficient good growing stock trees in most of these stands to provide the base for a productive future harvest. You can start rehabilitation of such stands by an improvement cut. Cut or kill undesirable trees to favor better ones. Always encourage the development of the best trees. You want to accelerate the growth of the best trees, not merely harvest or kill the poor ones.

There is considerable confusion outside of the forestry profession about selection silviculture. To many, the removal of scattered large diameter trees is an effective application of the selection method. However, without improvement cuttings throughout all diameter classes to regulate diameter distribution and release good growing stock, such cuttings are high grade harvests which lead to quality and value decline.

Intermediate cuttings can have both adverse and beneficial effects on nontimber values, so take care to enhance and protect all values. For example, you can improve scenic values by releasing understory flowering trees and shrubs. You can reduce safety hazards in recreation areas by felling live and dead trees, pruning branches, and thinning to maintain vigorous, healthy trees. Thinning and improvement cuts in young even-aged stands can be used to improve vertical diversity and ground vegetation for many animal and bird species.

Summary

Forests should be managed to meet specific landowner goals-usually a combination of goals. The goals are reached by applying silvicultural practices in an ordered sequence to individual stands. Prescriptions are developed to move each particular stand toward the overall goal for the property. Stand management practices are aimed at establishing regeneration; controlling species composition and density; reducing losses to insects, diseases, and fires; and enhancing nontimber values. These goals are achieved by applying regeneration and intermediate cutting methods.

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CENTRAL HARDWOOD NOTES

Improving Quality And Value Of Future Hardwoods

The central hardwood area is highly regarded both in this country and abroad for the high quality timber grown on both public and private lands. Buyers of standing timber and logs for lumber and veneer often look to this region first to meet their needs for raw materials. And these buyers have traditionally paid a lot more for quality timber than the usual market price for ordinary trees and logs. As world-wide supplies of quality timber continue to shrink, the demand for quality central hardwoods will grow. A strong potential demand coupled with rapidly growing young stands throughout the entire region, will provide abundant opportunities to encourage the production of high quality hardwoods for future harvests. The knowledge and technology are available-waiting to be put to use.

A General Strategy

- Grow the best trees on the best sites. Most landowners of central hardwoods will have some forest land suitable for growing high quality trees.
- Identify the best areas and prepare a plan with professional forestry assistance.
- Concentrate efforts and extend rotations on north and east slopes and on areas with deep, well-drained soils.
- Manage the poorer areas for other essential forest products on shorter rotations at less cost. Incorporate wildlife treatments and other uses on these areas as far as possible.
- Do not ignore small tracts and small stands. Small tracts are essential to the total supply of quality hardwoods.
- Exclude all livestock from all hardwood forests; control grapevines and wildfires.
- Treat areas designated for high quality hardwood production very gently. Do not thin past the pole stage. Intermediate treatments or harvests should be light. Keep growth rates a moderate eight rings to the inch for best color and texture.
- Keep roads and trails on poorer sites, not on good tree-growing sites.
- Find ways to insure continuity of management for long term crops despite ownership changes through sales or inheritance. We need to learn from European experiences. Family forestry ethics had more influence in the past; today's society has tended to weaken appreciation for land stewardship.
- Except for the last one, apply these strategies to public as well as private ownerships. Growing high value hardwoods for longer rotations on good sites helps support domestic industry. It also provides export for a more favorable balance of trade and is an appropriate role for public forests. These kinds of production areas also have high aesthetic appeal.

What is High Quality?

The best quality lumber and veneer logs come from trees with straight, limb-free boles with no signs of internal defects. These characteristics are only found on fairly large trees that have grown in closed forest stands on average to good sites.

A veneer log is hard to quantify or describe because of the large number of variables that determine what veneer looks like after it is processed. Written veneer log specifications tend to vary with supply and demand. The more demand, the greater the flexibility in grading standards for species, within limits. Generally, veneer logs must be at least 14 inches in diameter inside the bark at the small end. Ideally, logs should average 18 to 20 inches. They should be at least 8 feet long but length varies according to the kind of veneer being sliced for the near-term market. Log length and trim allowance of an additional 3 to 5 inches are very important to log quality and price; consequently, landowners and others not familiar with industry standards and current requirements should not fell and buck veneer trees.

Veneer logs often are only butt logs but occasionally second and third logs in very high quality trees of the best species will qualify. Veneer logs must be free of sweep, crook, spiral-grain, worm holes, bird peck, pin-knots, limb scars, frost cracks, lightning scars, and other surface indicators of interior defects.

Currently the greatest user demand is for veneer with a uniform look. So the veneer buyer looks for trees with bark patterns and overall characteristics that indicate the tree has grown under uniform conditions with even growth for a long time. If the buyer is looking at cut logs, he can easily determine these characteristics from the growth rings.

Lumber log requirements are similar to veneer logs, except that more defects are allowed because log yield is based on cuttings rather than use of the entire piece as in veneer. Most of the high quality hardwood lumber sawmills use at least four log grades: prime, #1, #2, and #3. It is often difficult to justify the labor necessary to extract #2 and #3 grade logs from the woods. This decision will often be based on species, log size, and available markets for the lower grade logs or the boards they might produce.

Select the Best Trees

Since quality depends upon the characteristics of individual trees, the timberland manager needs to select the best trees in the woods for special attention. In many respects you also need to identify the worst trees, plan for their removal and use them as firewood but not for lumber and veneer. When developing the management plan and selecting the best trees, make sure that:

1. The major species are growing in their natural environment, on the proper site.
2. They outwardly appear healthy and vigorous.
3. The best trees are dominant or codominant in the stand.
4. They have straight boles with very little sweep or crook, with bark in a straight, not spiraling pattern.
5. Where limbs once grew, the bark shows evidence of good healing.
6. The bark shows little to no evidence of worm holes, bird peck, seepage, bumps, or evidence of decay.
7. Trees exhibit no excessive butt swell, and no basal wounds or scars from fire, livestock grazing, or mechanical damage.

When you select areas for high quality hardwood production, it is also important to: (a) know the soil types and their productivity; (b) verify the fire and grazing history and pass up areas that were badly abused; and (c) avoid areas that will likely be subject to rights-of-way, urban expansion, or other developments.

What About Species?

As individual trees and stands are being selected for special attention, you often must choose among species. However, it would be unwise to recommend long-term management based only on today's popular species. If a tree has good form and is growing well, I believe it will eventually pay its way out of the woods and should be left standing rather than marked for indiscriminate elimination. Some species have fared better than others through the years and that fact needs to be considered when making choices. The most preferred species are:

black walnut	pecan	butternut
red oak group	white oak	the hickories
white oak group	sugar maple	hackberry
black cherry	black maple	American basswood
yellow-poplar (American tulipwood)		

Other species very worth considering are:

sassafras	persimmon	eastern cottonwood
the elms	American beech	sycamore
the soft maples		

"TLC" Needed

Research on black walnut has proved that single trees will respond to tender loving care. Because of the high value of walnut, the chances of increasing profits through cultural practices are excellent. In recent years, white oak and red oak have commanded nearly the same prices as walnut. In fact, I believe all high quality trees will eventually yield higher profits to landowners, unless there is a worldwide movement away from real wood to substitutes because of a shortage of quality timber.

Here are some things you can do to help develop quality trees:

1. Keep them free of vines.
2. Do not permit them to become over-crowded, but keep enough competition to encourage natural pruning and regulate diameter growth. When growth slows find out why (landowners should ask a professional forester); look closely at tree density.
3. Keep mechanical equipment away from the stump and root area.
4. Remove all crooked, hollow, diseased, deformed trees. If needed for wildlife, reserve some of them on west or south exposures where quality trees are already more difficult to grow.
5. Prune forest-grown trees sparingly. Prune only the best species and only when they are saplings or small pole size.
6. Use directional felling to protect high quality residual trees.
7. Do not harvest immature stands; their values and prices will be low. Find a way to wait.
8. Develop a plan that includes treatment schedules. For example, plan to thin and harvest every 10 to 15 years.

Other countries are turning to American hardwood resources for their raw material. The future for quality hardwoods is bright, but the situation demands action now. The real challenge is to encourage basic forest practices that will make common trees an uncommon commodity.

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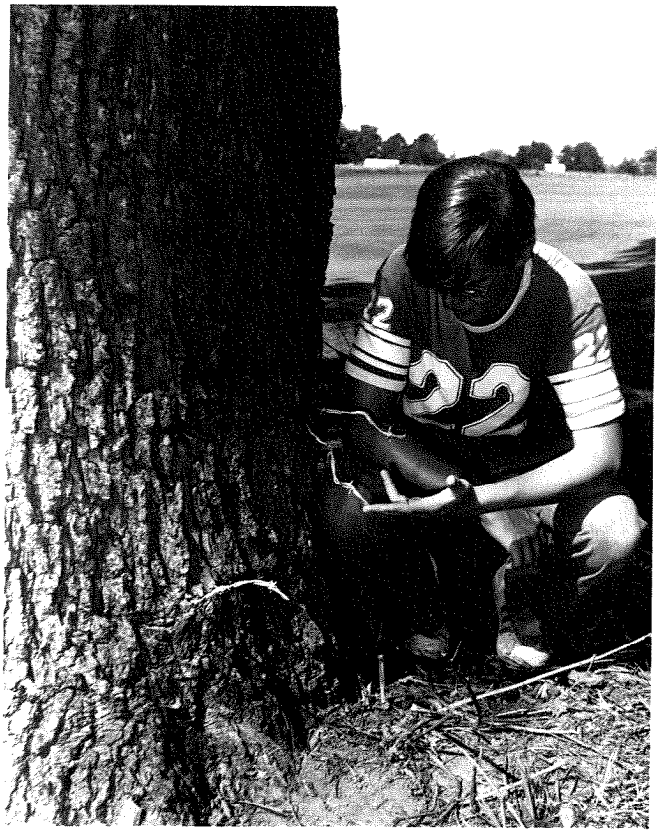
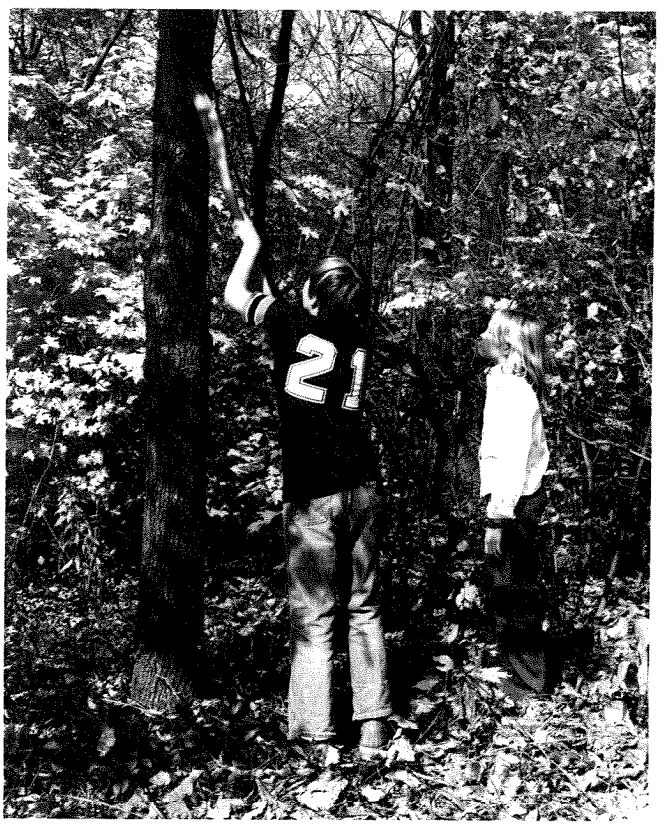
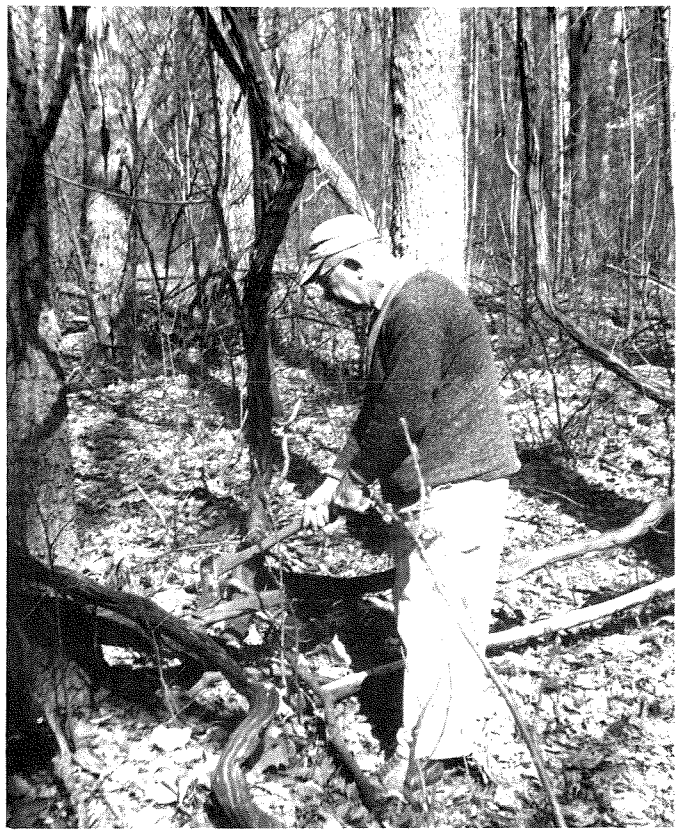


Fence wire is a serious problem when it exists in hardwood trees. (Larry Frye)



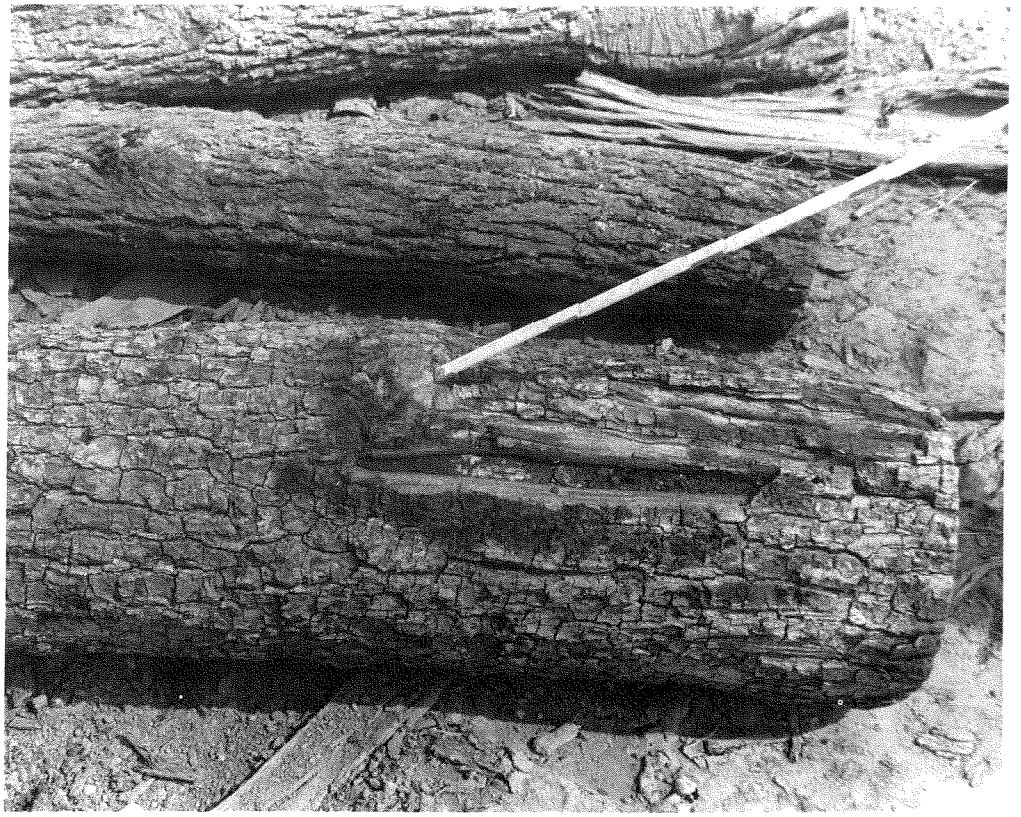
Pruning black walnut. (Larry Frye)

Fine furniture begins with well manufactured, high quality veneers and lumber. (Larry Frye)



Cutting a grapevine. (Larry Frye)

A good stand of hardwoods, Kosciusko County, Indiana. (Larry Frye)



Lower quality logs, like this one, are common place. Our forest landowners goals need to be directed toward the growing of high quality trees. (Larry Frye)

CENTRAL HARDWOOD NOTES

Silvicultural Treatments In Sapling Stands

Sapling stands are those in which codominant trees average less than 5 inches d.b.h. Silvicultural treatments in sapling stands can be summed up in two words: CROP TREES. Any silvicultural treatment must help crop trees if the investment in sapling stands is going to pay off. Just cutting "bad" or "undesirable" trees does not insure that crop trees will be helped *(see* Note *6.04 Response of Sapling Stands to Cultural Treatments).*

There are four silvicultural treatments that you can apply in sapling stands: (1) cleaning or weeding, (2) thinning by basal area control, (3) liberation cutting, and (4) crop tree release.

Cleaning or *weeding,* normally applied in very young sapling stands, removes undesirable species and poor quality trees without basal-area control or selecting crop trees. In older sapling stands, *thinning by basal area control* removes 1/3 to 1/2 of the basal area by thinning from below and cutting codominants that are poor quality or of undesirable species. Research has shown that neither of these treatments can be expected to increase growth or significantly alter species composition because in most cases too few trees were cut.

Liberation cutting is the release of young trees by cutting older or larger trees that are overtopping them. Desirable young stems can be overtopped by residual trees left after timber harvesting or by faster growing sprouts of an undesirable species. Liberation cutting should be applied only when potentially valuable crop trees can be helped. As such, it is best thought of as type of crop tree release where less desirable, larger trees are cut that overtop desirable crop trees.

Crop tree release is the selection and release of individual trees by eliminating stems that compete with or are likely to compete with the crop tree. Crop tree release is the best silvicultural treatment to apply in sapling hardwood stands. This is true for upland oaks, cove hardwoods, bottomland hardwoods, and the oak-pine type. Use the following guidelines to select and release crop trees.

1. Select crop trees that are:
   - Dominant or Codominant. Intermediate crown class trees should be released only if they are relatively tolerant species, such as maple. Intermediate black walnuts can also be released because of their potential high value.
   - Never release overtopped trees.

Well-formed. Crop trees at least 3 inches d.b.h. should be free from forks, crooks, and seams in the lower 17 feet of the bole and free from serious insect or disease problems.

Valuable Species. In order for crop tree release in sapling stands to return at least 4 percent on the investment, crop trees must be capable of producing high-value saw logs, such as red and white oak, black walnut, black cherry, and white ash. Never release crop trees that will be cut for poletimber products, small saw logs or low-value saw logs.

2. Select stump sprouts as crop trees if they meet all the previous crop tree criteria and originate at or below groundline. Select only one or two crop trees per clump and cut all remaining sprouts. Two crop trees can be retained on the same stump only when widely spaced with a U-shaped connection (see Note *6.12 Thinning Sprout Clumps).*
3. For seedlings, wait until codominant trees in the stand average at least 25 feet tall before releasing. This usually occurs between 10 and 20 years.

   Very small seedlings do not respond well to release. However, sprout clumps can be thinned as early as age 5 to improve stem quality and increase diameter growth.
4. Release 50 to 100 crop trees per acre. Spacing for 100 crop trees per acre is about 21 x 21 feet and about 30 x 30 feet for 50 per acre.
5. Apply a *crown* release that leaves the crop tree crown free to grow on all sides. Just removing 1 or 2 main canopy trees is not enough. In most sapling stands, a *crown touching* release is needed, i.e. cutting all main canopy trees, except another crop tree, whose crowns touch the crop tree crown.
6. Do not release substandard trees in areas void of good crop trees.
7. Do not leave groups of more than 2 individual crop trees. Two crop trees can be left close to each other provided each has the potential to reach saw log size. Treat the two as a single crop tree and apply a *crown touching release.* In areas where there is a concentration of potential crop trees, you will have to remove some good trees to release the best crop trees.
8. In oak-pine sapling stands, both hardwood and pine crop trees can be released, depending upon management objectives.
9. Generally, do not release crop trees in sapling stands where poletimber thinnings are economical. Let the stand develop naturally and apply a commercial thinning that removes poletimber products such as posts or pulpwood. However, crop tree release should be carried out in stands where a slower-growing, valuable species, such as red oak, is in danger of being crowded out by a less valuable species like red maple or blackgum. Also, sprout clumps should be thinned whenever the best quality sprouts are likely to be crowded out by lower quality stems within the same clump.

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CENTRAL HARDWOOD NOTES

Response Of Sapling Stands To Cultural Treatments

Why Precommerciai Treatments?

The main reasons for precommercial cultural practices in sapling stands (trees less than 5 inches d.b.h.) are to increase growth of residual trees, increase stand value, and improve or maintain species composition. On good sites (northern red oak site index 70 and above), treating sapling stands may be justified by increased diameter growth of high value species. On fair to poor hardwood sites (northern red oak site 60 and below) cultural practices are seldom advised unless desirable pines are present.

Cleaning and Thinning Using Basal Area Guidelines

In most cases, neither cleaning nor thinning to a certain basal area are economically justified. In cleaning, poor quality trees or less desirable species are removed and no attempt is made to release selected individual trees. In thinning to basal area guidelines, overtopped, intermediate and occasionally codominant trees are removed. Generally, response is short-term because only a few trees are removed from the upper canopy. Growth will persist for 5 to 10 years if 40 to 50 percent of the basal area is removed from precommercial stands. However, the more trees cut per acre, the greater the cost and the more growth is needed to pay for the treatment. Usually basal area thinnings are not recommended in sapling stands.

Crop Tree Release

The best way to increase growth in sapling stands is to release crop trees (see Note 6.03 *Silvicultural Treatments in Sapling Stands).* Select crop trees that will make high quality sawtimber or veneer and give the crop tree crowns room to grow. By releasing 50 to 100 crop trees per acre you should be able to provide adequate trees at final harvest. Remove any dominant, codominant or intermediate tree if its branches touch or encroach on the crown of the crop tree. (However, crown branches from adjacent crop trees may touch.) Removing trees that touch usually releases the crop tree on three and often four sides.

Growth Response

The diameter growth of released dominant and codominant crop trees can be twice that of the unreleased trees for a given period. Some tolerant species such as sugar maple in an intermediate crown class position will respond to crop tree release too. The response to a precommercial treatment varies widely throughout the region. The following species are grouped based on sapling diameter growth for a 1 O-year period.

High (3 inches d.b.h.)	Medium	
Black cherry	Northern red oak	Hickory
Yellow birch	White ash	
Yellow-poplar	Sugar maple	
American basswood (sprouts)	White oak	
Red maple (sprouts)		

In oak-pine stands, pines generally grow the same or faster than most hardwoods, depending upon site quality. On good sites where the oak site index is 70 or above, you can select both hardwoods and pines as crop trees. However, natural succession on good sites favors the hardwoods as the pines are difficult to regenerate and expensive to develop. On fair to poor sites your management objective might often be to increase pine and reduce hardwoods. On these sites pines produce higher merchantable volumes than hardwoods. On poor sites pines will produce moderate yields while associated hardwoods will grow more slowly, yield less, and usually be poor in quality.

Bottomland hardwoods may grow very rapidly. It is not unusual for released crop trees to have an annual d.b.h. growth of 0.8 inches and a height growth of 6 feet.

Is a Precommercial Treatment Worth It?

Yes, if you release crop trees in hardwood or hardwood-pine stands where the codominant crown canopy is at least 25 feet tall, and the trees are at least 10 to 15 years old. The effect of crop tree release may last for 10 years. On the best upland sites, released crop trees could grow 3 to 4 inches in diameter in 10 years or 1 .O to 1.5 inches more than unreleased crop trees. To pay for this precommercial release, trees need to grow about 1 inch more than unreleased trees. This 1-inch response is based on a 4 percent real rate of return, inflation excluded.

What would this 1 -inch difference in d.b.h. growth mean? About 35 board feet (International 1/4-inch) per tree for hardwood trees 16 inches d.b.h. with a merchantable height of three logs. For stands with 60 crop trees per acre, an early cultural treatment in sapling stands could add about 2,000 board feet per acre at the final harvest.

In summary, for sapling stands:

1. Concentrate cultural practices on the best sites. Marginal and poor sites will not produce enough growth to pay the costs.
2. Select crop trees that will make quality sawtimber and veneer.
3. Give the crop trees room to grow by removing all trees (except other crop trees) that touch their crowns. The trees will respond.

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CENTRAL HARDWOOD NOTES

Silvicultural Treatments In Immature Stands

Silvicultural treatments for immature central hardwood stands include precommercial and commercial thinnings, lateral branch pruning, fertilization, cull tree deadening, and vine removal. The specifics of these treatments are discussed elsewhere in these Notes. This Note discusses some basic concepts in the selection and application of silvicultural treatments for central hardwoods.

What Should Be Done?

To decide when and what silvicultural treatments might be useful in immature central hardwood stands you should answer the following questions in sequence:

1. What is the current condition?
2. What are the specific management objectives for the stand?
3. Given the current condition, are the management objectives realistic?
4. If the objectives are realistic, what specific silvicultural treatments are needed and practical?

Stocking Guides

An important tool to evaluate what to do and how to do it is the stocking guide. By stocking we generally mean the proportion of an area actually occupied by trees in relation to the optimum area that would be occupied by trees under ideal growing conditions. It is also referred to as “relative stand density.“ The basic premise is that, as individual trees grow larger in diameter and crown size, there will be fewer trees per unit area. A stocking chart shows the relationship between basal area, number of trees, average tree d.b.h., and stocking level (see Note 5.02 Stocking *Chart for Upland Central Hardwoods).*

Although number of trees and basal area are the variables usually measured and used to enter the charts, the “A” and "B" stocking level lines are the most important for management decisions. The “A-line” is also called the “average maximum density line” and is based upon the minimum area of land needed by trees of a given diameter. It is generally derived from undisturbed or “normal” stands. The “B-line” for oak-hickory is based upon the relationship between crown width and d.b.h. for open-grown trees and represents the maximum area occupied by trees of a given diameter.

When stocking is between the A and the B lines, wood production per acre is nearly constant. If the management objectives call for a dense, slowly growing stand to maximize tree quality, the stocking should be held near the A line. But if fewer, faster growing trees are desired for a shorter rotation or maximum species control, the stocking should be held near the B line. Or if you want to stimulate

understory growth for wildlife browse, it may be necessary to reduce the stocking below the B line. Once you select a specific stocking level target and have determined the existing stocking level, the number of trees and/or basal area to remove in the thinning can be obtained from the chart.

Stocking charts for other central hardwood types may be similar in principle but may differ slightly in detail from the oak-hickory chart. For example, the chart for black walnut was developed from the maximum tree area with stocking expressed as "crown competition factor" (CCF) since minimum tree area information was not available (see Note 5.07 Estimating Black Walnut *Growth* and Yield). A stocking of 100 CCF is the same as the B line, but an A line is not precisely known.

Because different species may have different minimum areas, variation in species composition in mixed stands may require direct summation of minimum tree areas by species and size classes, as has been proposed for Allegheny hardwoods. So it may well be necessary to determine minimum tree area equations for central hardwood species other than the oaks and hickories, or to test equations from other regions to use with central hardwoods.

Area-wide Versus Crop Tree Treatments

Silvicultural treatments are generally applied either to an entire stand (area) or to individual trees. For example, vine control would normally be applied to an area, while lateral branch pruning should normally be applied to selected crop trees. Thinnings can be either area-wide or by crop trees. In both cases, the objective is the same, to provide additional growing space for the best trees.

An *area-wide* thinning usually includes the following steps:

1. Determine the number of trees and/or basal area to remove by comparing the existing stand to target ("leave") stands. Consider both species composition and diameter structure.
2. Develop a priority list of trees to remove. Start with cull trees, then less valuable species, low quality individuals, and finally "excess" trees within diameter classes.
3. Mark so as to thin the entire stand as evenly as possible within the constraints defined in steps 1 and 2.

For a *crop tree* thinning focus on the trees expected to benefit directly from the thinning.

1. Determine the number of crop trees desired. For timber products, aim for 50 to 100 final crop trees per acre plus some "insurance" trees. The younger the stand, the more insurance trees you should retain.
2. Calculate spacing between crop trees = $\sqrt{\frac{43{,}560 \text{ sq. ft. per acre}}{\text{number of leave trees per acre}}}$

3. Mark the stand by first identifying crop trees plus insurance trees at the appropriate spacing; then mark for removal one or more trees competing with each crop tree, depending upon the thinning intensity.

Modify General Prescriptions

Past treatments and wide site differences have created highly variable central hardwood stands. Consequently, you will often need to modify general silvicultural prescriptions to accommodate both stand conditions and owner objectives. Carefully consider the biological bases from which silvicultural treatments are derived when making such modifications and when explaining treatment rationale to owners, managers, and forest workers.

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CENTRAL HARDWOOD NOTES

Thinning Even-Aged, Upland Oak Stands

Thinning produces bigger and better trees faster. Thinning removes poor quality trees and concentrates growth on the best. Total wood production increases because trees that would otherwise die from competition are harvested. Rotation ages for sawtimber can be shortened as much as 20 years. Or, we can grow bigger, more valuable trees using the same rotation age as an unthinned stand.

Four basic questions arise in thinning: (1) How, (2) When, (3) How much, and (4) How often do we thin? The answers depend a lot on management objectives. For example, thinning strategies to produce wildlife habitat are different from strategies to maximize pulpwood or saw log production. Even after the objective has been established, the answers are still complex because the expected growth and yield varies by such factors as stand age, residual stand density, and site productivity (fig. 1 a, 1 b).

Figure I.-(a) An unthinned upland oak stand. (b) Extremely heavy thinning in an upland oak stand

In this Note we discuss the general concepts of tree and stand responses to thinning. We also present thinning recommendations to produce high-value sawtimber. We limit our discussion to immature stands 30 years and older.

Sapling and mature stands are discussed in other Notes. We also limit our discussion to those central hardwoods we know the most about: even-aged upland oak stands that are fully stocked before thinning. Upland oak stands are composed primarily of white, black, scarlet, chestnut, and some northern red oaks.

How **to Thin Your Upland Oak Stand**

First, find out what you actually have on the ground. Determine the basal area and number of trees per acre using standard inventory procedures. Use these values to determine relative stand stocking from the stocking chart for upland oaks (fig. 2). The A-line on the chart represents average maximum stocking.

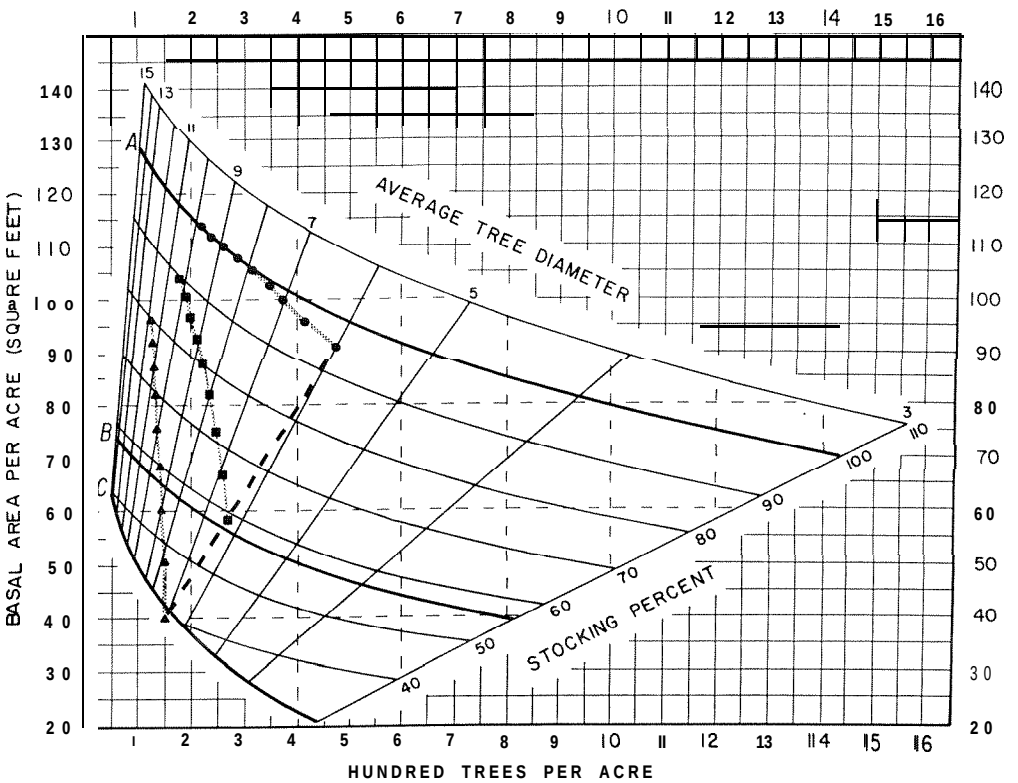

Figure 2.- Stocking chart for upland oak stands. Thinned and unthinned sample stands. Development of an unthinned stand (●) and thinnings to 60 percent (■) and 40 percent (▲) are shown for a 40-year projection. Each symbol represents a 5-year growth period.

Using a 40-year-old stand with a site index of 65 as an example, suppose a field inventory indicates that our stand has 92 square feet of basal area and 480 trees per acre. The chart reveals that it is about 96 percent stocked. A stand with such high stocking could benefit from thinning. A light thinning reduces the stocking to about 80 percent stocking, a moderate thinning to 60 percent, and a heavy thinning to 40 percent. We'll decide later on a thinning strategy for our stand, but let's look now at how to thin, regardless of residual stocking.

The method most frequently used to thin upland oaks is best called "free" thinning-the marker is free to remove trees from all crown classes. The objective is to leave the specified stocking distributed on the best trees as evenly spaced as possible. With due regard for wildlife objectives, larger cull and defective trees are cut first, then competing trees of poor form and quality, then intermediate and suppressed trees of lower quality and value. Finally, lower value species or even some desirable trees are removed from the main canopy if necessary to achieve uniform spacing and the target stocking level.

Free thinning is applied area-wide, as opposed to crop tree release thinnings. Nevertheless, we still concentrate on releasing the best trees. A light thinning to 80 percent residual stocking will not release many of the best trees. However, with a moderate thinning to 60 percent aim to release two or three sides of the crown on the best trees. A heavy thinning to 40 percent will release all four sides of the crown on most residual trees.

The First Thinning

The first thinning is the most important because: (1) it is usually made in younger stands that respond best, (2) it usually provides immediate financial returns from harvested products, and (3) it strongly influences the multiple use values of the stand for many years. The number of cords harvested from different age stands on an average site for upland oaks is shown in figure 3. The heavier the thinning, the more cords harvested. A 5-cord cut is a good rule of thumb for a minimum cut that will interest timber buyers. Figure 3 reveals that we would have to thin a 30-year-old stand on site index 65 below 40-percent stocking to get 5 cords per acre. But wait until age 40 and we can cut about 6 cords if we thin to 60 percent, and about 9 cords if we make a heavy thinning to 40 percent.

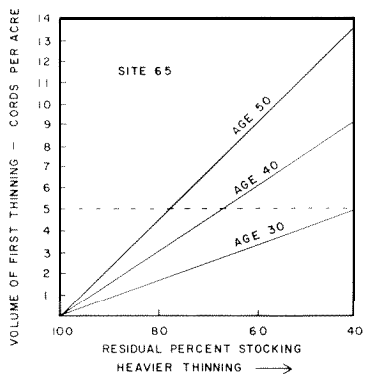

Figure 3.-Cords of wood harvested by thinning at various stand ages for site index 65.

Stand Response to Thinning

So a 40-year-old stand on site index 65 will produce at least 5-cords if we thin to 60 percent stocking. Let's also look at a heavy thinning to 40 percent stocking and then grow both stands to a rotation age of 80 years with a computer growth and yield program called OAKSIM. Development of both thinned stands, and an unthinned stand, is plotted on the stocking chart in figure 2.

Although we cut some bigger trees, a lot of small trees are also removed in thinning. Thus, the average diameter of the residual stand is increased: the heavier the thinning, the larger the average diameter. The unthinned stand tracks along the 100-percent-stocked A-line over the 40-year projection. The two thinned stands approach average maximum density as they move towards the A-line over time. There is little or no mortality in upland oak stands when stocking is below 60 percent.

Cubic foot volume growth and yield values are shown in figure 4. Cubic volume is to a It-inch inside top diameter for trees with at least a 4 foot bolt. For any 5-year growth period, gross growth (net growth + mortality) is constant over a wide range of densities from 100 percent down to 40 or 50 percent. Gross growth expresses the growing capacity of a given site. Net growth increases with thinning down to 40 to 50 percent stocking because mortality is reduced. Volume normally lost as mortality is salvaged by thinning. The increase in net growth explains why the yields of our two thinned stands approaches the unthinned stand over time. However, as stocking increases, the net growth rates of the thinned stands begin to decline (fig. 4). A second thinning at ages 60 to 65 may be appropriate. Thinning below 40 percent stocking causes both gross and net growth to decline because there are simply too few trees to utilize the space available.

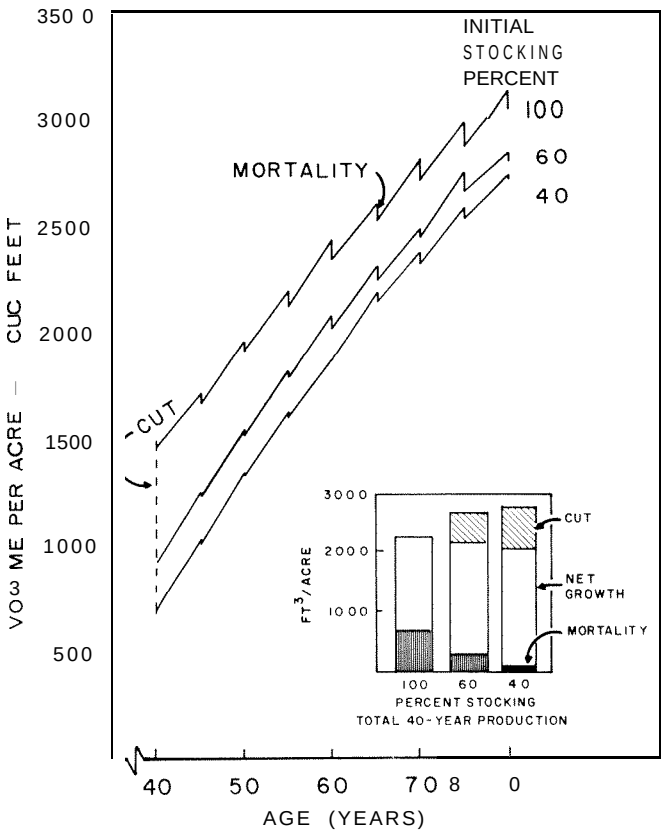

Figure 4.-Cubic foot volume growth and yield of sample stands on site index 65 unthinned and thinned to 60 percent and 40 percent stocking at age 40.

Total yields (final volume + cut volume removed in thinning) at the end of the 80-year rotation were: 3008 cubic feet per acre for the unthinned stand, 2,797 + 472 = 3,269 for the 60 percent thinning, and 2,705 + 689 = 3,394 for the 40 percent thinning. So we can boost total wood production about 9 to 13 percent with one early thinning. Additional thinnings would increase these percentages.

Tree Response to Thinning

Diameter growth of individual trees increases after thinning: the heavier the thinning, the more the increase. Diameter growth continues to increase even down to 20 percent stocking, but at this level there would be a big loss in stand volume growth. A light thinning (80 percent stocking) increases diameter growth of the larger residual trees about 10 to 20 percent, a medium thinning (60 percent stocking) about 40 to 50 percent, and a heavy thinning (40 percent stocking) about 80 to 100 percent.

In the two thinned stands, increased diameter growth produced more sawtimber trees at age 80. The unthinned stand has only 34 trees greater than 11.6 inches at age 80, compared to 41 for the 60 percent thinning, and 56 for the 40 percent thinning. Average stand diameters of all trees at age 80 was 9.7 inches for the unthinned stand, 10.1 inches for the 60 percent stand, and 11.5 inches for the stand thinned to 40 percent. The unthinned stand has only two trees that could qualify as Grade 1 (greater than 16 inches d.b.h.), the 60 percent thinning has 3, and the 40 percent thinning has 8. Additional thinnings would increase the number, size, and value of these sawtimber trees even more.

So far, the logical residual stocking level appears to be 40 percent. Gross growth per acre is not reduced, total production is maximized, and individual trees grow a lot faster. However, there are other factors to consider. While thinning does not significantly affect oak stem form, tree quality is another story. Some species, especially white oak, develop epicormic branches when stocking is reduced below 60 percent. In the absence of shading, these branches persist and become serious defects. To be on the safe side, 60 percent is often the recommended residual stocking level for species prone to epicormic branching. If the stand is composed primarily of the red oak group, we might cautiously thin down to 40 percent. However, as a compromise between growth and quality considerations, we recommend 50 percent as the lowest residual density.

Thinning Guidelines for Upland Oak Stands

The two thinnings we discussed in this Note were only for one age and one site index. The development of thinning guidelines is complex because we must consider various ages, sites, and rotation ages, along with when, how much, and how often to thin. In summary:

When to Thin

Commercial thinning (at least 5 cords per acre) may begin as early as 30 years in upland oak stands on site index 80 or better. On site 70 we have to delay the first cut until age 35, and on site 60 we should be able to start by age 40.

How Much to Thin

Regardless of the site, the first thinning should be as heavy as possible. Young stands respond most to thinning and the crowns close very quickly. If the stand is predominantly black oak and/or red oak, thin to the 50 percent stocking level. If the stand is predominantly white oak that could produce epicormic branches, only thin to 60 percent. If the stand is a mixture of black, red, and white oaks, thin to 50 percent. Trees that develop too many epicormic branches can be removed in later thinnings.

Subsequent thinnings should not reduce residual stocking below 60 percent. This stocking level will allow us to remove trees that developed epicormic branches after the first thinning, maintain vigorous growing conditions, upgrade quality, and permit the stand to approach average maximum density (A-line stocking) before harvest. You should aim for a well stocked stand with at least 50 high quality trees per acre for the final harvest cut.

How Often to Thin

Frequency of thinning depends on the intensity of the first and subsequent cuts, site index, and rotation age. Rotation age varies with site index if our goal is to produce high quality saw logs: 80 years for site index 80, 100 years for site 70, and 120 years for site 60. Shorter rotations simply do not produce enough sawtimber-size trees. Given these rotation ages and the initial thinnings discussed above, subsequent thinnings to 60 percent stocking can be made at age 50 for site 80, age 60 for site 70, and age 70 for site 60. These thinnings would produce a commercial 5-cord cut, maintain vigorous growing conditions, and allow the stand to close just before harvest. If the rotation age changes, then the frequency of thinning could also change. For example, if the rotation age for site 80 were lengthened to 100 years to produce more veneer logs, we could easily make a third thinning.

Thinning for Specific Applications

Detailed thinning prescriptions for specific upland oak stands can be developed with computer programs like OAKSIM. We have not discussed thinning guidelines for mixed species, uneven-aged, central hardwood stands. You can use such

programs as TWIGS to develop thinning guidelines for these kinds of stands. For information on TWIGS *see* Note *5.10 Growth and Yield Models for Central Hardwoods.*

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CENTRAL HARDWOOD NOTES

Managing Mature, Even-Aged Stands

Foresters generally consider central hardwood stands mature when they are 80 to 100 years old or have reached a specified rotation age. However, by the time stands are 50 to 60 years old and in the large pole/small sawtimber size, they have generally slowed in height growth, their annual basal area growth has leveled off, and except for size, they have many of the characteristics of older stands. Although most central hardwoods are long lived and some can be grown on very long rotations, they generally reach economic maturity at the recommended rotation ages in table 1. At these ages annual volume growth levels off and may even decline, and the trees no longer earn even a moderate rate of interest. There are basically two options for managing such stands.

A mature upland oak stand on a good site.

Active Management Option

This option assumes owners want either to sell or to cut timber for their own use. What you should do depends strongly on the current stand stocking, stand conditions, and the species composition.

Table 1 .-*Recommended and maximum rotation for some important central hardwood species*

Species	Recommended rotation	Maximum rotation
	-----Years-----	
American basswood	**90-100**	150
American beech	100-l 20	250+
American elm	100-l 20	200+
Bigtooth aspen	50-60	75
Black cherry	70-90	250
Blackgum	90-100	200+
Black locust	20-30	50
Black walnut	90-l 00	250
Black willow	50-60	90
Butternut	70-80	90
Cucumbertree	70-90	150
Eastern cottonwood	60-80	100
Green ash	70-90	150+
Hackberry	70-90	150+
Hickories	90-100	250+
Black oak	90-100	150
Chestnut oak	90-l 00	250+
Chinkapin oak	90-l 00	250+
Northern red oak	90-l 00	200+
Scarlet oak	70-80	100
Post oak	100-l 20	200+
Quaking aspen	50-60	75
Red maple	70-80	150+
Silver maple	70-90	125
Slippery elm	90-l 00	200
Sugar maple	100-l 20	300+
Sweetgum	80-l 00	150+
Sycamore	90-l 00	200+
White ash	90-l 00	150
Yellow-poplar	80-l 00	200+
Pin oak	70-80	125
Nuttall oak	70-80	100
White oak	100-l 20	300+
Eastern hemlock	100-120	900+
Eastern redcedar	100-l 20	300+
Eastern white pine	100-l 20	300+
Pitch pine	80-l 00	200
Shortleaf pine	70-90	150+
Virginia pine	70-90	150

In stands with 80 percent or more stocking, a very light thinning or improvement cut--often called a conditioning cut--can be used to remove some cull trees, undesired species, or some short-lived species or old residuals from past logging. Do not reduce stocking below 75 percent and do not make large holes in the stand. Take care not to compromise wildlife objectives if they are important to you (see Note 9.05 Treating Mature Stands for Wildlife).

Trees 60 years old and older in dense stands will have relatively small crowns and do not respond well to release. Bole sprouting may become a problem when trees this age are released too much.

If current stocking is 60 to 80 percent, it is usually best to wait. Any cutting in such stands will probably not benefit the entire stand and may allow an unwanted understory to develop rapidly. By simply waiting for about 10 years, stocking will increase and you may be able to get an operable cut without depleting stocking.

In mixed hardwood stands, remove as many trees of the shorter-lived species as possible. Although most central hardwoods can be retained 100 years or more, species such as aspen, butternut, scarlet oak, and several bottomland species start to decline in vigor and succumb to insect and diseases at an age much younger than 100 years (table 1). Remove these species first and keep your stands more vigorous.

At some point, you will need to consider regenerating the stand. Just when depends on how long you plan to try to keep the stand and whether it is an oak-hickory, mixed hardwood, or bottomland stand. You can use table 1 as a general guide to determine rotation age by considering the species present in the stand and your overall management objectives. In most cases, regeneration potential and needs should be evaluated at least 20 years prior to the anticipated rotation age *(see* Notes 3.01 *Principles of Natural Regeneration, 3.02 Assessing Regeneration Potential,* and *2.04 Choosing a Silvicultural System).*

No Management Option

If you choose not to manage an even-aged stand, it will gradually change in both character and composition over time. Natural forces such as wind, lightning, drought, insects, and diseases will cause individual or groups of trees to die. The shorter-lived species will disappear first and the small openings or gaps created by their death will be filled by whatever species are present in the understory, usually tolerant species such as red and sugar maple, beech, and perhaps dogwood. Individual trees of long-lived species present in the stand will eventually grow large. As time passes, the stand will resemble an uneven-aged stand but with more large trees than a managed uneven-aged stand. The understory will be gradually dominated by shade-tolerant species. Although the changes will not be apparent from year to year, the shade-tolerant species will increase at the expense of the intolerant species and eventually dominate the stand.

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CENTRAL HARDWOOD NOTES

Managing Uneven-Aged Stands

Maintaining uneven-aged stands involves cutting trees from a range of diameter classes in such a way that the residual stand has a balanced, steeply descending diameter distribution curve (fig. 1). The objective is to distribute trees by diameter classes so that over time the stand contains trees of different ages and sizes.

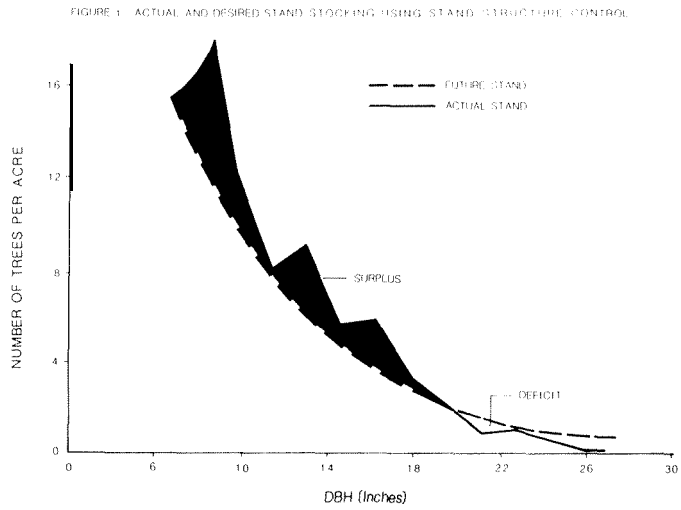

Figure 1.-Actual and desired stand stocking using stand structure control.

How to Structure the Stand

You should first try to conduct an inventory of your stand. With this information you can prepare a diameter distribution curve (see References). The three stand characteristics below can be used to help you determine the diameter distribution curve for future stands.

1. Establish the "largest diameter tree" (LDT) to be retained in the stand. In making this decision consider the optimum diameter of the primary species based on site quality, wind firmness, economic maturity, or the landowner's visual objectives for large trees.

2. Determine a "q-value" to establish the numbers of trees needed in each 2-inch diameter class. The q-value of a stand represents an average quotient between the number of trees in consecutive diameter classes for the stand. A stand with a low q-value such as 1.3 will have more large trees and fewer small ones than a stand with a high q-value of 1.7. A quick way to estimate the q-value of an existing stand is shown in table 1. It may be necessary to start with a relatively high q-value of 1.5 or 1.7, depending on the relative proportions of poles and sawtimber (table 1), working gradually toward a lower q-value such as 1.3 in successive harvests.

Table 1 .-*A quick estimate of q-values for existing stands based on basal area in pole and sawtimber classes*

Percent of basal area in each class		
Pole	Sawtimber	
6-to lo-inch	12-inch plus	q-value
55	45	1.7
50	50	1.6
40	60	1.5
30	70	1.3

3. The last step is to set a "residual basal area" (RBA) to control the overall stocking of the stand. For forest types with stocking guides, use the "B" level value of the existing stand *(see* Note *5.02 Stocking Chart for Upland Central Hardwoods).* An RBA range of 65 to 75 square feet can be used for bottomland hardwoods and other types lacking stocking guides. Use **a** higher RBA for above average sites or where lower "q-values" (1.2 to 1.3) are used.

If you cannot conduct an inventory and prepare a complete diameter distribution curve as described above, table 2 will provide you with generalized guides for structuring your stand.

General Marking Guidelines

1. To minimize epicormic branching and post harvest losses don't remove more than one-third of the total basal area in one harvest.

2. Mark trees over the full range of size classes and concentrate the removal of trees in the diameter classes with surplus trees where possible.

3. Don't arbitrarily remove all large merchantable trees, leaving the remainder of the stand untended.

4. If your stand is deficient of trees in a particular size class, leave additional trees in the next smaller size class to correct the deficiency.

5. On steep slopes, mark trees that are in the felling path of larger ones or leave additional basal area (RBA + 10 sq. ft.) to offset possible logging damage.

6. Make frequent prism checks of the residual stand basal area to insure marking is meeting the stand RBA and structure goals.

In previously unmanaged stands or even-age stands with few small trees, the first harvest should remove high risk and some poor quality trees, including suppressed poles that are prone to epicormic sprouting. New regeneration need not be a

Table *Z.-Suggested residual basal area per acre for upland hardwoods managed under the selection system'*

Stand structure diameter grouping (Inches)	Site index 55-64 LDT[2] 16- to 19-inch d.b.h. q-values			Site index 65-74 LDT 20- to 23-inch d.b.h. q-values			Site index 75+ LDT 24-to 28-inch d.b.h. q-values		
	1.3	1.5	1.7	1.3	1.5	1.7	1.3	1.5	1.7
	(Square feet)								
Sapling <5.0	5	5	10	5	5	10	5	5	10
Poles 6-l 0	20	25	25	15	25	30	1.5	25	25
Sm sawtimber 12-16	25	20	15	25	20	15	20	20	15
Med sawtimber 18-22	10	5	5	20	10	5	20	10	5
Large saw-timber 24							10	5	5
TOTAL RBA Square feet	60	55	55	65	60	60	70	65	60

[1] Based on "B" level stocking rounded to 5.5 square feet using mid-class diameters of 18, 22, and 26 respectively.

[2] LDT = Largest diameter tree.

primary objective in this cut if advance reproduction is present. Create 4 to 8 small openings (25 to 40 feet in diameter) per acre to enhance the development of any potentially high quality saplings in these gaps.

Remove trees that will not survive over the next 15 to 20 years, but don't reduce the stand below the basal area objective, even if it means carrying some poor quality trees to the next harvest.

Cutting Cycle

The cutting cycle (interval between harvests) can be flexible. You can harvest when the stand has reached 80 percent of full stocking, and you should harvest by the time stocking reaches 90 percent. For most healthy stands, stocking will increase about 1.33 percent per year.

Local operability standards and calculated growth rates for the product, i.e., cordwood, sawtimber, etc., can be used to help determine the cutting cycle. A cutting cycle of 15 to 20 years is probably economically feasible on most average and good sites. A growth rate of 150 board feet per acre per year will provide a harvest of 2,250 board feet per acre after 15 years, for a total harvest of 45,000

board feet on 20 acres. But, do not use board foot volume growth alone to determine when to cut. The diameter classes below sawtimber size must also be considered to maintain your structure goals.

Effects on Species Composition

The species composition of an uneven-aged stand is eventually influenced by whether trees are harvested singly or singly with provision for group selection harvests. Gaps created in the canopy by removing scattered mature trees are not large enough to allow survival and growth of the more light-demanding species, such as yellow-poplar, white ash, black cherry, and oaks. Ecological conditions under single-tree selection are most favorable for shade-tolerant species, such as the maples, hickories, basswood, beech, blackgum, dogwood, and sourwood. If oaks and other more light-demanding species are wanted, openings must be made to provide the necessary growing conditions *(see* Note 3.01 *Principles of Natural Regeneration).*

Group Selection: A Regeneration Met hod

Successful use of group selection to reproduce midtolerant and intolerant species involves more than simply cutting small patches in the forest at periodic intervals. To promote and maintain a high quality stand, groups of pole and small sawtimber trees that developed after previous harvests must be thinned, some saplings may require release, and scattered large trees beyond group boundaries may need to be harvested. For these reasons, marking for group selection must also include single-tree selection marking between the groups, using the stand structure guidelines.

If oaks are present and are to be regenerated, existing oak advance regeneration should be surveyed. Simply creating openings will not guarantee oak regeneration if existing oak saplings and seedlings are too few and too small. If oak regeneration is inadequate, special treatments may be necessary. (See Note 2.05 Silvicul*tural Systems for Oak-Hickory and Oak-Pine,* Note 3.03 *How to Assess the Oak Regeneration Potential in the Missouri Ozarks,* and Note 3.04 *Treatments to Encourage Natural Regeneration.)*

Oak seedlings require about one-third full sunlight for maximum photosynthesis, while the more intolerant bottomland forest species may require more. Table 3 shows the minimum opening size needed to provide one-third full sunlight on various aspects. The diameters of the openings are measured in multiples of the average height of the border trees. For a stand with an average tree height of 70 feet, a 2-tree-height opening would be 140 feet in diameter and occupy 0.35 acre.

Table 4 gives the number of openings that should be made in each cutting cycle to provide space for the development of oaks and other less tolerant hardwoods for three aspects and q-values. These groups can occupy 3 to 9 percent of the stand area and should be dispersed throughout the stand.

Table *3.-Minimum opening size needed on various aspects to provide one-third full sunlight*

Aspect	Opening size	
	Tree heights'	Acres
South & West	1	0.09
Level	1-1/2	.20
North & East	2	.35

[1] Based on average tree height of 70 feet

Table *4.-Number of openings on 20 acres needed in each cutting cycle for optimal stocking of the more light-demanding species (oaks, black cherry, yellow-poplar, etc.)*

Selected q-values	Area in groups	Aspect with required diameter of openings for 1/3 full sunlight'		
		South & West 70 feet	Flat 105 feet	North & East 140 feet
	(Percent)	*(Number of openings)*[2]		
1.3	3	6	3	2
1.5	5	11	5	3
1.7	9	18	9	5

[1] Based on 70-foot average tree height.

[2] Based on the average area occupied by a 2-inch sapling at B-level stocking and the target number of trees in the 2-inch class of 35 trees per acre (q-l .3), 70 trees per acre (q-l .5), and 115 trees per acre (q-l .7).

Locate Groups

- Where natural regeneration is occurring
- Where large diameter trees are to be harvested
- In pockets where trees are dying naturally
- In areas with excessive numbers of trees of a particular size class
- In the path of natural seed fall of desired species
- Where special wildlife habitats are benefitted

Effects on Quality

Single-tree selection develops good stem quality in shade tolerant hardwoods as the tighter crown closure and bole shading discourages forking and excessive branchiness. The less shade tolerant species, when regenerated in openings, will

also develop high-quality stems because of the inherent self-pruning abilities. Crop trees left along the borders of gaps or openings may develop epicormic branches that will persist and eventually degrade tree quality. This can be reduced by leaving smaller trees along the margin of gaps to screen crop trees behind them.

Logging damage to some of the residual trees is an unavoidable result of applying the selection system. Generally, the percentage of trees injured is low enough that future management is not adversely affected. If good logging practices are followed, trees with injuries severe enough to cause degrade should comprise less than 10 percent of the residual basal area, although damage up to 20 percent can occur (see Note 8.02 Logging Damage).

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CENTRAL HARDWOOD NOTES

Pruning Central Hardwoods

Pruning, properly done, is one of the best ways to assure high quality wood. Although the overall volume of hardwood has been increasing during the last several years, the volume of high quality hardwood continues to be in short supply. So high quality logs will continue to be worth more at market time. Potentially, pruning can be an important silvicultural treatment for central hardwoods. The primary questions are which species should be pruned and what is proper pruning?

Deciding Whether to Prune

The 70+ species that comprise the central hardwood forests vary considerably in how well they shed branches naturally and in the value placed on knot-free wood. Based on those two criteria, the following species should be considered for pruning in decreasing priority:

Very poor to poor branch shedding	Poor to good branch shedding	Good branch shedding
black walnut	black oak	red oak
sugar maple	white oak	cherrybark oak
scarlet oak	butternut	

The local markets and the stand stocking level will determine whether you should undertake pruning. A price differential of only 40 dollars per MBF between clear, pruned compared to rough, unpruned logs, is all that is needed to make pruning an economically viable treatment for black walnut, sugar maple, and scarlet oak. If, in addition, a stand is growing at less than "B" level stocking, you should consider other species for pruning as well, as they may not shed branches sufficiently well at this low stocking.

What To Do

Once you decide to prune, your most important job is to be sure that the pruning is done right. A proper cut removes the living, dying, or dead branch by cutting as close as possible to the collar at the branch base (fig. 1). The collar should not be injured or removed. The collar may be swollen, and the swollen collar that remains is not a stub. On dead branches, a ring or “doughnut” of living tissue surrounds the branch at its base. Do not injure or remove the ring of living wood.

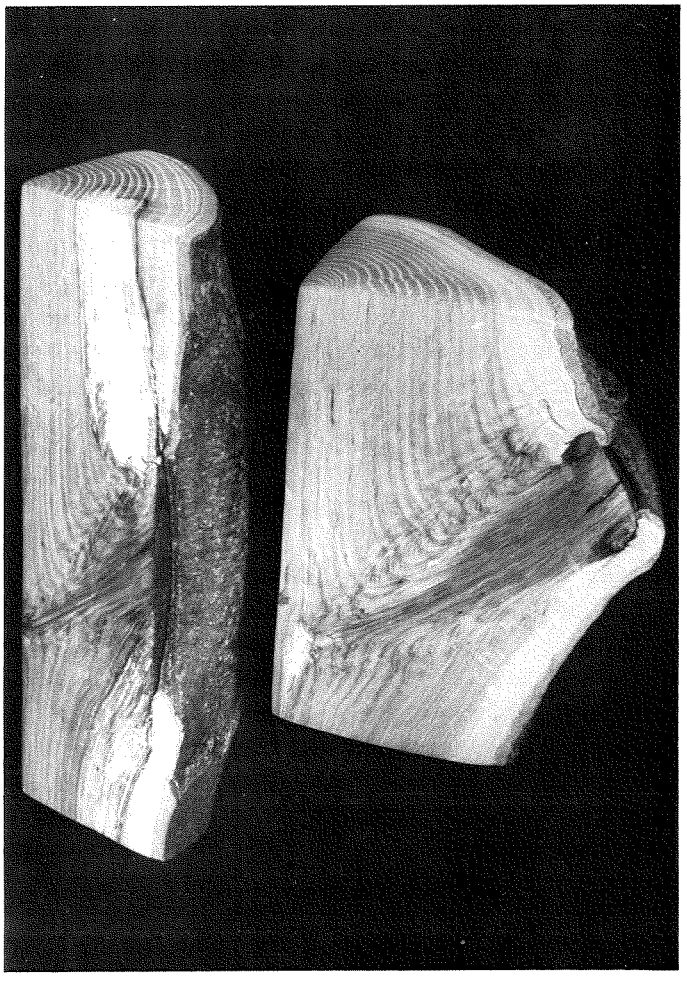

Figure 1 .-A proper cut (right) and improper flush cut (left) on red oak. Both samples are from the same tree 6 years after pruning. Decayed wood developed above and below the Rush cut.

Natural Target Pruning

Because every branch and every collar will be slightly different, a pruning method centered about targets was developed and is called *natural target pruning* (fig. 2). To implement:

1. Locate the branch bark ridge.
2. Find *target A* - outside of the branch bark ridge.
3. Find *target* 5 - where the branch meets the branch collar.

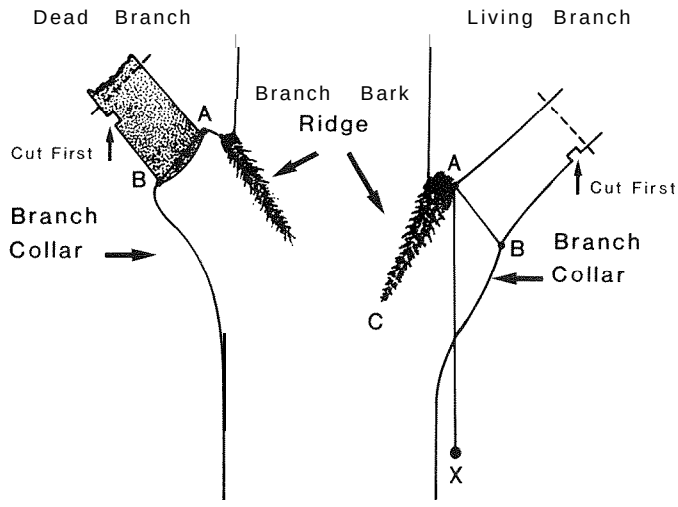

Figure 2.-Diagram of *natural target pruning.*

4. If B is hard to find - drop a line at AX. The angle XAC is equal to the angle XAB.
5. If the branch to be pruned is large, avoid splitting and tearing by making a stub cut a few inches from the branch collar.
6. Make the final cut at line AB.

CAUTION: Do not cut behind the branch bark ridge. Do not leave stubs. Do not cut the branch collar. Do not paint cuts.

When branches are pruned properly, a ring of callus will form completely around the cut after the first full growing season (fig. 3). Flush cuts will have callus only to the sides of the wound or in a horseshoe shape (open at the top if the cut was flush at the top and open at the bottom if the cut was flush at the bottom).

The best time to prune is during the late dormant season. However, when proper pruning cuts are made, pruning can be done at anytime. But it is best to avoid pruning when leaves are forming in the spring and are falling in the fall.

What Not To Do

Avoid making flush pruning cuts. We know through research that flush cuts start at least 14 serious problems, including discolored wood, decayed wood, resin-soaked wood in conifers, wetwood, a host of cankers, circumferential and radial cracks, and weak spots with low amounts of energy reserves that are sites where sudden cold or heat will cause cracks and dead spots, and where insects often infect wood. Indeed, the flush cut is one of the most injurious treatments man has inflicted on trees both in the forest and in the city.

Figure 3.-When proper pruning cuts are made, a circle or "doughnut" of callus will form about the cut after a complete growing season.

Flush cuts cause large wounds and rapid callus rib formation. We know now that callus formation is not associated with the decay process, and if wounds close rapidly, infection into the wood will be stalled. Unfortunately it is rare that large wounds completely close. And, when callus forms too rapidly, as it frequently does on flush cuts, the ribs of tissue turn inward to form a "ram's horn." When this happens, the wound will never close because bark will be between the inrolling ribs. Such a condition benefits the wood-inhabiting pathogens. Likewise, there are no data to show that any wound dressing stops rot.

How Much To Do

For best results, prune in two or more steps, starting when the trees are 4 inches d.b.h. and continuing until at least the first 17 feet of the bole is clear. Generally only dominant and codominant trees, and no more than 100 to 150 trees per acre, should be pruned. Pruning can reduce growth if too much of the live crown is removed. The "rule of thumb" is to remove no more than 25 percent of the live crown at any one pruning and to maintain a 50 percent live crown/bole ratio.

The time needed to prune depends upon several factors; the most important are the numbers and sizes of branches removed. Estimates of pruning time per tree range from 1.5 minutes to 9 minutes. The average time to prune to a height of 17 feet is 6 minutes.

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CENTRAL HARDWOOD NOTES

Individual Tree Control

Controlling individual unwanted trees in forest stands is a readily accepted method for improving the value of future harvests. The practice is especially important in mixed hardwood forests where species differ considerably in value and within species individual trees differ in quality. Individual stem control is a mechanical or chemical weeding operation that eliminates undesired trees competing for site resources. Both methods have advantages and disadvantages. The risk of bodily injury is an inherent safety problem with mechanical methods. Injury to desirable plants is a potential problem with chemical methods. However, since herbicides used in control are placed directly on the tree, the potential for plant injury results from "backflash" rather than foliage contact. Backflash is herbicide uptake by untreated trees adjacent to the herbicide-treated trees. This uptake may occur through root grafts, herbicide exuding from roots, or herbicide spillage.

Girdling

An ax or saw is used to cut through the bark and into the wood around the entire stem of the tree. When done with an ax, this strip is generally four inches wide and encircles the stem. The bark in this band is removed from the tree (fig. 1). When a chain saw is used (fig. 2), usually two rings, 2 to 4 inches apart, are cut around the tree (fig. 3). This double "chain saw girdle" is more effective in reducing the likelihood of the cambium growing over (bridging) a single narrow saw kerf of a single girdle.

Advantages

No special equipment necessary when done with an ax.

Disadvantages

Tendency for the tree to bridge a narrow girdle.
Ingrown bark must be cut or interrupted.
Sprouts will occur below the girdle.
Girdling with an ax is laborious.
Chain saw and ax use are hazardous.

Frilling

Frilling is a variation of girdling. With an ax, hatchet, or similar tool, a series of downward cuts are made around the tree (fig. 4). However, the bark and wood are left as a flap into which a herbicide is added to improve effectiveness (fig. 5). Since the cut is very narrow, the addition of herbicides helps prevent the tree from growing over the girdle. It is not uncommon to make the girdle with a chain saw and add the herbicide with a squirt bottle or hand sprayer (fig. 6). Suggested herbicides include glyphosate (Roundup)[1], 2,4-D amine, 2,4-D + picloram (Tordon RTU), triclopyr (Garlon 3A), and dicamba (Banvel).

[1] Use of trade names does not constitute endorsement of the products by the USDA Forest Service.

Advantages

Faster, more effective control than girdling alone
No specialized equipment required.
Can be done throughout the year.

Disadvantages

Frilling with an ax is laborious.
Chain saw and ax use are hazardous.

Spaced Cuts/Tree Injection

Spaced cuts are made around the stem with an ax, hatchet, or tree injector and small amounts of herbicide are added to the cuts. This is similar to frilling except the cuts do not overlap, so labor and herbicide usage are reduced. The cuts, about 1 to 2 inches wide, are spaced around the tree about 1 inch apart, edge to edge. A small amount of herbicide, 1 to 2 milliliters, is added to each cut (fig. 7). Specialized equipment is available, but its expense is probably not warranted for small ownerships (figs. 8 and 9). Suggested herbicides include glyphosate (Roundup), 2,4-D amine, 2,4-D + picloram (Tordon RTU), triclopyr (Garlon 3A), and dicamba (Banvel). The 2,4-D amine is more effective in the growing season than when the trees are dormant.

Advantages

Faster, more complete control than girdling.
Less labor and herbicide than frilling.

Disadvantages

Erratically spaced cuts result in incomplete control.
Injection during periods of rapid sap flow may reduce effectiveness.
Ax use is hazardous.

Cut Stump

Cutting down the undesired trees has immediate visual and release effects. Whether done with ax or saw, there is a very high probability that the stump will sprout if the cut surface of the stump is not treated with a herbicide soon after cutting. Stump sprouts can be important competition if allowed to develop too close to crop trees. The herbicide should be applied immediately after cutting to the cambial area of the stump, where the bark and wood meet. It is not necessary to treat the entire stump (fig. 10). The herbicides effective in frilling are also effective when applied to fresh cut stumps, i.e., glyphosate (Roundup), 2,4-D amine, 2,4-D + picloram (Tordon RTU), triclopyr (Garlon 3A), and dicamba (Banvel).

Advantages

Immediate visual and release effects.

Disadvantages

High costs relative to benefits.
Chain saw and ax use are hazardous.

Low Volume Basal Spray

Spraying the lower portion of tree stems with herbicides has been a long established practice on rights-of-way. In the past, treatments used low concentrations of herbicide and high volumes of carrier per acre, usually 50 to 80 gallons of diesel oil. More recently it has been found that increasing the concentration of herbicide makes it possible to control woody plants while using only one-tenth the amount of carrier (5 gallons of carrier per acre) if a hand sprayer with a very small diameter spray tip is used (fig. 11). The herbicide mixture contains 20 to 30 percent herbicide in an oil carrier and is applied to the entire lower 12 to 18 inches of the stem in sufficient quantity to wet the surface but not to the point of runoff. Suggested herbicides include triclopyr (Garlon 4), triclopyr plus picloram (Crossbow or Access), and 2,4-D plus dichlorprop Weedone CB).

Advantages

Effective year round.

An effective method for treating small stems.

Disadvantages

Working with oil carrier may be undesirable.

Tends to be less effective on stems larger than 4 inches diameter.

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Figure 1 .-A band approximately 4 inches wide is removed when girdling is done with an ax. (Harvey Holt)

Figure 2.-Chain saw girdling must be done carefully. Chain saw chaps are recommended. (Harvey Holt)

Figure 3.-When girdling is done with a chain saw and no herbicide is added to the cut, a double girdle should be made. (Harvey Holt)

Figure 4.-Frilling leaves bark and wood flaps encircling the tree. (Harvey Holt)

Figure 5.-Small amounts of a water soluble herbicide should be added to the frill. (Harvey Holt)

Figure 6.-Single girdles with a chain saw are treated with a water soluble herbicide to assure better control of undesired stems. (Harvey Holt)

Figure 7.-Applying herbicide in spaced cuts with a hatchet and squirt bottle is the least laborious method of controlling unwanted trees. Keep the spacing between cuts less than 2 inches. (Harvey Holt)

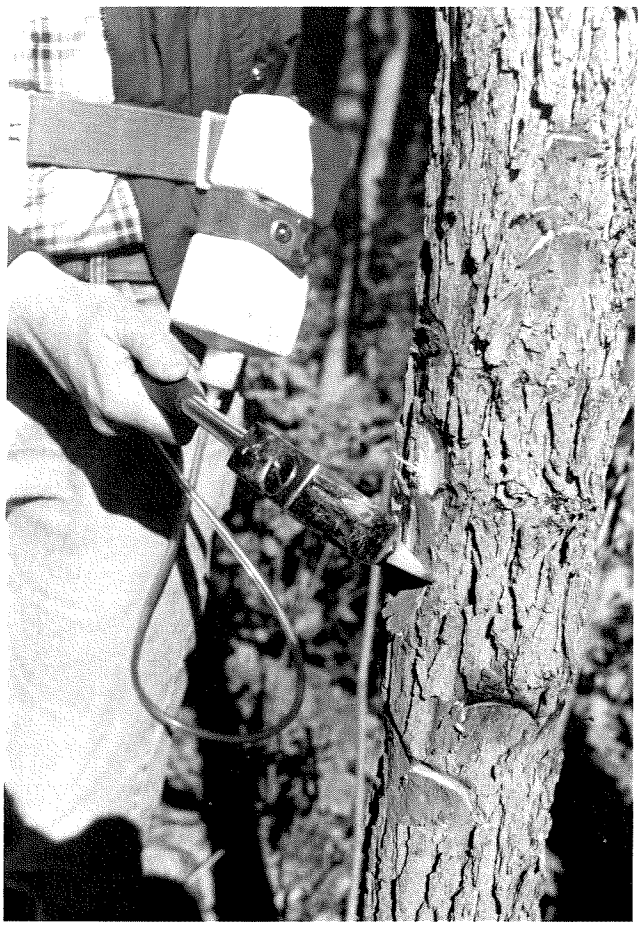

Figure 8.-The Hypo-Hatchet Injector automatically injects small amounts of herbicide into the tree when it strikes the tree. The reservoir is worn by the worker and is attached to the hatchet by a flexible hose. (Harvey Holt)

Figure S.-Tubular injectors are jabbed into the base of the tree at a 1 -inch spacing around the tree. This equipment has a long history of use in forestry. (Harvey Holt)

Figure lO.-The outer portion of the stump where the bark and wood meet is the most critical part of the stump to be treated to reduce sprouting. (Harvey Holt)

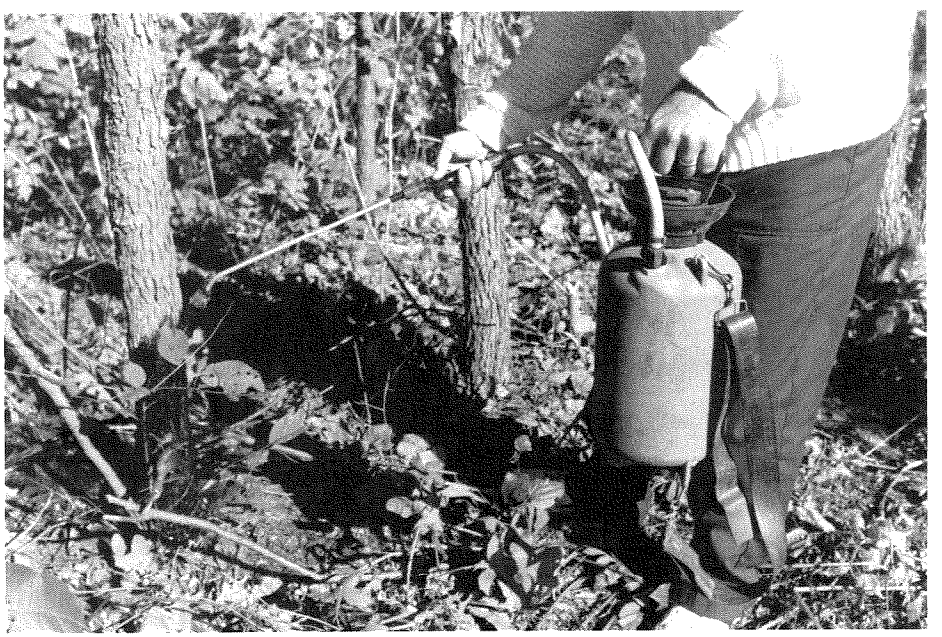

Figure i 1 .-Low pressure and a small diameter spray tip make it easy to wet the base of the tree with a minimum amount of oil-soluble herbicide. (Harvey Holt)

CENTRAL HARDWOOD NOTES

Fertilizing Natural Stands

Given our present knowledge, and under current costs and returns, there appears to be little reason to fertilize natural stands of central hardwoods. Yet, some of the numerous fertilizer tests conducted with hardwoods over the past 50 years have shown very positive--but short-lived-growth responses. One "operational" (non-experimental) use of nitrogen and phosphorus fertilizers on new black cherry stands has been successful on about 10,000 acres in northwestern Pennsylvania, on the fringe of the central hardwoods. Current costs of about 135 dollars per acre are justified by rapid height growth on soils severely deficient in nitrogen and phosphorus. This allows well established seedlings to outgrow severe deer browsing over the short term, avoiding spotty reproduction and occasional complete regeneration failure.

If you are seriously considering fertilization, read this background material and then consult local or regional experts before you proceed.

Requirements for Growth Responses

Forest responses to fertilizers are affected by many factors and, therefore, will vary greatly throughout the region. Three major requirements essential for responses to occur are: (1) species that will respond; (2) no limiting growth factors such as soil moisture deficits or excesses, or adverse climate: and (3) nutrient deficient soils.

Generally, the lesser the shade tolerance of a species, the greater its response to fertilization. Fast growing intolerants like yellow-poplar, white ash, sycamore, and black cherry have high nutrient requirements and the growth capacity to respond to fertilization. Intermediates like red maple and some oaks may respond to fertilization, but less than the intolerants. Tolerant black gum, beech, sugar maple, chestnut oak, and the hickories are least responsive. Also important is that young stands are more responsive than old stands.

The largest fertilization responses will occur where nothing other than nutrient deficiencies limit the site. Sites with good soil moisture are good candidates for fertilization. Poor sites are hot and dry southern exposures that support unresponsive species, sites with shallow or very stony soils, wet sites, and sites with adverse climate.

Of the 16 elements required for normal tree growth and development, nitrogen and phosphorus are the most important. Throughout the region, nitrogen almost always has been the primary limiting nutrient with phosphorus deficiencies of strictly secondary importance. For the majority of sites this means that nitrogen

alone will produce a response; that a larger response may be possible with nitrogen plus phosphorus; and that little repsonse can be expected with phosphorus alone where nitrogen is the primary limiting nutrient. Potassium can also be limiting on very coarse sandy soils.

How Fertilizers Increase Growth

When forests are fertilized the trees absorb the nutrients and build up foliage. Nitrogen particularly stimulates leaf size and number. It also produces dark green color leaves with improved photosynthetic efficiency. Bigger crowns and improved photosynthesis mean faster growth.

Diameter growth accelerates during the main part of the growing season and continues longer into autumn. Nitrogen fertilization also seems to sustain growth during dry periods, but does not stimulate growth earlier in the spring. In unthinned stands, fertilization also encourages expression of dominance and accelerates stand development. The larger dominant and codominant trees of responsive species grow faster, and intermediate and suppressed trees grow slower and die due to the increased competition.

Most growth from nitrogen fertilizer is temporary. Growth surges during the first several seasons after a single fertilization, then gradually declines as foliage mass declines and the added nitrogen diminishes to original levels. In hardwoods, growth from a single application of nitrogen rarely lasts more than five years. Continued growth depends on a continued supply of nitrogen over and above natural levels.

Fertilizer Use

Follow these simple guidelines if you are considering fertilizing hardwood stands:

1. *Be sure there is adequate justification or a special circumstance for a long-term investment in fertilizer.*
2. *Select the proper fertilizer.-High analysis urea* (45 percent nitrogen) and *ammonium nitrate* (33 percent nitrogen) are the most readily available and most commonly used nitrogen fertilizers. Ammonium nitrate provides an immediate supply of nitrate that can be absorbed in large quantities as well as providing a supply of ammonium. It is not subject to volatilization loss and it seems to stimulate growth of certain hardwoods more than urea. *Triple superphosphate* (46) is commonly used to supply phosphorus.
3. Select *stands* to *be* treated.-Young stands of intolerant, nutrient-demanding species are the most likely to respond. Very young seedling stands, such as those that develop immediately after clearcutting, should not be fertilized until they have developed strong roots that have penetrated mineral soil deeply. Very young stands can suffer serious mortality from an overdose of nitrogen. Fertilize stands only on good soils with no obvious site limitations.

4. *Fertilize at appropriate* rates.-Experience has shown that most hardwood stands will respond to nitrogen at rates ranging from 150 to 300 pounds of nitrogen per acre (equivalent to 450 to 900 Ibs per acre ammonium nitrate and 333 to 666 Ibs per acre urea). Appropriate phosphorus rates range from 40 to 80 pounds per acre (217 to 434 Ibs per acre triple superphosphate).
5. *Apply fertilizers at the proper* time.-Apply nitrogen in the spring when leaves are emerging and nutrient demands are high. Earlier applications when the vegetation is dormant are subject to leaching losses. Applications late in the growing season may not provide the nitrogen when needed. Phosphorus is not subject to leaching and can be applied before or simultaneously with the nitrogen.
6. *Apply fertilizers* evenly.-An even distribution of both nitrogen and phosphorus is best but the initial distribution of nitrogen is less critical than for phosphorus. “Double coverage” is best, applications made at right angles to each other.

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CENTRAL HARDWOOD NOTES

Thinning Sprout Clumps

Only stump sprouts originating in clearcuts or extremely heavily thinned stands have significant potential for developing into good trees. Stump sprouts can account for as many as half the stems after a clearcut of central hardwoods.

Questions often asked about stump sprouts include: Should I thin, and if so, how and when? In the past, sprouts from stumps often were considered inferior to trees of seedling origin. Sprouts were believed to be susceptible to decay and disease and likely to produce poorly formed trees. However, recent studies show that good quality and vigorous stems can result from stump sprouts provided the sprouts originate at or below ground line.

Why Thin Sprout Clumps?

Sprouts in thinned clumps grow faster and produce higher quality stems than sprouts in unthinned clumps. Thinning allows you to select the best formed, most vigorous stem or stems for crop trees. Thin clumps if you want to grow high quality stems to a large diameter as fast as possible.

What Species?

Select species that are long-lived, have high value potential, and whose clumps respond well to thinning. Suitable species include the oaks, red maple, sugar maple, yellow-poplar, black cherry, American basswood, sweetgum, and white ash.

When to Thin?

The earlier you thin, the larger the resulting stems. Sprout clumps can be thinned as early as 5 years after harvest cuts. The longer you delay thinning the more growth will be reduced. For example, if you delay thinning northern red oak sprout clumps from age 5 to age 10, stem d.b.h. will be 12 percent smaller at age 25. If you delay thinning until age 15 or 20, stem d.b.h. will be 23 to 30 percent smaller. In most cases, if you wait until age 25 to thin, you will lose the growth advantage of sprout stems. Exceptions are basswood and red maple that maintain high clump densities in older ages. With these species, thinning as late as 25 years will substantially increase stem diameter.

Clumps can be thinned at any time of the year. Sugar maple is an exception because it may become infected with sapstreak disease if thinned during the summer months.

Which Stems to Leave?

Regardless of clump age, leave the best one or two sprouts that are widely separated on the stump. Leave only well-formed dominant or codominant sprouts that are free from defect and are attached to the stump at or below ground line. Decay organisms can enter stump sprouts through heartwood connections with either the decaying parent stump or dead companion stems. Decay hazard from the parent stump is minimal for sprouts originating at or below ground line. In red maple, decay commonly enters sprouts through branch stubs. Consequently, red maple stump sprouts with numerous large branch stubs should not be selected as crop stems even when they originate at or below ground line.

On slopes, favor sprouts that are on the uphill side of stumps. If you must choose between a larger sprout of poor quality and a smaller sprout of high quality, choose the smaller sprout. For stems larger than 3 inches d.b.h. select those that are straight with no decay, are free of V-shaped connections with other stems, show little evidence of epicormic branching, and have no forks, crooks, and seams on the lower 17 feet of the bole.

Thin Between Clumps

When thinning clumps to a single stem, apply a crown release that leaves the stem free to grow on all sides. To do this, cut all main canopy trees including other sprout clumps whose crowns touch the crop stem crown. Clumps thinned to two stems should be treated as a single crop tree *(see* Note *6.03 Silvicultural Treatments in* Sapling *Stands).* Do not over thin. Stems given too much growing space will have reduced height growth and poorer natural pruning. These problems can be minimized by following the crown release guidelines.

What Sites?

Sprout clumps growing on good sites benefit most from thinning. However, even on poor sites, thinning sprout clumps produces larger stems in less time than not thinning.

Advantages of Thinning Sprout Clumps

1. Increases value of timber.
2. Reduces rotation length.
3. Increases stem quality.
4. Reduces or minimizes risk of defect.

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CENTRAL HARDWOOD NOTES

Wild Grapevine Management

Wild grapevines are a problem for forest managers in many areas of the central hardwood forests. The vines grow on a wide range of soil and site conditions but usually are more concentrated on good sites (northern red oak site index 70 and above), on the faster growing more valuable timber. Presently there is more interest and concern in controlling grapevine for the cove hardwood type than the oak-hickory, oak-pine, or bottomland hardwood types.

Grapevines are a problem because they damage trees by breaking tops and limbs, and twisting, bending, and often breaking tree boles. Merchantable volume is lost, and tree growth and quality are reduced. They can also cause trees to be uprooted and killed. On the other hand, grapevines produce food and cover for many species of wildlife, so measures to control grapevines may conflict with wildlife and recreational goals.

Once grapevines get in a tree crown or bole, the vines begin to dominate the tree. When this occurs, the potential use of that tree for future timber products is low. An overabundance of grapevines can also conflict with wildlife management goals for maintaining mast-producing trees. So even where wildlife is the primary concern, vine control is important for mast management in some stands.

Wild grapevines need light to grow well. Vines are prolific stump sprouters and they root easily. Male and female flowers are usually on separate plants, and periodically they produce large quantities of seed which remains viable in the soil for at least 15 years.

Grapevines can be a more serious problem when the stand is cut heavily, as in clearcutting and other even-age type practices. They are less serious under partial cuts such as single-tree selection or thinnings. After heavy cuts in areas where grapevines are present, newly germinated grape seedlings can easily exceed 100,000 per acre.

Recommendations to Control Growth

The keys to controlling grapevines are in canopy shading or herbicides.

Even-age management-In sapling, poletimber, and immature sawtimber stands, you can control vines by cutting near groundline using tools such as blades, loppers, hatchets, and chain saws. The cut vine stumps will sprout but the sprouts will die within 3 to 4 years from shade. Do not cut grapevines in sapling stands until the crown canopy provides shade, about 8 to 10 years after cutting when you

can easily walk under the canopy. If a precommercial crop tree release or thinning is planned and grapevines need control, treat the vines first. Wait at least 5 years before doing the release or thinning.

Use herbicides to control grapevines only when mature stands are ready to harvest. If you schedule some even-age practice in a grapevine problem area within the next 4 to 5 years, spray vines at their base with an herbicide-oil mixture. Spray the stems of vines attached to trees and the "layered" vines (ones sprouting roots) at groundline. Vines can be basal sprayed with an herbicide-oil mixture throughout most of the year. Even if you herbicide before harvest, grape seedlings will germinate prolifically in the new stand and you will have to control vines when it becomes sapling size.

If the mature stand has a major grapevine problem and is not going to be harvested during the next 5 years using an even-age cutting practice, no herbicides are necessary. Cut the grapevines near groundline. These stumps will sprout, but the dense canopy shade will cause the sprouts to die in 3 to 4 years. Again, you will have to control grapevines in the new sapling stand.

Uneven-age management.-Normally, partial cuts such as single-tree selection, improvement cuts, and some diameter-limit cuts result in residual stands with understory shading. Grapevines can be controlled in mature stands by severing vines that grow in tree crowns before, during, or after logging. The vine stumps will sprout, but will die within a few years. Barring any drastic overstory removal or natural disaster, the vines will not become a major problem for future timber production.

Costs

The costs of cutting vines depend on size and number of vines per acre. In mature stands, it takes one person about 2.2 hours to cut 100 grapevines per acre. And for *sapling* stands it takes about 1.2 hours to cut 100 grapevines per acre. To basal spray 100 grapevines per acre in mature stands, it takes a person about an hour and about 1 gallon of herbicide-oil mixture. You don't need herbicides in immature stands unless a clearcutting-type practice is planned.

When are Grapevines a Problem?

How many vines per acre should you tolerate? It depends on what percentage of the stand is dominated by grapevines, and, of course, on management objectives. On high-value hardwood sites you may want to eliminate all grapevines. For wildlife managment on the other hand, 1,000 grapevines per acre may be desirable. Where "arbors" are present (vines overtopping vegetation, creating an opening in the stand canopy), few additional grapevines are needed in the remaining stand for wildlife food. For timber production, 50 grapevines per acre (6 percent of the trees in the stand have grapevines in their crowns) are usually tolerable.

To determine what percent of the trees in your stand have grapevines, count the rooted grapevines on several sample plots, convert to a per-acre basis, and then go to the left-hand column in table 1. For example, 100 rooted grapevines per acre correspond to 190 trees with grapevines in their crowns. Table 1 does not estimate grapevines in arbors. It is not economically feasible to control arbors.

Table 1 .--*Estimate of grapevines in tree crowns, sapling stands*

Rooted grapevines per acre (Number)	Trees with grapevines	
	Number/acre	*Percent of stand*[1]
25	80	4
50	115	6
100	190	IO
200	335	18
400	625	33
600	910	48
800	1,200	63
1,000	1,490	78

[1] Stands averaged 1,900 trees/acre 1.0 inch in d.b.h. and larger.

Summary

Grapevine management must be consistent with forest management objectives. Controlling the growth and development of wild grapevines is not difficult in most situations. If your objective is to grow only high quality timber, you may try to eliminate all grapevines (excluding arbors). If wildlife management is your objective, you may want to create openings to stimulate reproduction and growth of grapevines by felling small groups of trees that have vines in their crowns. However, in most cases, you will probably want to grow quality timber as well as encourage wildlife development. This means that although there are some grapevines, the stand is not dominated by them. Allowing grapevines to develop in arbors and applying grapevine control in the remaining stand is a feasible compromise. It provides wildlife food and cover while simultaneously allowing the remaining stand to be managed for quality hardwood timber, mast-producing trees, and other resources as well.

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CENTRAL HARDWOOD NOTES

Using Silviculture To Minimize Gypsy Moth Impacts

Silvicultural treatments can be used to minimize gypsy moth impacts on hardwood stands. There are two major strategies of these treatments: (1) to decrease susceptibility to defoliation by gypsy moth and (2) to strengthen the stand against mortality and encourage growth after defoliation.

The treatments discussed here are based on biological information and concepts rather than long term trials. Some proposed practices would be expensive and might only be practical under the right combination of stand characteristics, location, markets, and product value.

Decreasing Susceptibility

Maximize tree growth and vigor.-Maintain trees and stands in a vigorous, healthy condition to minimize the probability of defoliation. Stressed trees are more disposed to attack by defoliating insects. Treatments that can increase tree vigor include thinnings, fertilization, and irrigation. However, treatments other than commercial thinnings are expensive and difficult to implement in forest stands. Thinning can increase the vigor level of residual trees by increasing both crown and root growing space.

Eliminate gypsy moth habitat.--The best way to reduce stand susceptibility is to decrease the number of trees in stands that are favored food of the gypsy moth. For example, gypsy moths prefer oaks over maples, yellow-poplar, ashes, and most conifers. By reducing the percentage of stand basal area in oaks to 15 to 20 percent or less, the probability of defoliation decreases from moderate to low. This strategy would work best in mixed stands where a variety of species are available and where management goals are flexible. It might also work well in oak-pine mixtures by favoring pine and by reducing oak considerably. On poor site oak stands with pine understories, the oak overstory could be removed. Also, low quality sites could be converted by planting pine and controlling the hardwoods, although this practice is quite expensive. On high quality sites, favor mixed hardwoods over oaks using regeneration cuts and intermediate treatments.

Where conifers are surrounded by highly susceptible stands, cutting an isolation strip about 75 to 150 feet wide around the conifers will reduce damage. The isolation strip reduces the number of late instar (older) larvae that invade the conifers.

You can also reduce the number of hiding places or refuges for gypsy moth larvae and pupae. Older larvae feed at night and seek refuge during the day. Predators can more effectively find larvae and pupae resting low on the bole or on the ground. Reducing natural refuges such as bark flaps, large dead branches, holes or wounds on the bole, dead sprout stubs, and deep bark fissures-especially

those high in the trees-will force the larvae out in the open and downward where predators have a better chance of finding them. Remove artificial refuges such as signs, old wood fences, abandoned buildings, and trash.

Predator habitat can be increased by creating brush piles to provide cover for small mammals, along with retaining snags and cavities or den trees for birds and other cavity dwellers.

Increasing forest diversify.-Right now, the central hardwood forest with its stands of similar age, size, species composition, and stand structure, under low-level management, offers a huge foodbasket favorable for the gypsy moth's rapid expansion. The gypsy moth does not seem to defoliate stands 1 to 15 years old, and we don't know at what age stands become susceptible. By creating more diverse age classes, stand structures, species compositions, and management systems, we may be able to reduce the potential for large gypsy moth outbreaks. Smaller, more limited outbreaks occurring in scattered stands would be less catastrophic and easier to manage.

Strengthening the Stand Against Mortality

Maximize tree growth and vigor.-Maintain trees and stands in a vigorous, healthy condition through thinnings and pest control. Healthy, vigorous trees are more likely to survive and recover from gypsy moth defoliation and resist secondary organisms. Trees under stress from drought, nutrient deficiencies, fire, grazing, defoliation by other insects, and ice storms will have higher mortality rates when gypsy moth defoliation occurs. High value trees at risk may need protection. Aerial spraying is the most cost-effective method.

Remove *high risk* trees.-Remove high risk trees before they are defoliated and die, especially intermediate and suppressed trees. Tree vigor, as measured by crown condition (table 1), is the single most important factor for predicting mortality. Trees with poor crowns are very likely to die after defoliation. Intermediate and suppressed trees are more likely to die than dominant and codominant trees.

Reducing the habitat of secondary organisms.-Defoliation-stressed trees are often invaded by two secondary organisms, the shoestring root rot and the two-lined chestnut borer. By decreasing the habitat of these two organisms, you can reduce tree mortality. Remove unhealthy trees and borer-infested trees before new generations of borers emerge; attract borers by using girdled "trap" trees. Root rot habitat is much more difficult to eliminate. Thinnings may actually increase levels of the fungus by increasing the food base in the stumps and roots of cut trees. Where possible, thin several years ahead of the invading front of the gypsy moth.

Table 1 .--*Guidelines for determining crown condition.*

Crown condition	
Good	Tree with a healthy crown that has (1) less than 25 percent dead branches or dieback in the upper crown, (2) normal foliage density, color, and size, and (3) little or no epicormic branching.
Fair	Tree that has (1) more than 25 percent but less than 50 percent dead branches or dieback in the upper crown, (2) some subnormal foliage density and color, and (3) some epicormic branch sprouting.
Poor	Tree that has (1) more than 50 percent dead branches or dieback in upper crown, (2) subnormal foliage density, color, and size, and (3) heavy epicormic branch sprouting.

Salvage

Despite your efforts some trees will die, mostly within 1 to 3 years after defoliation. The longer a tree has been dead, the lower its utility and the price it brings. Dead veneer-quality trees are usually reduced to sawtimber prices. Sawtimber trees decrease in value at a rate of 10 to 15 percent per year, so the faster dead sawtimber trees can be salvaged, the better. Trees dead longer than 3 to 5 years are difficult to sell. Dead trees are actually better for firewood and pulpwood than live trees and remain so for periods up to 5 years and perhaps longer. In cases of very heavy mortality, you will have to regenerate the stand.

In Conclusion

Although the above suggestions have not been extensively tested, they represent our current knowledge of gypsy moth and its impacts. In spite of past gypsy moth outbreaks or potential outbreaks there are opportunities to manage forests economically without sacrificing management objectives or allowing the insect to dominate management actions. Hopefully the forest, forest managers, and this exotic insect pest will eventually approach a state of tolerable coexistence.

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CENTRAL HARDWOOD NOTES

Economic Considerations Of Managing Stands

Managing central hardwood stands involves making choices. Each year landowners face at least three alternatives for managing a stand: (1) allow it to grow undisturbed, (2) undertake a partial or complete commercial harvest, or (3) culture the timber crop through a precommercial investment. Each activity affects long-term monetary returns. The "best" choice in a given year depends on your goal as a landowner, stand characteristics, and local markets. Understanding the economic elements of managing stands can help you make good choices and improve the productivity of your forest land.

Clarify Your Goals

Landowner goals may limit management alternatives. To some private landowners, esthetic or recreation goals are often more important than strict profits. Clearcutting, prescribed fire, or chemical treatments may not be acceptable, even though they may increase timber income. Such owners may not necessarily disregard the financial benefits of timber management, but are willing to forego some potential timber income to achieve other objectives. The key is to identify management practices that harmonize with your goals for generating both income and other benefits from your land.

Know Your Markets

Species composition, average tree size, and local product markets may also define options in the near future. For example, management options in sapling stands include "do nothing" or a precommercial treatment. With no merchantable products, commercial harvests are not possible. Where there are pulpwood markets, the landowner can wait a few years for a commercial thinning and avoid a cash investment for precommercial thinning. Getting to know your stand and local markets makes economical management choices easier.

Think Crop Trees

Commercial hardwood trees are assets you should deliberately manage. As trees mature, increases in d.b.h., merchantable height, and grade determine future tree value. Like other assets, some trees increase in value faster than others. Those that offer the highest potential rate of return are your crop trees, the money-makers that determine future income from your stand.

With each thinning or partial harvest, provide proper growing space for the best available crop trees in the residual stand. The best crop trees in your stand depend on your markets. Favor high-value species, and individual trees with potential increases in grade and merchantable height. Crop trees should be grown to at least 16 inches d.b.h. to allow the butt log to qualify for grade 1, the most valuable saw log grade. Although species groups differ, most central hardwood species earn competitive rates of return up to 22 inches d.b.h. Focus on crop trees for both even-age and uneven-age practices.

Plan Your Road System

Well-planned roads are a strong foundation for economical timber management. They permit access for all management including harvesting and protection. Topographic and geologic features, as well as location of existing roads, determine the most desirable location of new access roads. This is why for either even-age or uneven-age management in a particular stand, there is only one "best" road location. Get advice on proper road location (see Note 11.03 Forest Access Roads). Advice may cost you a little money, but poor roads cost you much more in the long run.

Road construction is the most costly of all timber management activities. If roads are poorly located, additional roads may be needed in later harvests to correct problems. Good planning usually reduces total road length and grade, which in turn reduces the cost of post-logging activities such as seeding and installing water breaks. Well-located roads also provide more reliable access between harvests for other management activities like firewood sales and recreation. All these factors lead to a more useful forest and higher future timber income.

Sell When Prices Are High

Timing is the key to profitable timber management. Become familiar with stumpage price trends in local markets. Management plans should be flexible so that commercial thinnings or regeneration harvests can be conducted when markets are favorable. Sticking to a rigid harvesting schedule can drastically reduce timber income if stumpage prices are down when the planned harvest date arrives. Hardwood sawtimber, like other cash crops, should be sold when prices are high. It's just good business to keep abreast of local stumpage prices, even though no harvests are planned for the current year.

When it's time to sell, shop around. Competition helps increase stumpage income. Don't sell to the first bidder. Chances are you'll get a higher price if several buyers make offers. For many private woodland owners, consulting a professional forester can result in higher timber income. Consultants assist with overall management planning and use their knowledge of local wood product markets to help clients get a fair price.

Even-age Versus Uneven-age Management

Management systems affect the timing and amount of your timber income. Generally, even-age management promotes high-value intolerant species and offers a sizeable revenue at final harvest. After clearcutting, however, timber sales are not possible for 40 to 60 years until volume accumulates for a first commercial thinning in the new stand. Uneven-age management promotes tolerant species, provides smaller revenues at regular intervals, and maintains a continuous forest cover which provides many land-use alternatives.

For initial harvest operations in unroaded stands, stumpage prices are reduced to compensate the logger for constructing permanent haul roads. If the initial harvest is a clearcut, road costs are spread over total merchantable stand volume. If the initial harvest is a thinning or selection cut, only a portion of stand volume bears the cost of roads. As a result, initial partial harvests in some unroaded areas can result in nearly break-even or deficit sales where roads cost more than the value of the timber harvested. In later harvests, however, road costs are greatly reduced, and stumpage returns are generally higher than for initial harvests.

Once roads are in place, logging costs for selection harvests and clearcutting are similar. Selection harvests remove trees throughout a range of diameter classes, and clearcutting includes numerous small stems in addition to the larger mature trees. Although clearcutting removes much more volume per acre, average d.b.h. of harvest trees is about the same for both systems and resulting logging costs are comparable. However, selection harvests involve additional costs of marking trees to be cut in each sale. Thinnings or shelterwood cuts in even-aged stands involve similar but less frequent costs.

Logging costs and product values influence commercial harvest schedules. In mountainous terrain, where logging is costly, minimum sale volumes may be 5,000 to 6,000 board feet of sawtimber per acre. In more gentle terrain, several cords of pulpwood may constitute a commercial operation. Minimum sale volumes, in turn, determine when commercial thinnings are possible in even-age stands or the interval between harvests in uneven-age stands. In uneven-age stands, harvests should remove no more than periodic growth to ensure sustained yield. As a result, cutting cycle length depends on how long it takes to accumulate the minimum sale volume. In most of the central hardwood region, practical cycles for partial cuts are 10 to 20 years.

Uneven-age management favors the regeneration of tolerant hardwood species, such as sugar maple, red maple, and American beech. Generally, most commercial tolerant species have lower market values than intolerant species regenerated by even-age practices. Also, tolerant species usually have slower growth rates and less volume per tree than intolerant species. During conversion to uneven-age management, some valuable intolerant trees may remain in the residual stand for several cutting periods. When these trees are removed in later harvests, they are gradually replaced by less valuable tolerant species. Higher volume removals and longer cutting cycles could result in some intolerant species reproduction. However, repeated partial harvests will lead to a stand in which tolerant species make up 60 to 75 percent or more of the growing stock.

Partial harvest practices produce multi-age stands that provide landowners with a variety of land use alternatives. The continuous forest cover preserves recreation and esthetic attributes. Periodic road activity provides ready access to the property which facilitates non-timber uses. And the residual stand enhances the marketability of the forest property if the landowner decides to sell the land in the future. In addition, the residual timber alone serves as a marketable asset if the landowner later converts to a single-age stand by clearcutting.

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CENTRAL HARDWOOD NOTES

Investment Decision Criteria

Is owning and managing central hardwood timberland a good investment for you? First answer the question, 'Compared to what?" Then consider such factors as:

- The expected financial return.
- The chance you will realize this expected return, given the physical and economic risks involved.
- The other investments you own.
- Your costs to acquire and manage the timberland.
- Your tax circumstances.
- The value you give to wildlife, scenic, and other intangible benefits from owning timberland.

Investment Attributes

Investing in central hardwood timberland won't make you "rich," but it may increase your wealth. Because of the relatively slow growth rate of hardwood timber and the small acreages of most owners, income is usually not realized more often than every 15 to 20 years. Thus, your spendable income won't be enhanced regularly. On the cost side, quite the opposite occurs since expenses must be paid each year. Timber and timberland are appreciating assets. The major contribution they make to your investment portfolio is long-run growth.

Appreciation in timber value is about evenly split among volume growth, increase in quality as trees increase in size, and increases in the market price of timber. Annual price increases of 1/2 to 2 percent above inflation for the best species and log qualities boost the purchasing power represented by the value of your timber assets. In addition, these increases for high-quality timber offer a real inflation hedge.

Risks from fire, insects, diseases, and natural disasters are very real, but very low The probability that your particular stand will be significantly damaged is minimal. The species mix in central hardwood stands provides a natural diversification of your timber "portfolio" and good management can reduce risks even further.

Starting on the Right Foot Financially

Central hardwood management investments should be evaluated in financial terms, just like any other investment. Management guides and computer programs are available for making financial and timber management analyses. They can help you decide on the best options and figure out if the payoff is competitive.

In light of the long time you and your family may own timberland, consider the following rules of thumb to help improve long-run financial returns. If you are going to purchase timberland look for land with poletimber to very small saw log-size timber. Timber of this size contributes very little to the seller's asking price since the timber isn't marketable. But, within 10 to 20 years, you should be able to make a reasonable timber sale. Also, look for stands where the site index is 70 or greater for oak.

It is still sometimes possible to find true bargains on the rural land market. A bargain allows you to purchase the land with a good level of young growing stock for about the price of the bare land.

Minimize Costs

Your management goal should be to minimize costs but without sacrificing the essential management practices needed to keep your forest healthy and productive. The major annual costs are taxes and liability insurance. Be certain to take advantage of the property tax reduction programs available for forest land in all central states. Your homeowners' insurance policy should provide coverage high enough for any added liability exposure resulting from timberland. Unfortunately, casualty insurance is not available to protect timber from natural hazards.

Timber management practices can improve the quality of the timber you grow, but be frugal. Demand a reasonable return for the money your forester suggests you invest to manage timber. Expenses can be reduced by taking advantage of federal or state cost-sharing programs for practices such as tree planting and timber stand improvements. State foresters can provide more information. You may also qualify for a very favorable10 percent federal income tax credit and amortization deduction for your tree planting expenses.

Use natural regeneration whenever possible. Natural regeneration can be low cost, but plan this with a forester before cutting timber. If timber stand improvements are necessary and cost-sharing assistance isn't available, try to make stand improvements pan of a commercial harvest.

Other Sources of Income

Generate income by producing firewood yourself, or selling cutting rights to firewood dealers. Make certain that culls and other trees to be removed are clearly marked and make regular inspections for compliance.

Lease your timberland and cropland for exclusive use by organized groups of hunters. Consider forming a cooperative type arrangement with your neighbors in order to offer a large enough block of land to attract hunting clubs.

Tax Considerations

Income taxes can be significant costs, but there are ways to reduce your tax liability. Minimize your after-tax costs by planning your activities so that management costs are deductible against other income in years you don't have timberland

earnings. To qualify, you must hold the property with the intention and reasonable expectation of eventually realizing a profit. Profit includes income and appreciation of land and timber, even if the timber or land has not been sold. All your management expenses should be ordinary, necessary, and reasonable; in other words, "typical" timber management practices. To qualify for the most favorable tax treatment, you should be actively involved in managing the property. Personally make management decisions and do a significant portion of the work required. If you aren't sufficiently involved in active management, your annual costs may have to be carried forward for deduction in years when you have timberland income or other "passive" investment income.

Keep track of your cost to acquire the property, and other costs which you don't deduct year-by-year. These "capital costs" are recovered when you sell the land and timber. If you make a gift of the property the person receiving the property will need to know these costs.

Consider the timberland's impact on your estate plan. If you want the property to go to your heirs and don't expect your estate to owe federal estate tax, then you likely will want to include it in your estate. Your heirs will pay income tax on these assets based on their fair market value at the time of your death. Another option is to make a lifetime gift, but your heirs will pay tax based on what you paid for the property plus a portion of any gift tax due. Timberland can be worth more than you think, so it is wise to consider the estate tax implications carefully.

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CENTRAL HARDWOOD NOTES

Grading Hardwood Trees

Tree grading provides a way to evaluate the quality characteristics and value of standing hardwood trees. This is important because the differences in price between high-quality and low-quality end products can be very large. Since hardwood timber varies greatly in quality and value among species, within species, and even within specific geographic areas, timber producers and buyers know that an accurate tree grading system is an objective way to account for quality variation and provide a basis for negotiation between buyers and sellers.

Tree grading provides basic information for managers (Robert Brisbin)

Who Can Use Tree Grades?

Four broad groups of people can benefit directly from a knowledge of tree grades: timber owners and managers, timber appraisers, loggers, and primary processors of forest products. Timber managers need to estimate the relative present and future value of individual trees in a stand before they can make sound decisions on which trees to mark for cutting and which to leave to grow. Similarly, the results of alternative timber management practices cannot be adequately evaluated without predicting the effects on quality as well as on quantity of wood produced.

Timber appraisers must determine the value of timber stands for purchase or sale. Volume estimates by tree grades greatly improves the accuracy of appraisals. Loggers are an important link in manufacturing products from trees. The bucking decisions made after a tree is felled determine, to a large extent, the quality and quantity of products that can be produced from the logs. Tree grades and associated log grades can help the logger decide where to buck to maximize profits. Primary processors need quality standards to estimate the volume of various products that can be produced from a group of trees or logs, and to decide how best to process each tree or log.

What are Tree Grades?

The U.S. Forest Service hardwood tree grades were developed to separate trees into groups of high, average, and low quality. When combined with published lumber grade yields, they accurately predict the quantity and grade of lumber that can be produced from graded trees. Tree grade is based on tree size, surface characteristics, straightness, and soundness of the butt 16-foot section of the tree. The tree grade rules are summarized in table 1. The steps to follow in grading are:

1. Measure the d.b.h. of the tree.
2. Identify all grading defects on the surface of the butt 16-foot section of the tree. Defects include limbs, overgrown knots, bumps, holes, splits, bird peck, and cankers.
3. Locate the best 12-foot section and divide it into four faces.
4. Grade the faces according to the rules that relate to the length, number, and total length of clearcuttings on the faces.
5. Estimate the amount of scalable defect in the 12-foot grading section.

Table 1 .-*Hardwood tree grades for factory lumber*

Grade factor	Tree grade 1	Tree grade 2	Tree grade 3
Length of grading zone (feet)	Butt 16	Butt 16	Butt 16
Length of grading section' (feet)	Best 12	Best 12	Best 12
D.b.h., minimum (inches)	16[2]	1 3	1 0
Diameter, minimum inside bark at top of grading section (inches)	13[2] 16 20	11[3] 1 2	8
Clear cuttings (on the 3 best faces)?			
Length, minimum (feet)	7 5 3	3 3	2
Number on face (maximum)	2	2 3	([5])
Yield in face length (minimum)[6]	5/6 81 percent	4/6 67 percent	3/6 50 percent
Cull deduction, including crook and sweep but excluding shake, maximum within grading section (percent)	9	9'	50

1Whenever a 14- or 16-foot section of the butt 16-foot log is better than the best 12-foot section, the grade of the longer section will become the grade of the tree. This longer section, when used, is the basis for determining the grading factors such as diameter and cull deduction.

[2] In basswood and ash, d.i.b. (diameter inside bark) at top of grading section must be 12 inches and d.b.h. must be 15 inches.

[3] Grade 2 trees can be 10 inches i.b. (inside bark) at top of grading section if otherwise meeting surface requirements for small grade #1 s.

[4] A clearcutting is a portion of a face free of defects, extending the width of the face. A face is 1/4 of the surface of the grading section as divided lengthwise.

[5] Unlimited.

[6] Yield in face length is the total length of the clearcuttings on the grading faces divided by the length of the grading section; i.e., two 5-foot clearcuttings equal 5/6 or 81 percent of the length of a 12-foot grading section.

[7] Fifteen percent crook and sweep or 40 percent total cull deduction are permitted in grade 2 if size and surface of grading section qualify as grade 1. If rot shortens the required clearcuttings to the extent of dropping the butt log to grade #2, do not drop the tree's grade to #3 unless the cull deduction for rot is greater than 40 percent.

From: Research Paper NE-333, see References

The results of these steps are used to determine the grade of the tree. The grading system seems difficult to understand at first glance, but it is relatively easy to use after a little training and experience. The detailed grading specifications and procedures are fully explained in Research Paper NE-333, published by the USDA Forest Service (see References).

How are the Tree Grades Used?

If you know the d.b.h., grade, and merchantable height of a tree, you can estimate the amount of lumber by grade that can be produced from that tree. Table 2 is an abbreviated example of a lumber grade yield table for grade #1 northern red oak trees with a merchantable height of 32 feet. For example, a tree with a d.b.h. of 20 inches will produce about 183 board feet of #1 common and better lumber (add board foot yields from first 4 columns), 71 board feet of #2 common lumber, and 48 board feet of #3 common lumber (add board foot yields in last 2 columns). In addition to the lumber yield tables, lumber grade yield equations are available to use with computers.

Table *2.-Predicted lumber grade yields for northern red oak*

D.b.h.	Lumber grades						
(inches)	FAS	FAS1F	Select	#l C	#2 c	#3 A	#3 B
			Tree grade 1				
			Merchantable heiuht-32 feet				
			(Board feet)				
16	16	10	7	46	60	37	4
18	36	18	8	66	65	38	6
20	59	27	9	88	71	39	9
22	84	37	10	113	78	40	12
24	111	48	12	140	84	41	15

Adapted from Research Paper NE-333.

You can multiply the lumber yields in table 2 by lumber prices to estimate the value of lumber contained in the 20-inch Grade #1 red oak as shown in table 3. The lumber prices can be the actual prices that a producer receives for lumber or they can be average prices that are quoted in marketing bulletins. Lumber prices are normally given as dollars per thousand board feet but they are shown as dollars per board feet in table 3 to simplify the illustration. In this example the tree will produce 302 board feet of lumber with a value of $163. You can estimate the value of the tree as it stands in the forest by subtracting harvest, transportation, and processing costs.

Table 3.-Lumber volume and value estimation

Species ----------Northern red oak
Tree grade _____1
D.b.h. _____20 inches
Merchantable height----------32 feet

Lumber grade	Predicted volume	Lumber price	Lumber value
	Board feet	*Dollars/ board foot*	*Dollars*
FAS	59	0.82	48.38
FAS1F	27	.81	21.87
Select	9	.75	6.75
#1 c	88	.64	56.32
#2 c	71	.28	19.88
#3 A	39	.23	8.97
#3 B	9	.10	.90
Total	302		163.07

If you want to learn how to grade hardwood trees, we recommend technical instruction with field practice. Tree and log grading seminars are conducted by the State and Private Forestry branch of the Forest Service, by most state forestry agencies, and by universities with forestry schools. More detailed information is available from any of these organizations.

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CENTRAL HARDWOOD NOTES

Let The Market Help Prescribe Forest Management Practices

To obtain the best economic returns from a hardwood forest, you must consider markets. Management decisions made now will affect a stand's future character and value, whether or not the decision results in immediate timber sales. Progressive forest landowners will have a management plan for their woodlots. Typically, such plans are largely land- and resource-oriented, with very little attention to market considerations. But a comprehensive management plan for a forest should combine objectives for timber, wildlife, recreation, and other resources with consideration of current and potential markets. In other words, product and market information are just as important as resource information for good forest management decisions. Use the following four steps to incorporate a market analysis into your forest management planning and practice.

1. Identify Potential Products and Markets

This may seem obvious, but sometimes forest managers are careless in looking for marketing opportunities, or seem to think that good markets will be there when they need them. This isn't necessarily so! The most obvious and common commercial product from forests is timber stumpage. Certainly anyone wanting significant cash income from forestry should consider growing and marketing timber products. But what *specific* products are marketable in the short and long term? Just identifying potential stumpage products from a given tract as "sawtimber and pulpwood" is not as useful as identifying "red oak and walnut veneer logs, white ash and hickory handle bolts, saw logs from other species, softwood pulpwood, and firewood from hardwood tops, poletimber, and timber stand improvement (TSI) removals."

Key phrases in the preceding paragraph raise some essential points concerning product identification. First, look at long-term as well as immediate market prospects. For instance, there may be no current market for pulpwood in a given locality, but if a pulp and paper company plans to extend its procurement range into the locality, then pulpwood markets will develop in the future. This is especially true for softwood pulpwood in hardwood-dominated regions, since pulpmills value softwood material highly in such areas. As another example, veneer mills traditionally demanded large diameter logs-20 inches or more. But decreases in the number of large diameter veneer logs available, and advances in veneer production technology, have resulted in more 16- to 18-inch logs being used; this trend opens opportunities for some veneer log production on shorter rotations. Even so, large logs are still the best and most valuable.

Second, look for local market "niches," such as the handle bolts mentioned above. Be aware of established and developing local forest products industries and how your future products could meet their needs. Local speciality product markets

might be fence posts, rustic fence rails, house logs, or other products for which the revenue could be greater than with conventional sawtimber or pulpwood markets. With increasing transportation costs, local markets will increase in importance.

In contrast to local markets, the forest manager should be aware of the export market. Presently, the devalued U.S. dollar and demands have made our logs and lumber highly competitive in Europe and the Pacific Rim countries. Exporting is accomplished through log and lumber brokers; we suggest you get several bids at the time of the sale.

In identifying markets, look for those that will return the highest *value* from your timber resource. Then manage your forest to attain the highest economically feasible production. Be aware that this may be a long-term project. Typically, veneer logs and high grade saw logs of select species are the highest value timber products from hardwood forests. Of course, an immature or previously poorly managed forest will not contain many large, high quality trees. In this case, management practices such as improvement cuttings, crop tree release, and cull removal can improve stand composition and condition, to foster significant volumes of high quality timber in the future. In summary, manage in the short run with a goal to serve high value markets in the long run.

Finally, in considering potential products don't overlook income opportunities for nontimber resources such as hunting or fishing, mushroom production, recreation, etc. These may not generate substantial income, but they can help defray pre-harvest management costs.

2. Develop a Market Information File

A number of states and some forestry schools regularly publish market reports that contain price and sometimes volume information on timber product sales for their states or regions. Subscribing to area reports will give you current market information. Maintain a file of reports and review them periodically to look for long-term market trends or cycles.

Trade and industry periodicals, such as the *Northern Loggerand Timber Processor* and *Southern Lumberman,* often contain valuable articles, columns, and news items on marketing topics. Subscribing to trade periodicals will keep you informed of industry developments which could affect forest management and marketing.

Personal sources of information should not be overlooked. Forest owners should keep up to date on market information and review it periodically, looking for new developments and opportunities. Seek information and opinions from consulting, governmental, industrial, and academic foresters, who have a wealth of experience and insight on forest product production and marketing. It is worth the time to seek out the most knowledgeable persons and determine what sorts of information and help they can give and at what cost, if any.

3. Be An Opportunistic Marketer

Use market insights you gain from steps 1 and 2, along with current inventory information on your forest, to recognize developing market opportunities and take advantage of them. For instance, how can you quickly seize the opportunity of a surge in the oak veneer market if you do not know whether your tract contains an economical volume of the material? Suggestion: update your inventory information after each cutting, or at least every 10 years.

To be an opportunistic marketer you must not be rigidly bound to your management plan. For instance, if the plan calls for a given saw-timber stand to be harvested at age 60, but a very good sale opportunity arises when the stand is 55 years old, calculate the economic advantage of the earlier harvest. Conversely, if the market price is low at age 60, wait a few years before harvesting. This is not to say that the management plan should be routinely ignored or severely altered without careful thought; rather, it should be viewed as a reasonably flexible guide.

Finally, have tracts set up for opportunistic marketing by developing an efficient road system. This allows access when needed, minimizes costs of harvesting, and gets you top dollar for your timber. Developing the road system in advance of harvesting will involve cost outlays not covered by current revenues, but these should be viewed as an investment that will yield returns later. Roads will also make your forest accessible for other uses including recreation (see Note 11.03 *Forest Access Roads).*

4. When in Doubt, Seek Help!

Forest landowners may not receive full value from sale of products because they are not knowledgeable about forest product market conditions. Or they may not understand that the future productivity and value of their forest can be reduced by unwise harvest operations. If you follow the suggestions we made in the preceding three steps, you can avoid some of these hazards. Even so, we urge forest owners to seek professional advice about marketing opportunities and their forest management implications. Assistance is available from consultants, state employed service foresters, or industrial foresters representing companies with cooperative forest management programs. Money spent in securing professional services can be a good investment. Returns are in the form of increased product sales and protection and enhancement of the forest's future value. Case studies show that landowners who use professional forest management services generally gain higher net returns from their forests than do owners who do not use such services.

Remember, forest products marketing is not simple, but if you follow the straightforward methods we suggest to incorporate marketing into forest management planning and practices, you can enjoy greater returns from your land, both in the short and long run. For additional assistance to identify forest products markets in

your area, contact your state's forest products utilization and marketing specialist-every state has at least one-through your State Forester. Finally, remember that the market provides lots of jobs, a wealth of useful products and a way for you to successfully practice forest management.

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CENTRAL HARDWOOD NOTES

Computer Models For Economic And Silvicultural Decisions

Computer systems can help simplify decisionmaking to manage forest ecosystems. We now have computer models to help make forest management decisions by predicting changes associated with a particular management action. Models also help you evaluate alternatives. To be effective, the computer models must be reliable and appropriate for your situation.

Modeling is a forecast system that allows managers the flexibility to develop various alternative scenarios, for both financial analysis and silvicultural practices The goal may be wildlife habitat improvement, enhancement of visual quality or timber production. Treatment options to meet these goals might include thinning, harvesting, releasing, or doing nothing at all. Treatment options usually must comply with limited budget and workforce constraints.

Some basic guidelines for using computer models in decisionmaking are:

1. Establish goals for a given area and define the decision criteria
2. Define alternative actions
3. Obtain appropriate/applicable software to fit specific situations
4. Obtain necessary inventory data to describe the area (i.e., stand characteristics, costs associated with specific treatments, etc.)
5. Predict the consequences of alternative actions
6. Interpret results of the computer predictions
7. Evaluate alternatives
8. Select preferred alternatives
9. Choose and schedule actions to meet specified goals
10. Monitor results and revise plans as necessary

Critically evaluate computer-generated predictions. Computer results cannot replace experience or common sense, but they can be powerful tools to help you decide. Remember, models predict the average experience for stands growing under a range of conditions. For any given stand a variety of site-specific factors may not be included in the model.

Tables 1 and 2 list some available computer models to help managers evaluate financial analyses and/or silvicultural treatments in a management regime. The tables also list growth and yield computer models for silvicultural decisions and economic models to evaluate management practices. Economic evaluation systems are incorporated into some of the growth and yield models. The tables identify appropriate areas of use by state for single models and by region for consolidated models.

Table 1 .-*Available economic software*

Model	Applications	Features	See complete reference under these authors
INVESTMENT ANALYSIS FOR TIMBER MANAGEMENT	Timber management plans	Present net value ▪ Benefit/cost ratio ▪ Composite rate of return ▪ Equal annual equivalent	Perkey (n.d.)
QUICKSILVER	Forestry investments	▪ five output reports ▪ Input transaction for the case ▪ Cash flow details in two tables ▪ Financial return ▪ Before- and after-tax replacement costs and future discounted values A business operating statement	Vasievich (1984)
CASH	Project analysis (Forestry, Agriculture, Engineering, etc.)	▪ Annual cash flows ▪ Measures of project performance ▪ Sensitivity analysis of discount rate	Blinn (1985)
WORTH	Forestry investments	▪ Net present worth ▪ Soil expectation value ▪ Annual equivalent ratio ▪ Internal rate of return ▪ Discounted benefit/cost ratio	Martin (1987)
STUMP	Timber utilization and mill processing	▪ Appraises timber ▪ Determines appropriate stumpage value ▪ Maintains log-yard inventories ▪ Predicts end product yields ▪ Monitors sawmill production	Brisbin (1988)

Table *2.-Available growth and yield software*

Model	Type	Species and area of application	Type of management	See complete reference under these authors
GROAK	Stand level	Upland oaks; IA,IL,IN,KY,MO,OH	Even-age	Dale (1972)
SILVAH	Stand table	Allegheny hardwoods; PA,NY	Even-age; uneven-age	Marquis (1984)
OAKSIM	individual tree	Upland oaks;' KY,OH	Even-age	Hilt (1985a, b)
CENTRAL STATES TWIGS	Individual tree	Pure and mixed species; Central States-particularly IL, IN, MO	Even-age; uneven-age; economic analysis	Shifley (1987) Belcher (1982)
NORTHEAST TWIGS	Individual tree	Pure and mixed species; CT,DE, KY,MA,MD,ME,NH, NJ,NY,OH,PA,RI, VT, WV	Even-age; uneven-age; economic analysis	Hilt et al. (1987)
G-HAT	Individual tree	Appalachian mixed hardwood stands; GA,NC,TN,VA	Even-age	Harrison (1986)
YIELD-MS	Consolidated models	Pure and mixed species; Central States; Appalachian Region	Even-age; economic analysis	Hepp (1987) Hepp (1982)
ERGYS	Consolidated models	Pure and mixed species; Central States, Lake States, and Northeast	Even-age; uneven-age; economic analysis	Gullet (1986)

'OAKSIM works for any upland oak stand as long as oaks compose 75 percent of the stand.

Much of the software and documentation listed may be obtained from the Forest Resources Systems Institute (FORS), a clearinghouse for forestry related software, publications, and special services. FORS is not limited to growth and yield and financial analysis models, but can also provide inventory, harvesting, and sawmilling software. Their address is 201 North Pine Street, Suite 24, Florence, AL 35630. The phone number is (205) 767-0250.

For more information on growth and yield models see Note 5.10 Growth and *Yield Models for Central Hardwoods.*

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CENTRAL HARDWOOD NOTES

Deer Damage In Central Hardwoods: A Potential Problem

A major part of the diet of white-tailed deer consists of herbaceous plants, acorns, other tree fruits, and the twigs of trees and shrubs. Deer browsing on young tree seedlings can influence the success of regeneration in forest stands. Excessive deer browsing is not a major problem in the central hardwood forest type, except in parts of Pennsylvania and, to a lesser extent, in West Virginia.

Kinds of Impact

Based on a few examples in central hardwoods and numerous examples in northern hardwoods, we know that deer browsing can impact regeneration in several ways. First, deer can reduce the height of tree seedlings by browsing. Height reduction increases the amount of time it takes for a new stand to develop. If seedlings are repeatedly browsed, individual tree seedlings may die and, in extreme cases, this can lead to regeneration failure of entire stands.

Second, heavy deer browsing can alter the species makeup of the next stand dramatically. Seedlings that are preferred food items are usually eaten first so the new stand may have very few trees of these species. Preferred food items vary throughout the central hardwood forests, as shown below:

Missouri	West Virginia	Indiana	Pennsylvania
Sugar maple	Red maple	Yellow-poplar	Yellow-poplar
Red maple	Oaks	Sumac	White ash
Eastern redcedar	Dogwood	Sassafras	Sugar maple
Shortleaf pine			Red maple
Blueberry			Oaks
Coralberry			Sassafras
Sumac			Wild grape
Sassafras			Dogwood
Witch-hazel			Blackberry

Some kinds of tree seedlings are able to recover from heavy deer browsing more easily than others. In Pennsylvania, for example, species like striped maple and American beech can be browsed and still dominate the developing stand.

Of all the kinds of browse used by deer, stump sprouts are probably most preferred. Where deer populations are high, stump sprouts are heavily browsed and may even be eliminated. Sprouts provide a flush of new growth immediately after cutting and are generally more nutritious than seedlings. In many parts of the central hardwoods, we depend on sprouts for oak regeneration, so browsing could eliminate a major source of oak regeneration where deer populations are high.

High deer populations can also have an indirect impact on regeneration by changing ground cover vegetation. In parts of central Pennsylvania where deer populations are high, mixed oak forest understories are often dominated by ferns or grasses. This ground cover can be so thick as to interfere with the germination, growth, and development of tree seedlings. Little research has been done on plant interference in oak stands, but research in the cherry-maple type suggests that this indirect effect of deer may be as important as direct damage to seedling regeneration.

Wildlife habitats (including deer habitat) can suffer when deer browsing reduces the amount of understory cover. This is primarily limited to parts of Pennsylvania and West Virginia where wildlife species that depend on a brushy understory for food, cover, or nest sites are either absent in heavily browsed forests or their numbers are few. Species that might be affected by heavy deer browsing include ground- or shrub-nesting songbirds, eastern cottontails, and ruffed grouse. While wild turkeys may prefer the greater visibility associated with these park-like understories, turkey survival may be reduced in harsh winters due to the lack of fruit-producing shrubs and herbaceous vegetation around spring seeps heavily used by deer.

Possible Methods of Control

Silvicultural techniques can often reduce the impact of deer browsing on tree regeneration, and you should usually consider them the first means of control on large properties. The idea is to maximize the amount of deer food available within the particular forest area where regeneration is desired. In this way, deer feeding is spread over a large amount of vegetation, making it unlikely that all seedlings in the regeneration area will be consumed.

Steps You Can Take

- Maximize the amount of cutting of all types within the vicinity of the regeneration cut. All types of cuttings-thinnings as well as regeneration cuts-increase understory vegetation, and therefore, deer food. Since the home range of deer is small, intensified cutting should occur within a radius of about 3/4-mile from the regeneration areas (or within the same 1 ,OOO- to 1,500-acre forest compartment). If possible, at least 10 percent of the total area should be in final regeneration cuts and at least 30 percent in partial cuts, all completed within a few years time.
- Avoid extremely small regeneration cuts of 5 or 10 acres. Small cuts mean that you must make many of them to obtain the desired total cut described above. In addition, deer tend to browse more heavily along the edge of forest openings. Since most of the area in a small opening is within that edge zone, browsing is sometimes more severe than in larger areas.

- Wait until advance regeneration is abundant before you remove all of the overstory. While advance seedlings are critical to successful regeneration of oak and some other desired central hardwoods, the numbers of advance seedlings required is greater where deer populations are high. In Pennsylvania, guidelines for required numbers of oak advance seedlings are 25 times greater in areas of high deer populations than in other areas. Where advance seedlings are not abundant, shelterwood cuttings and control of interfering vegetation may be needed to increase advance regeneration.

In some cases, more direct, expensive means to control deer damage may be the only way of securing adequate tree regeneration.

The most obvious way to reduce deer damage is to erect a fence around the stand to be regenerated. An 8-foot-high, woven wire fence is the most effective-but also the most expensive-option. Recent advances in electric fence technology (high tensile strength wire and high impedance chargers) have reduced problems of fence damage from falling branches and voltage losses from vegetation touching the wires. Although not completely deer proof, well-maintained electric fences provide adequate protection at a cost well below that of conventional fences, and are a practical solution where direct protection is required.

Chemical repellents are another possibility, but these products may only work at moderate deer densities. At high densities, deer tend to browse seedlings despite repellent treatments. In experiments in northern hardwood forests, Big Game Repellent' was the only chemical repellent that significantly reduced the amount of deer browsing.

The most cost-effective and perhaps the most ecologically sound method of deer damage control is by the state wildlife agencies each year as they set their seasons and determine the number of deer of each sex that can be taken. By altering these seasons and bag limits, deer populations can be maintained at levels compatible with other forest uses.

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[1]The mention of trade names does not constitute endorsement of the products by the USDA Forest Service.

CENTRAL HARDWOOD NOTES

Logging Damage

The best commerical logging will damage at least some residual trees during all forms of partial cutting, no matter how carefully done. Yet recommendations at the end of this Note show there is much that you can do to limit damage by proper road and trail layout, proper training and supervision of crews, appropriate equipment, and diligence.

Disturbance from Skidding

Felling mature and other large-diameter trees will snap off, bend over, or break branches from smaller or younger residuals. Skidding will knock bark off the lower bole of some trees no matter what their size, and push over many small ones.

Skidding wounds degrade the butt log and reduce its value. Trees with major injuries-broken branches larger than 3 inches diameter or wounds exposing more than one-third of the bole circumference-will also likely develop internal discoloration and decay. In addition, skidding scrapes off the litter layer, exposes shallow roots and the mineral soil, and rips out advance regeneration in the trails. Indiscriminant skidding can disturb a high proportion of the stand. This could lead to a decline in the residual stand, increased potential for surface erosion, and the unnecessary destruction of some understory vegetation.

When a skidder mires in saturated soil, it leaves deep ruts and severs the roots of trailside trees. This increases the chances of windthrow. It also diminishes tree vigor by restricting moisture and nutrient uptake, and reducing the energy storage capacity of the root system. And deep ruts often make a trail unsuitable for future use.

Damage During Uneven-age Management

Due to their abundance in uneven-age stands, more saplings and poles will be injured than sawtimber. In some cases, the losses may upset the residual structure within the lower diameter (age) classes. Many trees remain standing, but have major injuries to the crown or main stem. They may comprise one-fifth of the residual basal area in partially cut uneven-age stands.

Every re-entry at subsequent cutting cycles will wound additional trees, and reinjure some previously damaged ones. Some trees will have multiple wounds. Reinjury adds grading defects and increases discoloration and chance of rot. As a result, stands under uneven-age management will likely have a base level of defect despite efforts to upgrade stand quality through marking. While some trees with old wounds can be removed at each cutting cycle, to harvest most of the damaged trees would usually force a reassessment of the management objectives.

Thinning of Even-age Stands

In most thinning, residual crop trees are in the upper crown positions. The shorter and smaller ones are cut, so felling primarily destroys or damages intermediate and overtopped trees. Their loss is not important. Most of the important damage comes from skidding. By contrast, cuttings that remove the largest trees from even-age stands will more likely damage your future crop trees, as happens with uneven-age management.

Overall, the combined losses of small trees in felling and skidding during conventional thinning may drop the residual relative density by as much as 10 percent below the target level. In addition, up to 20 percent of the remaining trees in thinned stands may be damaged by skidding. The greater the thinning intensity, the more extensive the damage. In the worst case, there may not be enough undamaged dominant and co-dominant trees to fully occupy the site at the end of the rotation.

Improvement in logging machinery design and capability have changed harvesting operations, even for intermediate stand treatments. In some thinnings, the entire tree is skidded, rather than just the main stem. Mechanized felling and bunching, and grapple skidding are also used for thinning. When done properly, whole-tree skidding and mechanized logging need not cause more damage than conventional tree-length operations. Small, highly mobile cable yarding equipment has proven efficient for thinning operations on steep slopes. A well-planned cable yarding operation might even leave fewer injuries, especially along the corridors.

Recommendations for Reducing Logging Damage

Most skidding damage results from turning loads onto a skidding trail, or when loads do not “track” in the center of a trail along curves. While you can remove some previously damaged trees along trailsides in subsequent logging, cutting all of them would widen the corridors excessively. Felling injuries cannot be avoided in a well-spaced residual stand, whether even- or uneven-aged.

The best way to limit damage during logging is through preventive measures as follows:

1. Share your concern about limiting logging damage with the logging contractor and review ways to promote careful work among tree fellers and machine operators.
2. Consider marking “leave” trees instead of “cut” trees if it will help the logger avoid them.
3. Use directional felling to divert falling trees away from high-quality residuals, and align the boles for efficient skidding with minimum turning.
4. Cut out forks and remove large branches from the felled trees so they track well and fit the skidding corridors.

5. Insist on a well-planned access system that does not cover more than 10 to 15 percent of the area, and monitor for compliance.
6. Do not allow skidding when the soil is too wet.
7. Use well-organized and fairly straight skidding trails that bypass poorly drained spots and accommodate machine operations. Minimize turning; avoid sharp turns and keep loads in the center of the trail.
8. Use the smallest size machinery possible without making the operations inefficient, and make sure the trail is wide enough and straight enough to accommodate the equipment.
9. Log when the soil is well drained or frozen. Avoid springtime operations when the bark is easily skinned off the tree trunks.
10. Plan ahead for mechanized logging. Specialized equipment requires different kinds of skid trails.
11. In mechanized tree- or long-length operations, place the wood piles left by the feller-buncher inside major skidding corridors (not among the residual trees). This avoids damaging trailside trees as loads are turned.
12. In cable yarding, make sure corridors are wide enough, properly spaced, and oriented. Make sure the crew is experienced and the equipment is properly used.

Take an active rather than passive approach to harvesting operations to insure compatibility between logging and the silvicultural goals. To succeed, you must continually think about and take direct steps to keep the damages within tolerable levels for your management objectives.

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CENTRAL HARDWOOD NOTES

Appraising Fire Effects

Fire effects in the central hardwood forest vary greatly. Depending on a number of factors, some trees will be killed immediately; others will be injured and die in a year or more; still others will incur basal wounds that can provide entry for decay; and some trees will not be affected.

What makes a tree or stand in the central hardwood forest vulnerable to fire? In addition to fire intensity, tree size is a major factor in whether it will live or die. A large tree usually has thicker bark than a small one, and it also has a larger cambium circumference. Even if a portion of the cambium is killed by fire, a large tree can usually continue to function. Other important factors in tree responses to fire are species and the season of the fire. Historically, the most intensive fires that cause the most damage occur in the spring before green-up. However, given fires of equal intensity, mortality and damage are greatest for fires occurring during the growing season.

Fire Killed and Injured Trees

Trees can be killed by heat-either in the crown or in the lower bole. Top-killed, merchantable-size trees can often be salvaged. There may be value loss because they have not reached optimum rotation age or because fire-killed or damaged timber may sell for less. Wildfires can also kill a portion of tree crowns. Crown reduction, in turn, may cause reduced growth and/or mortality. Generally, trees shorter than the height to which crowns have been killed will not survive.

Trees With Basal Wounding

Basal wounds are of greatest concern in pole-size and small sawtimber trees (5- to 16-inches d.b.h.), which will not reach merchantable and/or optimum rotation age and size for a number of years. Basal damage with subsequent decay can eventually weaken trees and cause major losses in both volume and quality at harvest.

Decay following wounding by fire has caused volume and value losses in the butt section of this tree.

While trees smaller than pole-size are usually killed in intense fires, small tree survivors with basal wounds will generally heal with negligible defect. Similarly, wounds on surviving trees at or near rotation age will seldom cause significant volume or grade loss if trees are harvested within a few years.

Estimating Mortality or Survival

When tree mortality is uncertain, a fire-effects appraisal may have to be delayed until at least one growing season passes. Late summer or early fall is often the best time for appraisal because mortality has usually occurred by that time, and you can make survival estimates of damaged trees more accurately. Basal wound size and configuration is easier to see because new callus growth may clearly outline the wounds. Use ax cuts to determine the extent of dead cambium, which is noticeably different from the bright white living cambium.

Burned areas often require inventory and evaluration to determine potential damage and loss.

For various reasons, you may want to assess damage soon after a fire is controlled. If a fire occurs in the dormant season, the appraisal is more difficult. When an immediate appraisal is needed, "scorch" height can be used to determine the likelihood that a tree will die (table 1). For some central hardwood species, scorch (bark discolored by fire) is a visual indicator of the fire's intensity and duration. Scorch includes all degrees of bark discoloration, ranging from slightly browned to blackened or charred. Estimates of volume loss require knowing the height and width of the actual wound. Wound size can be estimated from scorch size when dimensions of the actual wound cannot be measured.

You can get a rough estimate of the likelihood of mortality and volume loss as follows:

1. Select Samples

   Determine the number of sample plots and/or trees in a manner similar to making other timber surveys. Consider desired sampling precision, size of burned area, and timber value involved. Very often, a few representative plots and trees can quickly provide adequate estimates. Use at least two 1/5-acre plots for each timber type-size class combination present in the burned area. The estimating procedure is not reliable for trees less than 3 inches d.b.h. so depend on your own judgment about such trees considering the general appearance of the fire area and apparent fire intensity. Generally, hardwood trees 3 inches d.b.h. and smaller are likely to die if scorch height is greater than 2 feet.

Table 1 .-*Percent of trees that are likely to die from fires that occur in the dormant or growing seasons*

Season	D.b.h.	Scorch height[1]	Black oak[2]	Scarlet oak	White oak	Post oak
	Inches	*Feet*		*--Percent---*		
Dormant	4	2	42	60	30	13
		4	69	88	49	30
		6	96	100	67	48
	5	2	30	48	18	4
		4	57	76	37	21
		6	a5	100	55	39
	6	2	21	38	9	0
		4	48	66	27	14
		6	75	94	46	32
	7	2	12	29	1	0
		4	40	57	19	a
		6	67	a5	37	25
	a	2	5	22	0	0
		4	33	50	12	3
		6	60	78	30	20
	9	2	0	15	0	0
		4	26	43	6	0
		6	54	71	24	15
	10	2	0	9	0	0
		4	21	37	0	0
		6	48	65	19	11
	11+	2	0	4	0	0
		4	16	32	0	0
		6	43	60	14	7
Growing	4	2	59	79	43	24
		4	100	100	70	50
		6	100	100	97	76
	5	2	47	66	31	14
		4	88	100	58	41
		6	100	100	a5	67
	6	2	37	55	21	7
		4	78	97	48	33
		6	100	100	75	59
	7	2	29	47	12	0
		4	69	a9	40	27
		6	100	100	67	53
	a	2	21	39	5	0
		4	62	81	32	21
		6	100	100	60	47
	9	2	15	32	0	0
		4	56	74	26	16
		6	97	100	53	42
	10	2	9	26	0	0
		4	50	68	20	12
		6	91	100	48	38
	11+	2	4	21	0	0
		4	45	63	15	a
		6	86	100	43	34

[1] Scorch height is measured beginning at ground level.

[2] Black oak values can also be used for northern red oak, hickory, and ash.

2. Take Measurements

For each sample plot tree 4 inches d.b.h. or larger:

a. Record species.

b. Measure d.b.h. to the nearest 0.1 inch.

c. Record whether the tree is alive or has been killed by fire.

d. If the extent of the fire wound is apparent, measure the actual wound height to the nearest 0.1 foot from 1 foot above the ground level (stump height) and wound width at the same point to the nearest 0.1 foot measured on the arc of the circumference.

e. If the extent of the wound is not apparent, measure scorch height to the nearest 0.1 foot from ground level and scorch width to the nearest 0.1 foot at 1 foot above ground level (stump height).

f. Exclude trees that have butt rot or large basal wounds from a previous injury.

3. The likelihood of mortality for each tree can be estimated from scorch height (table 1). Actual wound height can be substituted for scorch height by adding 1 foot to the measured wound height.

Estimating Volume and Value Loss

You can get a rough estimate of future volume loss from fire using table 2. If more precise estimates are needed, seek help from a professional fire damage appraiser.

Estimating volume loss requires knowing the actual wound size. If the actual wound dimensions cannot be measured, estimate them from scorch height and width (fig. 1). The values read from figure 1 and table 2 apply only to trees that have basal fire wounds from a single fire and that are expected to survive until harvestable.

You can estimate sawtimber value loss by applying the current stumpage value to the volume losses in table 2. Any tree having a fire wound covering more than two-thirds (one-half for scarlet oak) of the circumference at 1 foot above ground is unlikely to survive until harvest time. (This procedure of estimating volume and value is most applicable for State and regional timber surveys of fire damage. It may also be used for individual fires and stands, but the estimates are less accurate.)

Mortality and the extent of injury to central hardwood species not mentioned in this Note may be quite different. Species with thinner bark will sustain greater damage compared to those with bark having better insulating properties. The southern pines associated with the central hardwood forest are resistant to fire, and basal wounding is seldom a problem. The extent of crown kill generally determines whether or not pine species will survive.

Table 2. Estimated volume losses per tree due to basal fire wounds 10 20. and 30 years after the fire

D.b.h.	Wound	10 years since fire Wound width-feet					20 years since fife Wound width-feet					30 years since fire Wound width-feet				
(Inches)	height'	0.5	1.0	1.5	2.0	2.5	0.5	1.0	1.5	2.0	2.5	0.5	1.0	1.5	2.0	2.5
	feet	-- Board feet-international l/4-inch rule ----------														
10	1	0	0	0	0	0	0	1	4	8	11	4	8	11	15	19
	2	0	0	0	0	3	1	5	8	12	15	8	12	15	19	22
	3	0	0	0	3	7	5	8	12	15	19	12	16	19	23	26
	4	0	0	3	7	10	9	12	16	19	23	16	19	23	26	30
	5	0	4	7	11	14	12	16	20	23	27	20	23	27	30	34
	6	4	7	11	14	16	16	20	23	27	30	23	27	31	34	38
	7	8	11	15	18	22	20	24	27	31	34	27	31	34	38	41
	8	12	15	19	22	26	24	27	31	35	38	31	35	38	42	45
12	1	0	0	0	0	2	0	4	7	11	14	7	11	15	18	22
	2	0	0	0	2	6	4	8	11	15	18	11	15	18	22	25
	3	0	0	3	6	10	8	11	15	18	22	15	19	22	26	29
	4	0	3	6	10	13	12	15	19	22	26	19	22	26	30	33
	5	3	7	10	14	17	16	19	23	26	30	23	26	30	33	37
	6	7	10	14	18	21	19	23	26	30	33	27	30	34	37	41
	7	11	14	18	21	25	23	27	30	34	37	30	34	37	41	45
	8	15	18	22	25	29	27	31	34	38	41	34	38	41	45	48
14	1	0	0	0	2	5	3	7	10	14	17	11	14	18	21	25
	2	0	0	2	5	9	7	11	14	18	21	14	18	21	25	29
	3	0	2	6	9	13	11	14	18	22	25	18	22	25	29	32
	4	2	6	9	13	17	15	18	22	25	29	22	26	29	33	36
	5	6	10	13	17	20	19	22	26	29	33	26	29	33	36	40
	6	10	14	17	21	24	22	26	29	33	37	30	33	37	40	44
	7	14	17	21	24	28	26	30	33	37	40	33	37	41	44	48
	8	18	21	25	28	32	30	34	37	41	44	37	41	44	48	51
16	1	0	0	1	5	8	6	10	13	17	21	14	17	21	24	28
	2	0	1	5	8	12	10	14	17	21	24	17	21	25	28	32
	3	2	5	9	12	16	14	18	21	25	28	21	25	28	32	35
	4	5	9	13	16	20	18	21	25	28	32	25	29	32	36	39
	5	9	13	16	20	23	22	25	29	32	36	29	32	36	40	43
	6	13	17	20	24	27	25	29	33	36	40	33	36	40	43	47
	7	17	20	24	28	31	29	33	36	40	43	37	40	44	47	51
	8	21	24	28	31	35	33	37	40	44	47	40	44	47	51	55
18	1	0		14	8	11	9	13	17	20	24	17	20	24	27	31
	2	14		8	12	15	13	17	20	24	27	21	24	28	31	35
	3	5	8	12	15	17	17	21	24	28	31	24	28	31	35	39
	4	9	12	16	19	23	21	24	28	32	35	28	32	35	39	42
	5	12	16	19	23	27	25	28	32	35	39	32	36	39	43	46
	6	16	20	23	27	30	29	32	36	39	43	36	39	43	46	50
	7	20	24	27	31	34	32	36	39	43	47	40	43	47	50	54
	8	24	27	31	34	38	36	40	43	47	50	43	47	51	54	58

[1]Wound height is measured beginning at 1 foot above ground level (stump height).

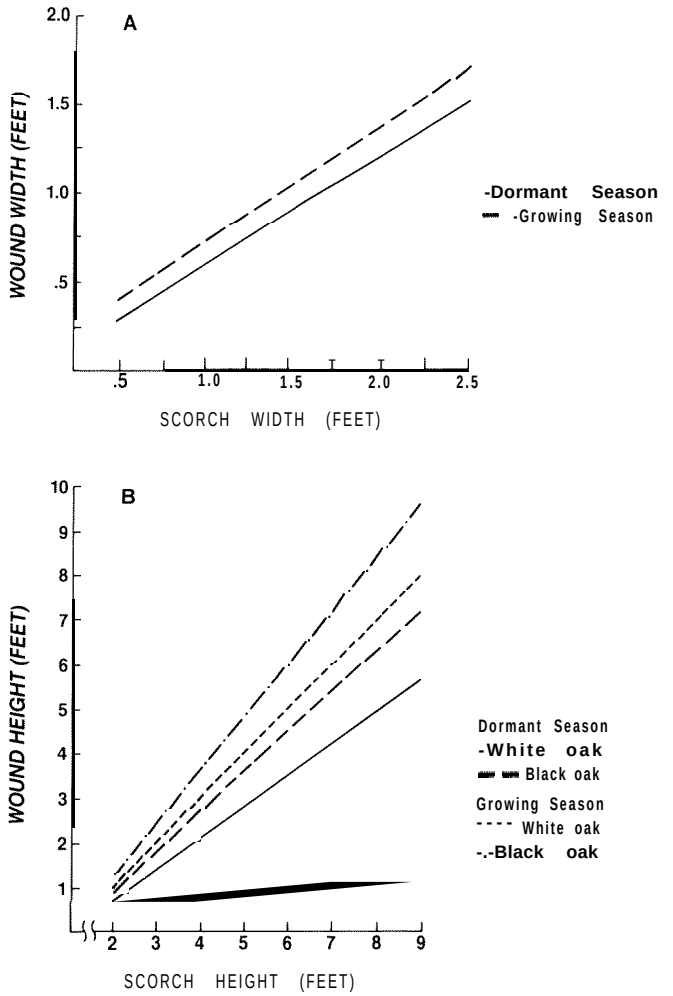

Figure 1.-Relationship between (A) scorch width and wound width for white and black oak and (B) scorch height and wound height for fires occurring during the dormant and growing seasons. Values for white oak also apply to chestnut oak and post oak. Values for black oak also apply to scarlet oak, northern red oak, hickories, and white ash.

Non-Timber Values

Non-timber wildland values may also be affected by fire. These include wildlife, soil, water, recreation, and structures. Most fires occurring in the central hardwoods have little negative impact on wildlife. In fact, the post-fire impacts often benefit wildlife by improving cover and increasing the supply of preferred foods. Impacts on soil and water quality are not usually severe. Recreational value losses are not usually important except when fires burn on or near developed sites. Of course, fires can result in important value losses when they damage buildings and other structures. This problem is most severe at the wildland/urban interface and is likely to increase as more and more people choose wildland sites for their homes.

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CENTRAL HARDWOOD NOTES

Oak Wilt

Oak wilt, a major disease of oak trees in North America, is caused by a fungus. It infects the sapwood and stops sap flow to the branches, twigs, and leaves. When sap flow is restricted during the growing season, trees wilt and soon die. In addition to killing trees, oak wilt makes it more difficult to export oak logs to other countries. Logs must be free of oak wilt before shipment. However, our knowledge of oak wilt makes it possible to safely export oak logs to other countries without the risk of transmitting the fungus.

Diagnosing Oak Wilt

The leaf symptoms and pattern of disease development in a stand are the best clues for diagnosing oak wilt. The first obvious symptom is a change in leaf color from green to pale green, yellow, and then brown. Close examination of infected trees reveals diagnostic symptoms, which are: drying or "bleaching" of leaf margins and tips, progressive inward browning of leaves from the margins and tips, yellowing and browning of leaf veins and midribs, and premature accumulation of both green and symptomatic leaves beneath trees. If either the trunk or the lateral roots are dead when leaf symptoms develop, the disease is probably not oak wilt but root rot or oak decline.

Symptoms of Stand Infections

Another characteristic of oak wilt is separate "infection centers" within a stand. These infection centers vary in size from a small pocket of trees to large acreages with many trees. The largest oak wilt infection centers have been discovered in natural stands of live oak trees in central Texas. Generally, trees of the same species make up an infection center. The typical infection center is composed of dead trees in the center, surrounded by partially dead trees, with initially infected trees along the perimeter. The most active part of the infection center is along its perimeter, where diagnostic leaf symptoms develop.

How to Tell Oak Wilt from Oak Decline

Most red oaks die soon after infection with the oak wilt fungus, but white oaks may only develop a few symptoms in one or two branches. When red oaks survive oak wilt, they exhibit thin crowns, dieback, and decline. These symptoms may be confused with what is commonly called "oak decline," however, in oak decline separate infection patterns or centers are not evident. Instead, several oak species may be affected and they are usually widely scattered throughout the stand. Also, the diagnostic leaf symptoms of oak wilt are not present.

Limiting the Losses

The amount of damage caused by oak wilt varies with the value of affected trees and composition of the stand. High value or urban trees justify more protection than scrub oaks on poor sites. However, oak wilt in low value trees should not be ignored Infections in these trees may later spread to valuable trees. The potential for damage is higher in pure oak stands than in mixed stands. Pure stands have extensive root grafts, which serve as conduits for transmission, and may account for about 95 percent of the new oak wilt infections each year. Insects may transmit the remaining 5 percent and are very important because they start new infection centers.

Stopping Transmission by Root Grafts

Losses can be limited by disrupting the normal transmission of oak wilt. Infection center expansion through root transmission must be stopped. You can do this by destroying root connections between infected and non-infected trees. A 3-foot-deep trench or plow line between the trees will disrupt most interconnected roots. The entire infection center should be encircled with the trench or plow line about 50 feet beyond the perimeter of infected trees. Another way you can limit disease spread through roots is to kill trees of the affected species along the perimeter of the infection center. Trees should be injected with silvicides that kill roots.

In cities and suburbs infected trees shouid be removed as soon as the disease has been positively identified if there are nearby oaks. Adjacent, uninfected oaks can be protected by trenching between healthy and diseased trees.

Stopping Transmission by Insects

The number of new infection centers can be minimized by reducing insect transmission. You can do this by preventing the fungus from releasing spores and by reducing the number of fresh wounds on trees in the springtime. Oak wilt-infected trees should be killed immediately with silvicides or by tree girdling. When trees are killed soon after infection, other fungi colonize the wood and prevent spore release by the oak wilt fungus. If infected trees are not deadened, fungal mats may develop under the bark and provide spores for insect transport to fresh wounds on healthy trees, Tree wounding through logging, road building, and pruning should be avoided in the springtime if oak wilt spores are being released and insects are active in nearby stands. Logs cut from trees in or near oak wilt infection centers should not be moved outside the affected area unless they are processed for lumber or burned for firewood. These precautions will help contain oak wilt infections.

Oak wilt affects only a small portion of the oak stands in the United States. When properly managed, this disease is not a serious threat to commercial oak production.

Restriction on Oak Timber Products

There are no restrictions on the domestic use of oak bolts, logs, lumber, or veneer because of the oak wilt disease. Even diseased trees can be used for firewood, bolts, and logs. (However, care should be taken not to wound residual trees when cutting and hauling out of oak wilt areas.)

Oak logs from counties having the oak wilt disease must be fumigated prior to export to foreign countries. Kiln dried lumber may be exported without restriction.

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CENTRAL HARDWOOD NOTES

Elm Diseases

Dutch Elm Disease

Dutch elm disease was found in Cleveland, Ohio, in 1930, and is now in most of the contiguous 48 states. The disease is caused by a fungus that has killed millions of wild and planted elms. Losses have been the greatest in the eastern United States. The fungus attacks all elms, but our native species, American, slippery, and rock elm have little or no resistance to the disease. The most important and common of these, the American elm, is found on a wide range of forest sites and old fields.

Dutch elm disease produces wilted yellowing foliage, followed by dead, brown leaves dropping from the trees. In late summer, disease symptoms may be confused with typical fall coloration. Infected branches die after leaf drop. Affected branches develop a brown stain just under the bark, or a discoloration of the outer annual ring in a cross section of the branch. Disease symptoms usually start at the tips of one or more branches in the tree crown, followed by infection of all branches. Infected trees usually die within a year, but some die within weeks. Trees that become infected in the spring usually die quickly, whereas trees that are infected in the late summer or fall usually die the following season.

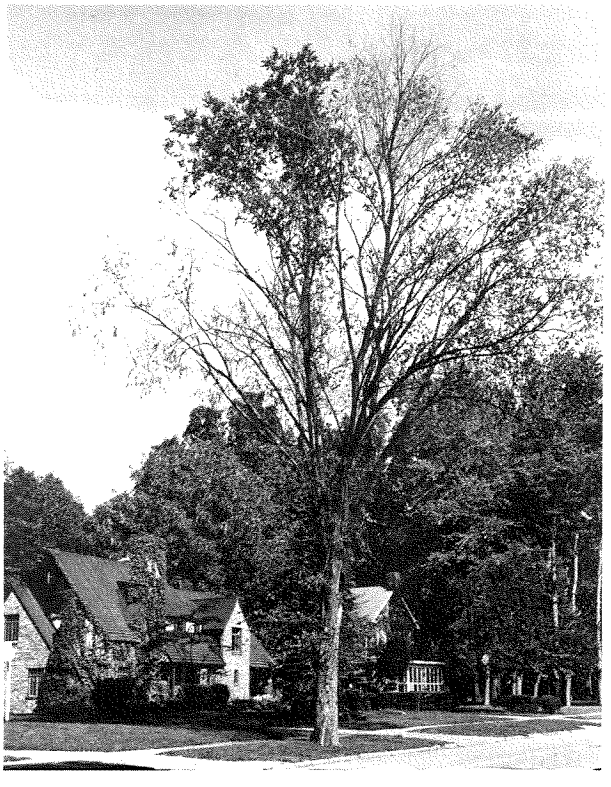

Figure 1 .-An American elm with Dutch elm disease. (U.S. Forest Service)

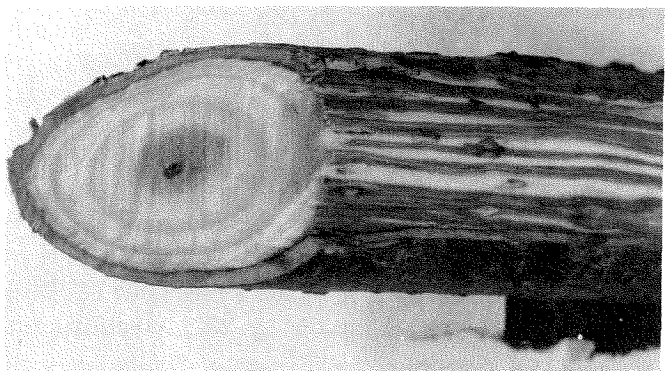

Figure 2.-Twig from American elm discolored from Dutch elm disease. (U.S. Forest Service)

In the U.S., the principal carriers of the Dutch elm disease fungus are two small, dark brown beetles: the smaller European elm bark beetle and the native elm bark beetle. The European species is the more common vector in most of the U.S., except in northern areas. Both of these beetles reproduce in diseased elms. Adults emerge from infected trees and carry fungus spores on their bodies to healthy elms. The spores germinate in feeding wounds and the fungus spreads throughout the tree, plugging the water conducting tissue and killing infected portions of the tree.

Figure 3.-Galleries of smaller European elm bark beetle. (U.S. Forest Service)

Dutch elm disease can also pass from infected trees to adjacent healthy elms via natural root grafts. When grafts occur, disease symptoms can develop suddenly throughout the entire tree. In some stands where elms are abundant, this form of disease transmission can be more significant than the spread resulting from beetles.

Even though Dutch elm disease has been present in the eastern U.S. for over 50 years, and despite the loss of millions of elms, this disease continues to cause significant mortality. The disease will cause significant losses in the future because elm continues to reproduce prolifically in many habitats.

It is difficult to predict the impact of Dutch elm disease in a hardwood stand. In general, large and closely spaced elms are susceptible to both beetle and root graft transmission of the disease thus promoting the rapid spread of the disease. Saplings and smaller trees are also susceptible to the disease and may serve as a reservoir of both beetles and the fungus. Control of Dutch elm disease in a forest stand is seldom feasible, but dead and dying trees can be salvaged if the quantity and quality are adequate for local markets. On a positive note, Dutch elm disease has increased the number of suitable nesting sites for birds and other animals.

Elm Yellows (Elm Phloem Necrosis)

Elms can be killed by a phloem infection commonly called elm yellows (previously known as elm phloem necrosis). The disease is caused by an organism intermediate between viruses and bacteria that is transmitted by the whitebanded elm leafhopper, or through root grafts between adjacent trees. Infections are known to occur naturally in American elm, slippery elm, cedar elm, winged elm, September elm, and slippery elm-Siberian elm hybrids. The susceptibility of rock elm is unknown. There have been localized epidemics of the disease in the east-central U.S. The range of elm yellows now includes portions of 22 states.

The foliar symptoms of the disease in American, cedar, September, and winged elms begin in mid-July to mid-September when the leaves yellow and droop and begin to fall prematurely. This sequence may take only a few weeks, and in most cases all branches have the symptoms. Occasionally, only a single branch shows symptoms, followed shortly thereafter by symptoms appearing on the remaining branches. Bright yellow leaves may be interspersed with green leaves on a branch, but usually all leaves become yellow-green, then yellow. The yellowing and premature leaf fall are similar to symptoms produced by water stress or poor nutrition. Symptoms that first occur in late summer or early autumn are difficult to distinguish from normal fall coloration. Twigs and small branches in elms killed by elm yellows seldom show the crooking or bending commonly seen in trees killed by Dutch elm disease. The phloem of yellows-infected trees is characterized by a butterscotch to dark brown color, particularly in the roots and butt. In larger stems, this discoloration occurs as vertical bands; in smaller crown branches, discoloration is usually absent.

Perhaps the most distinguishing character of yellows-infected elms is the presence of an oil-of-wintergreen odor on the surface of freshly exposed bark, especially in summer. This odor is sometimes present even before the phloem becomes discolored. When a tree has both Dutch elm disease and elm yellows, the symptoms of Dutch elm disease usually mask those of the yellows.

In cedar, September, and winged elms foliar symptoms usually develop first on a single branch, and trees off en live more than one year while showing symptoms. As in American elm, they do not recover. In infected slippery elms, witches'-brooms usually form during the final season before death and the wintergreen odor is never present.

The whitebanded leafhopper that efficiently transmits the organism among American elms has the distinctive white band across its back only in its immature stage. Adult leafhoppers (dark brown with whitish spots on the wing covers) are present from early June until killed by frost, which coincides with the period when most disease inoculations occur. Other insect vectors are probably involved in disease transmission.

Epidemics of elm yellows, which can cause great losses, are geographically localized, spreading slowly (if at all) into surrounding areas. The disease can be endemic in an area for many years, so once an outbreak occurs, most of the elms in a locality die. Yellows epidemics proceed more slowly than Dutch elm disease. The disease is prevalent in stands having large elm populations, but very likely the symptoms and the significance of elm yellows is overshadowed by the presence of the more aggressive Dutch elm disease.

The injection of certain antibiotics into yellows-infected elms has arrested the disease for a short time. However, no practical means for vector control or long-term disease prevention or cure is available.

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CENTRAL HARDWOOD NOTES

Sycamore Diseases

Canker Stain Disease

The canker stain disease, one of several fungi that cause cankers of sycamore, can cause serious loss of sycamores in natural stands, plantations, and urban areas. As many as 35 percent of the trees in some stands may be diseased. Affected trees develop thin crowns, twig dieback. small leaves and epicormic branches. The narrow, elongate, bark covered, flat, spiraling stem cankers may be obscure (fig 1A). Probing the edge of a suspected canker with a knife will expose both bright-colored healthy and darkened diseased tissues. The "wedge" of wood beneath cankers will be dark stained.

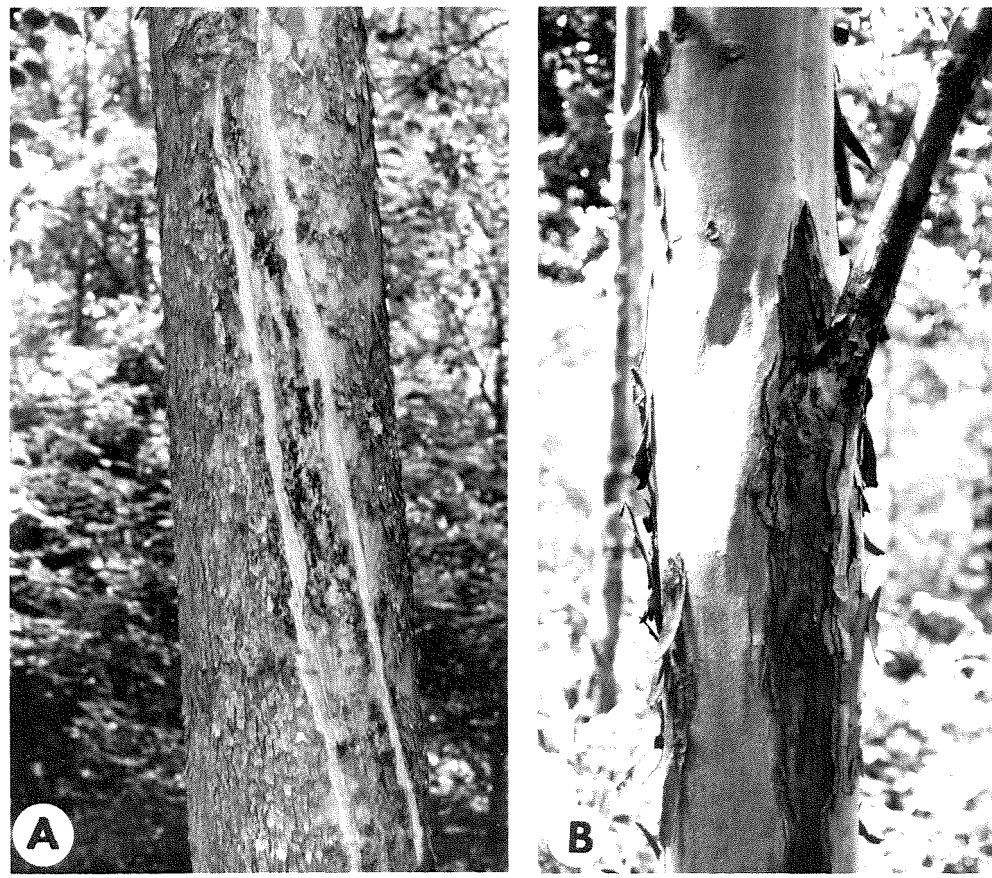

Figure 1 .-Stem cankers of sycamore (A) edges of canker caused by the canker stain disease and exposed by scraping (B) canker and dieback caused by *Phomopsis* scabra (Sacc.) Trav.

Older cankers are marked by decay, insect, and bird damage. Trees may be killed in a few months to several years depending on their age. Canker stain can easily be transmitted mechanically to healthy trees. The spores may remain viable for months on tools that have been used to cut diseased trees. So, before you use these tools again on healthy trees, you should wet them thoroughly with a 1 :1 mixture of alcohol and laundry bleach. The only practical means of control are removal of diseased trees, sterilizing tools, and wound prevention. Injection of fungicides, excising or otherwise deadening cankers are not effective control measures. Some trees show tolerance to this disease but true resistance to canker stain has not been found.

Other Canker Diseases

Cankers caused by *Phomopsis* scabra (Sacc.) Trav., *Dothiorella* spp., and Bot-*ryodiplodia theobromae* Pat. look alike and are usually visible on the stems. However, these cankers are easier to see when the stems are wetted. Cankers may be up to a few inches wide, a few feet long, and usually are associated with dead terminals or lateral branches (fig. 1 B). At first, canker surfaces are somewhat dark and slightly sunken, they then become completely dark with dead tissues and noticeably sunken after l-2 growing seasons. The fungi produce inconspicuous structures in the darkened areas where spores are produced. Cankered trees may go unnoticed until small off-color leaves, dieback, or death prompts close inspection. The severity of the disease varies greatly depending on the interaction of host and pathogen, environment, and site.

Chemical treatment is not effective. To minimize losses due to these cankers, you should avoid wounding and stress while using cultural practices that maintain and promote tree vigor. Plant only on good sites using high quality nursery stock derived from certified local seed.

Sycamore Anthracnose

Anthracnose is an important leaf disease caused by a fungus. The pathogen attacks the foliage when the leaves first emerge. Young leaves typically appear brown and wilted similar to frost damage (fig. 2A). The leaves may have irregular brown areas in the veins, midribs and leaf tips. Minute cream-colored spots will be produced on the underside of the leaves. Damage can also occur on twigs, which results in shoot blight and small cankers (fig. 2B). Severe defoliation will be followed by growth of new leaves. Outbreaks are more severe when spring temperatures are mild and rains prolonged. Leaf and twig infections decrease with increasing temperatures (above 60°F). Early fall defoliation may also occur when temperatures and rain favor disease development.

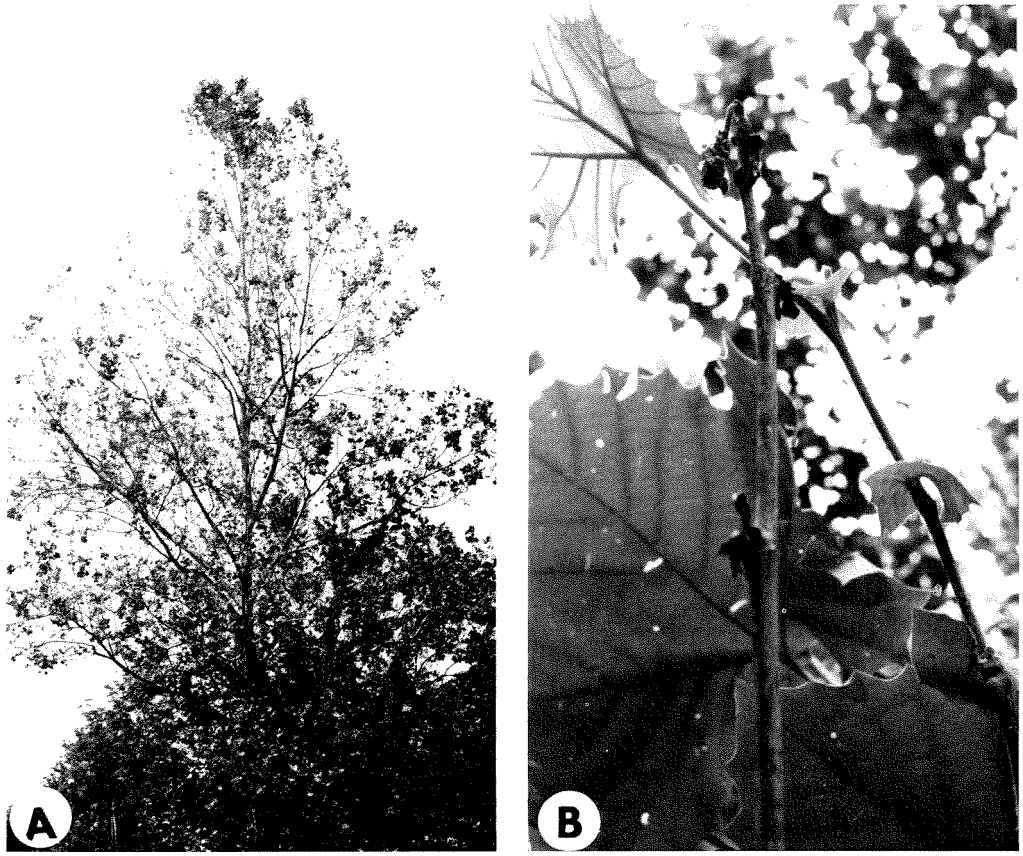

Figure P.--Sycamore anthracnose (A) spring defoliation (B) close-up of affected leaf and twig

Fungicide sprays can reduce severity but are not practical since frequent applications are required. Some seed sources show tolerance to anthracnose. Use cultural practices that maintain and promote tree vigor.

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CENTRAL HARDWOOD NOTES

Trunk Decays

Trunk decays are major causes of low quality wood-wood with little or no economic value. As a forest practitioner you should be able to recognize trees at high risk for decay and remove them if timber production is your primary objective. Remember, however, that decayed trees often develop into den trees or nesting sites and provide essential habitat for wildlife.

Wounds and dead branches and roots start the processes that can lead to trunk decays. Even though decay is a natural process, much can be done to prevent, assess, regulate, predict, and detect trunk decays in trees that are not overmature. Start by preventing wounds, pruning properly, and detecting and assessing internal defects accurately.

Preventing Wounds

You should try to prevent wounds by minimizing logging and fire damage, keeping increment borers out of trees, and developing and managing recreation sites carefully. When you construct roads and trails or manage wildlife and grazing areas, avoid injuring trunks and roots as much as possible.

Prune Properly

Remove living, dying, and dead branches in such a way that the "collar" at the branch base is not injured or removed. The collars should not be removed to make a cut flush with the trunk or joining stem. Flush cuts are major causes of serious defects: discolored wood, decayed wood, wetwood, resin-soaked wood in conifers, shakes and radial cracks, cankers, and areas of weakened wood above and below the wound that may be easily infested by insects. Also, do not leave stubs! Do not paint the cuts! (See Note 6.09 Pruning Central Hardwoods.)

How Trees Resist the Spread of Pathogens

Unlike animals, which restore injured and infected cells through a process called healing, trees can only "compartmentalize" infected wood by forming new wood cells in new spatial positions. The tree survival system depends upon forming protective boundaries to resist the spread of pathogens. The boundaries also defend the liquid transport, energy storage, and mechanical support systems of the tree. The boundaries are made up of protective chemicals, and in some cases after wounding, the cell arrangements are altered to form protective boundaries.

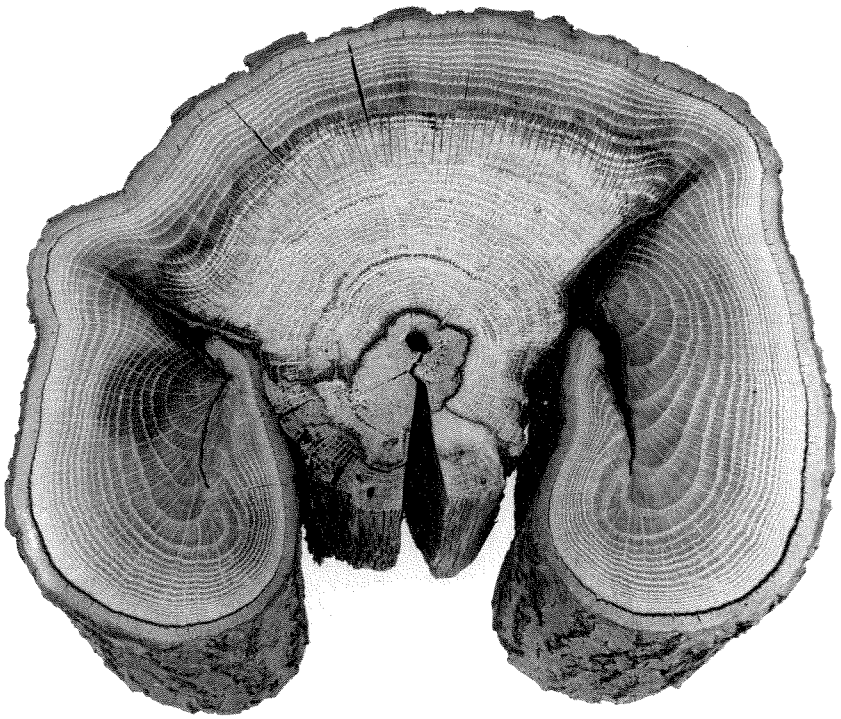
The root and butt injuries on this black walnut have ruined the most valuable part of the trunk. Logging wounds must be reduced.

The Q-year-old wound in this northern red oak was well compartmentalized. The decayed wood was surrounded by a protective boundary of discolored wood. The wood that formed after the wound was inflicted was not infected by the wood-inhabiting pathogens.

Which Defective or Decayed Trees Should You Remove?

Here are some general guidelines for detecting and assessing decays and other internal defects in trunks:

1. Wounds at groundline and below living branches are associated with less defect than wounds at 1 to 3 meters above ground.
2. Wounds that are deep or wide, or both, are associated with more defect than wounds that are shallow, or long in a vertical plane.
3. Wounds directly above or below other wounds or old branch stubs are associated with more defect than wounds elsewhere on the trunk.
4. Wounds with hard, bleached surfaces are associated with less defect than wounds with dark, soft surfaces.
5. Wounds inflicted during leaf formation and leaf shedding will lead to more defects than similar type wounds inflicted at other times.
6. Wounds inflicted in the spring during the onset of growth will have larger callus "ribs" than wounds inflicted at other times. But, callus formation is not associated with development of decay. When callus formation is too rapid, the callus ribs turn inward and form a "ram's horn." When this occurs, the wound never closes, creating conditions perfect for wood-inhabiting pathogens.



The wound on this northern red oak not only led to a large column of decayed wood, but the callus turned inward and caused the wood to crack in vertical planes. When such vertical cracks break outward to the bark, frost will be blamed. Frost does not start "frost cracks;" wounds do.

7. Wounds treated with wound dressing often form large callus ribs that turn inward to form “ram’s horns.” There are no data to show that wound dressings stop decay.
8. Wounds oozing fluids indicate internal wetwood, a disease caused by bacteria. wetwood is difficult to dry for products.
9. Wounds with fungi fruiting bodies-conks or sporophores-are associated with advanced decay. When many conks are present the entire trunk will be decayed. Conks on wounds from 1 to 4 meters above ground are associated with large columns of decay. Conks at groundline indicate decay in roots and in the trunk to at least 2 meters height. Conks on a swollen butt indicate decay to at least 3 meters height. Conks on a swollen butt with cracks indicate decay, wetwood and cracks to at least 4 meters height. Conks near large hollows indicate decay and wetwood to at least 5 meters height. Removing conks will not stop or stall decay. Be alert for conks or sporophores that grow for only a short time on the wound surface. Often the dried remains of the sporophores will be on the wound surface or on the ground near the tree base.
10. Wounds on roots indicate decay in the base of the trunk. Be alert for the fresh or old mushrooms of the shoestring root rot or “honey” mushroom. Other indicators are wet spots or water-soaked areas at the tree base. Basal decay may spread to 2 meters above ground on old trees.
11. Wounds with vertical cracks above and below them indicate internal decay and ring shakes. Ring shakes are circumferential cracks or separations.
12. Vertical cracks on the trunk indicate ring shakes, star shake, heartshake, and wetwood. Trees with many internal cracks cannot be used for valuable wood products.
13. Sapsucker (birds) wounds cause streaks of discolored wood and ring shakes.
14. Cankers with hard, bleached surfaces indicate very little defect above and below. Cankers with sunken surfaces and margins indicate long columns of advanced decay. Such cankers are called canker rots. To check for canker rots, cut into the surface of the canker. If compact fungus material is present, the defect is a canker rot. Often old conks from the canker can be found on the ground. Canker rots may also be centered about old branch stubs. The stubs may be swollen to form a round structure, or the canker may be long vertically to form a spindle-like canker. Trees with canker rots should be cut as soon as possible.
15. Broken tops or trunk leaders leave a stem stub. Decay associated with stem stubs will develop downward, and the diameter of the column of decayed wood will be the diameter of the stem when it died.
16. Trees with many decayed branch stubs will have many internal columns of discolored and decayed wood. wetwood and ring shakes may also be associated with old branch stubs. Stubs between the 2 and 4 meter portion of the trunk are associated with the largest columns of defect.
17. Basal cracks or collar cracks indicate root and butt decay that may spread to 2 meters or more above ground. Trees with many basal cracks should be cut as soon as possible.

18. Old fire wounds are often associated with swollen butts, internal cracks, and advanced decay to 3 or more meters above ground.
19. Increment borer wounds are associated with long streaks of discolored and decayed wood.

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CENTRAL HARDWOOD NOTES

Root Rots

Root rots of central hardwoods are diseases caused by fungi that infect and decay woody roots and sometimes also invade the butt portion of the tree. By killing and decaying roots, root rotting fungi reduce growth, decrease tree vigor, and cause windthrow and death. The most common root diseases of central hardwoods are Armillaria root rot, lnonotus root rot, and Ganoderma root rot.

Root rot fungi spread above ground by air-borne spores produced in fruiting bodies that vary in appearance from fleshy mushrooms to rubbery or woody conks. These fruiting bodies are found on or near infected trees or stumps, and are reliable outward signs of disease. Other indications of root rots may be dwarfed off-color foliage, dieback of the crown from the top down, decreased diameter growth, and windthrow. Unlike red oaks infected with oak wilt that rapidly wilt and die, hardwoods with root rot are often found in gradually enlarging groups (pockets) of slowly dying trees.

The fungi spread underground when healthy roots come in contact with decayed roots. Some of these fungi also spread by the growth of specialized fungal strands (rhizomorphs) that develop from decayed roots, stumps, or buried wood and grow through the soil to nearby healthy roots. Infection is more likely in trees that either have been wounded at or below ground, or that are being stressed from such factors as drought or insect defoliation.

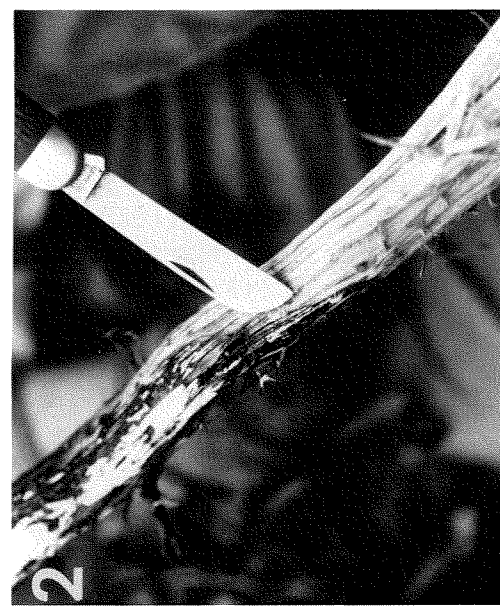
Potential damage from root rots should be considered when you plan intermediate cuttings and stand regeneration.

Intermediate Cuttings

Avoid making intermediate cuttings during seasons when wounding of residual trees is most likely-such as during the spring when bark is easily injured. Also avoid logging when the ground is soggy and equipment is more likely to compact the soil and to injure roots along skid trails and roads.

If a stand has been heavily or repeatedly defoliated or is stressed from prolonged drought, consider postponing intermediate cuttings to see which trees will die in response to the stress, and to avoid causing the additional stress that often occurs when a stand is cut.

When marking trees to be cut, keep in mind that the risk of root rots can be decreased by increasing species diversity, removing wounded and diseased trees, and avoiding soil compaction. Proper log road and skid trail layout will minimize wounding roots and lower boles of residual trees.

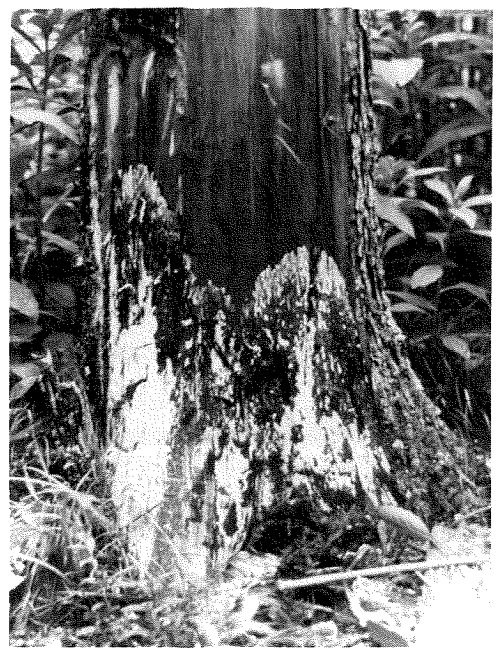


1 .-Removing tree to observe root disease.
2.-Armillaria under the bark on a woody root.
3.-A broken root at the point of Armillaria girdling.
4.-Armillaria at the root collar of a red oak.
(Philip Wargo)

Occasionally, root rot becomes so widespread and severe in a stand (e.g., following repeated severe defoliation by gypsy moth) that the only solution is to cut the entire stand and regenerate it to less susceptible species.

Regeneration

In general, root rots cause more damage to planted than to naturally regenerated stands. With artificial regeneration there is more chance for planting on improper sites, wounding seedlings, and bringing in disease-causing fungi on the planting stock (e.g., walnut root rot). When you select trees to be planted on former hardwood sites, choose species and seed sources that are best suited to that area because stressed trees are more susceptible to infection and damage by root rots. Species diversity, whether due to artificial or natural regeneration, will reduce the risk of losses due to root rots and other diseases and insects.



A white oak with root collar girdled by *Armillaria* (Philip Wargo)

Armillaria root rot often damages conifers planted on cutover hardwood sites. As hardwood stumps die, whether naturally or following herbicide treatments, *Armil-/aria* invades the stumps, uses them as a food base, and spreads via rhizomorphs through the soil to nearby conifer seedlings and saplings. If stumps produce sprouts, colonization of the stumps by *Armillaria* is either reduced or prevented. The greater the size and number of stumps on a site, the greater the risk of mortality to planted conifers. To delay planting after clearcutting is not an effective way to avoid losses since stumps can act as food bases for the fungus for 10 or

more years. If you can justify the costs, intensive site preparation up to or including stump removal reduces the food base for *Armillaria* and decreases the risk of subsequent disease. Whether there is similar risk to hardwood seedlings planted on cutover sites is not known.

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CENTRAL HARDWOOD NOTES

Reducing Borer Damage In Oak Regeneration And Sawtimber

Borers cause millions of dollars in damaged wood annually to oak stands, and adversely affect the form and vigor of oak regeneration. A moth and four species of beetles cause most of the damage; the carpenterworm moth, the oak timberworm, the red oak borer, the living-beech borer, and the white oak borer. The larvae of these insects chew holes in the wood ranging from shotholes made by the oak timberworm to holes as large as 20 mm in diameter made by the carpenterworm. The life histories of these insects are complex and can be found in the literature.

You can safely assume that unmanaged stands will sustain at least some-perhaps heavy--damage from one or more of the above borers. So you should manage oak stands to reduce borer damage.

In general, heavily-stocked slow-growing stands on poor sites have the most borer damage. Wet spots and/or fine to coarse sawdust-like wood particles around variable size holes on the trunks or at the bases of the trees are the usual signs of borer activity.

You can greatly increase the quality of your oak stands with little added timber stand improvement (TSI) cost by following these recommendations in your stand management:

1. Maintain stocking levels at optimum to promote good growth and quality (refer to current recommendations on managing oak stands). Most borers deposit eggs under bark scales or in holes made by the females on suppressed, slow growing trees. Vigorous trees with good sap flow can off en “drown out” young borer larvae especially in years of above normal rainfall. Vigorous trees can also better survive climatic stresses such as drought, late frosts, and damage from insects such as defoliators and root feeders.
2. Remove the small, suppressed, understory trees first in thinning. These suppressed trees in sawtimber stands serve as “brood” trees for borers that can greatly reduce quality of the overstory trees.
3. Cut rather than herbicide or girdle these trees. If left standing, girdled or poisoned trees become heavily infested with secondary dead wood insects. These insects furnish abundant food for woodpeckers, and reduce woodpecker predation on the primary (living tree) borers. Also, cutting promotes stump sprouts which add to oak regeneration potential at harvest. Otherwise, suppressed understory oaks in maturing oak stands may eventually succumb to a combination of insects, disease, and physiological factors.

4 Do your thinning in oak stands between August of odd-numbered years and late April of even-numbered years, especially if the killed trees are not removed or felled. TSI during this period kills first year larvae of several borer species, otherwise red oak borers can complete development into adults if TSI is done from late May of even-numbered years to July of odd-numbered years.

5 Leave non-oaks for den trees where possible, or substitute den or nesting boxes when wildlife considerations are important. Although oak "wolf trees" are valuable for wildlife dens, they are generally borer "brood trees."

6 Remove trees damaged or killed by logging operations, vandalism, lightning or other causes promptly, especially where a very fine, white powder appears on the wounds indicating borer attacks. Such trees can produce heavy populations of oak timberworms and carpenterworms. In just 2 to 4 years insects from these trees cause damage to healthy trees in adjacent areas.

7 Make clearcuts as large as possible yet still compatible with other forest uses. Current research in Ohio indicates heavy borer damage to regenerating northern red oak 2 to 6 inches d.b.h. in small clearcuts adjacent to mature oak stands. Adult borers emerge from the tops and limbs of large oaks surrounding the opening and attack nearby young oaks which can be killed, deformed, or have their growth greatly retarded.

8 Thin black oak stems before the largest stem is 2 inches d.b.h. to avoid leaving the smaller stems of sprout clumps and the smaller side of forks near the ground. These are more susceptible to borer attack than the larger vigorous stems and can become brood trees.

Hardwood borers can also damage other economically important species, but to a lesser degree than oak. Damage from some borer species may be a localized problem related to site and/or climatic conditions or improper harvesting procedures such as delayed removal and processing of logs. Increasing the vigor and growth of some tree species such as black cherry and maple may increase attacks from peach bark beetles and the Columbian timber beetle so specific recommendations for borer problems in non-oak species should be sought from a forest entomologist familiar with local borer pests.

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CENTRAL HARDWOOD NOTES

Gypsy Moth

The gypsy moth is the most important hardwood defoliating insect in North America. Since its inadvertent introduction into Massachusetts in 1869, it has spread naturally south and west at approximately 5 miles per year. Long distance spread has occurred from human activities such as moving household belongings, camping equipment, motor homes, or other articles harboring life stages. In North America, gypsy moth tends to erupt every 8 to 11 years and defoliate forest and urban trees and shrubs. Gypsy moth larvae can feed on over 500 plant species, but they prefer oaks. Other species readily attacked include bigtooth and quaking aspen, willows, paper birch, American basswood, maple, eastern hemlock, eastern white pine, and larch. Yellow-poplar, ash, and dogwood are avoided. Forests composed of less than 50 percent oak have less than half the likelihood of being defoliated than those with higher percentages of oak.

Gypsy Moth Bioecology

Gypsy moth may be confused with other hardwood defoliators so it is critical to accurately identify life stages and understand the gypsy moth development and behavior. The buff brown egg masses are the life stage most often observed since they persist even after larvae have emerged (fig. 1). Viable egg masses are hard to the touch; hatched masses are spongy. Masses vary from 1/2-inch long, containing 75 to 100 eggs or less (dense, declining populations) to 1 -1/2 inches long, containing 700 to 1,000 eggs (increasing populations). Although egg masses may be found anywhere from the leaf litter to the tops of trees, most are laid in protected locations on the tree such as bark flaps, crevices and holes, or on the ground on rocks, fallen branches, and other debris.

Egg hatch begins in late April-early May and continues for 2-3 weeks. First instar larvae (caterpillars between their first and second moults) climb to the tops of trees and are wind dispersed on silken threads. Dispersal distance is usually only several hundred yards, but a small fraction of the hatch may be caught in thermal updrafts and carried a few miles. Inadvertent dispersal by man-rather than wind-is responsible for establishing gypsy moth in new areas.

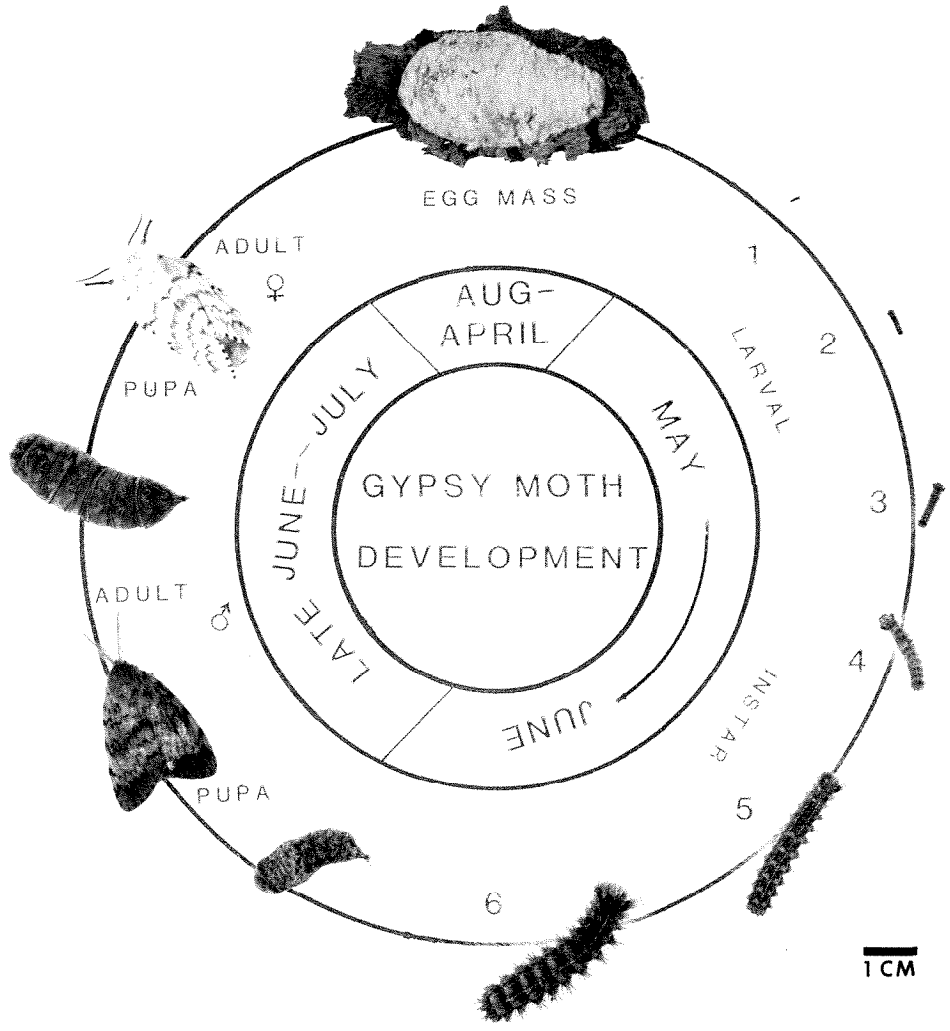

Figure 1 .-A generalized life cycle for gypsy moth in a northern climate depicting the time of year for each stage of the insect.

During the first three instars larvae remain in the tops of the trees. The fourth, fifth, and sixth instar larvae feed only at night, and descend the tree at dawn and rest under bark flaps, dead limbs, or other structures on the tree. Lacking such hiding places, they descend to the ground and rest beneath leaf litter, dead wood, or rocks. The brightly marked fifth and sixth instar larvae have 5 rows of blue dots and 6 rows of red dots along their backs. The last instar (fifth for males, sixth for females) causes 85 percent of total leaf consumption. Larval development is completed about 50 days after egg hatch, generally by late June to early July. Pupae are found in the same larval resting locations, adults emerge from pupae in 10 to 14 days. Both sexes are winged, but only males fly and are attracted to the flightless female by a sex pheromone (attractant). Eggs are laid immediately after mating.

Defoliation can lead to tree mortality but this depends on tree vigor, number and severity of prior defoliations, and the presence of organisms that attack stressed trees. Generally, if defoliation is severe enough to cause the trees to leaf out again the same year they are attacked; two or more consecutive defoliations significantly increases mortality. While trees may be killed directly by defoliation, most succumb to opportunistic organisms such as the shoestring rot fungus and two-lined chestnut borer. Mortality is the most visible result of defoliation but growth loss of surviving trees is also important. Highly susceptible stands have lost up to 17 percent of their timber value. So, potential mortality and growth loss must be weighed against protection costs when valuable stands are threatened with gypsy moth attack (see Note 6.14 *Using silviculture to Minimize Gypsy Moth Impact).*

Monitoring

Repeated surveys of egg masses, larvae, and adults are used by regional and state specialists to assess population trends and recommend action programs. Trapping male adults is an economical means to detect and delimit isolated infestation in newly invaded areas. Traditionally, egg mass surveys using the prism point sampling method or small plots or transects have been utilized to predict density and control measures. Many pest managers consider 250 large egg masses per acre a threshold for starting controls to keep defoliation less than 50 percent. Even though you are presently outside the gypsy moth area it is important to be able to recognize the life stages of this very serious pest. This is especially true if infestations are nearby and state and local monitoring programs are started.

Indirect Controls

An array of natural enemies attacks gypsy moth, including parasites, predators, and pathogens. Certain fly parasites, small mammal, bird and invertebrate predators help keep gypsy moth densities low. However, once populations expand beyond natural control, an outbreak occurs which terminates in 1 or 2 years by starvation or a virus epidemic.

Except for reducing the proportion of oaks in the stand, it is not clear what silvical procedures can be used to modify gypsy moth populations. Try to maintain and improve forest habitats important to predators. For example, you should avoid frequent disturbances, particularly those which destroy understory vegetation important to small mammals. Also maintain dead tree snags for cavity nesting birds. Try to reduce the number of nesting locations for larvae by: removing excessive numbers of broken tops or branches after a storm; removing “hard” litter such as old cans or trash metal; avoiding use of board-backed signs nailed to trees (larvae rest in the angles created).

Direct Control

If your forest is large you should: (a) assess stand values and vulnerability to gypsy moth; (b) maintain a system for monitoring densities of gypsy moth; and (c) be able to preemptively intervene at the correct time with an effective control. To date, larvae have been controlled through aerial spraying of biological and chemical insecticides and by insect growth regulators. Each gives predictable results when properly applied. Together they provide several options for various environmental, economic, and gypsy moth population considerations.

New approaches to gypsy moth management are under extensive study and development. You should consult federal and state agencies as well as universities, experiment stations, and cooperative extension service personnel to get the most up-to-date recommendations for control.

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CENTRAL HARDWOOD NOTES

Forest Insect Defoliators

Defoliation is the removal of all or part of the foliage from the tree. Forest insects are the primary agents that can cause defoliation. They produce the widespread, noticeable defoliation that forest landowners, foresters, and the general public can easily recognize.

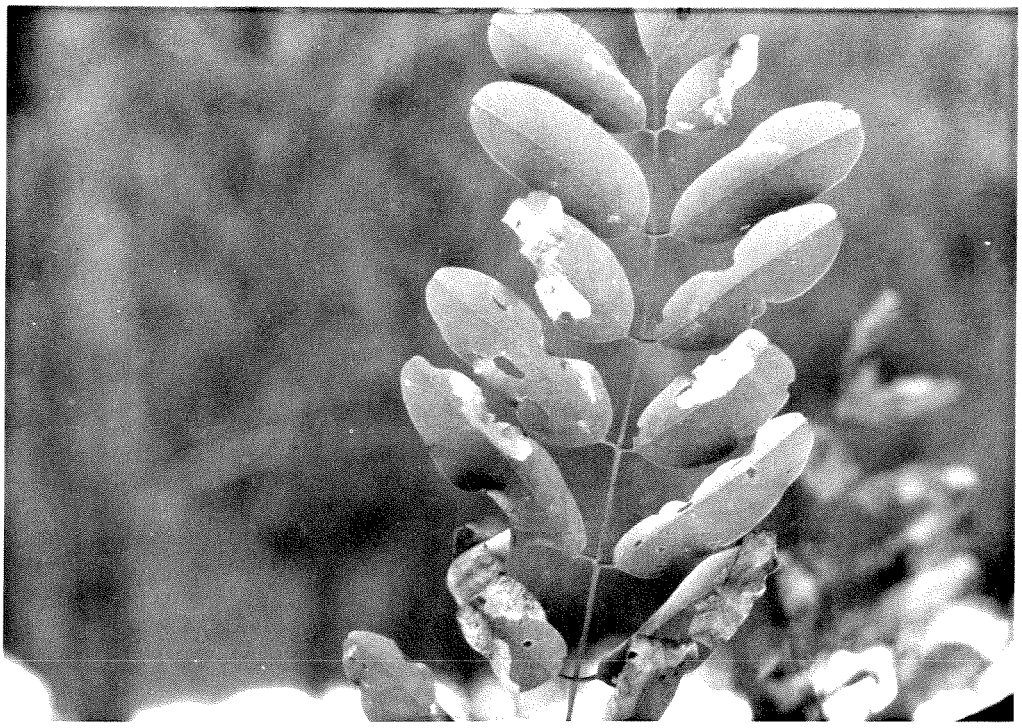
Classification

Forest insect defoliators can be classified or described in several ways: defoliation pattern on individual leaves, structures that they create from which to feed, the scientific insect order, and time of the growing season that feeding occurs.

Defoliation Pattern

Defoliators create many patterns of defoliation on the individual leaf. Some insects completely eat the leaf blade leaving only the large veins. Some create a "shot hole" pattern by eating holes in the leaf blade. Other insects make "leaf mines" by eating the middle layer of the leaf. And, one group makes a "skeleton" of the leaf by eating everything but the large and small veins.

"Shot hole" defoliation in sugar maple leaves. (Philip Marshall).



"Leaf mine" defoliation in black locust leaves (Philip Marshall).

"Skeleton" defoliation caused by the maple trumpet skeletonizer, *Epinotia aceriella* (Clem.). (James Hanson)

Feeding Structures

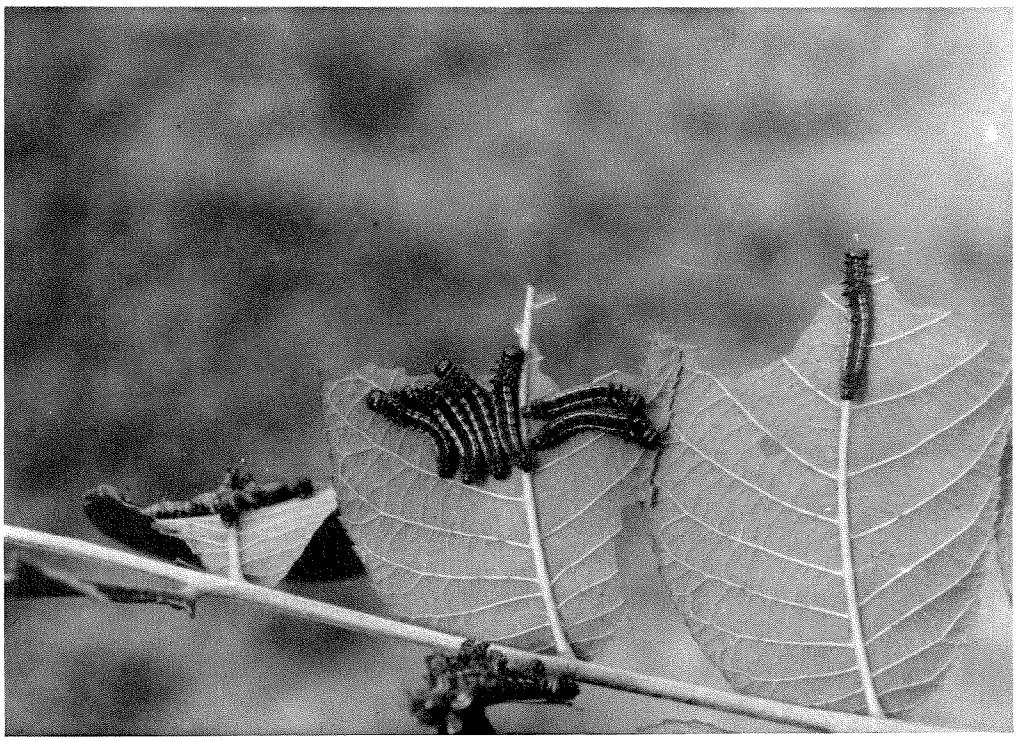
Forest insect defoliators are also classified by the structures that they create and use while feeding. These structures range in size from large “tents” holding hundreds of insects, to individual structures containing a single insect. Examples of these are webworms, leafrollers, leaftiers, bagworms, and casebearers.

However, many defoliators do not make a structure. They are called “free feeders” and eat individually or in groups.

“Tent” feeding structure of the eastern tent caterpillar, *Malacosoma Americanum* (Fabricius). (James Hanson)

"Web" feeding structure of the fall webworm, *Hyphantria cunea* (Drury). (Philip Marshall)

"Roll" feeding structure of the oak leaftier, Croesia *semipurpurana* (Kearfott). (James Hanson)



A "free feeder," the redhumped caterpillar, Schizura concinna (J.E. Smith), feeds in groups and eats the whole leaf. (Philip Marshall)

Insect Order

Forest insect defoliators can be classified scientifically by the order of insect, such as Lepidoptera, Hymenoptera, Coleoptera, Orthoptera, and Diptera. Common names or examples of the forest insect defoliators of these orders are caterpillars, sawflies, beetles, walkingsticks, and miners, respectively.

Time of Feeding

Forest insect defoliators can be classified as spring defoliators, spring/summer defoliators, or summer defoliators. Spring defoliators feed from budbreak until mid- to late June. Spring/summer defoliators feed from late May or early June until July or August. Summer defoliators feed from late June or early July through September. Generally, the forest insect feeds only during one of the three periods, but there are a few forest insects that feed in two or more periods, such as oak sawflies. Each defoliation period has a different impact on the health of the defoliated trees.

Forest Damage

The damage to the forest is primarily done by the immature and not the adult stage of the insect. It is the caterpillars, larvae, maggots, and nymphs that

defoliate the trees in the various patterns described above. The extent of damage to a tree or forest depends on the amount of leaves eaten and the time of the growing season when defoliation occurs.

Direct damage, such as growth reduction, twig dieback, and mortality, begins when more than 60 percent of the foliage is eaten. At this level of defoliation, the tree may be forced to refoliate by expending food reserves. The new leaves are smaller, lighter green, and not as efficient in photosynthesis. The depletion of stored food and the decreased efficiency in photosynthesis weakens the trees and increases chances of attack and death from Armillaria root rot and attack by the two-lined chestnut borer. These secondary forest pests are the main reason that trees stressed from defoliation, drought, or other disturbances die 1 to 3 years later.

Defoliators also damage the forest environment indirectly. The loss of foliage can have negative impacts on the watershed value and indirectly lower water quality. Defoliation can alter wildlife habitat and change or shift wildlife composition. The nuisance of insects, especially overabundant caterpillars, also discourages forest recreation.

The time that defoliation occurs also influences the damage to the forest. Spring defoliators are more likely to cause mortality than spring/summer and summer defoliators. The amount of twig dieback and growth reduction may also be greater for spring defoliators. Spring defoliation occurs just when the tree has already expended food to form leaves. If the defoliation is greater than 60 percent, the tree refoliates and even more food reserves are depleted. The new leaves do not totally replace food reserves, resulting in a weak tree that has a greater chance of dying. Trees that do not refoliate and simply use the damaged, less efficient leaves to produce food, are less likely to die, even though growth is reduced and twigs die back.

Spring/summer and summer defoliated trees may not refoliate even if more than 60 percent of the leaves are eaten. By this time trees have already replaced the food used to form leaves at the start of the growing season. They are not as weak and have a greater chance to survive with less growth reduction and twig dieback.

How to Recognize Defoliation

Generally, you will not notice that a tree has been defoliated until more than 25 percent of the leaves have been eaten. The first symptom will be a change in crown color from green to yellow green then toward reddish brown. You may hear what sounds like rain in the woods even though it is not raining. This is the excrement of the insects falling through the forest canopy. You might also observe or mentally note that more light is penetrating the forest canopy or that something “looks” different about a tree or a forest. But, the best way to recognize defoliation is to observe the actual insect feeding on the foliage.

How to Recognize Forest Insect Defoliators

Caterpillars (Lepidoptera) cause the most defoliation. Caterpillars are wormlike insects, from less than 1 inch to more than 3 inches long, with segmented bodies. They have one pair of legs on the 3 segments behind the head and one pair of legs on 2 to 5 of the remaining body segments. Color, markings, and degree of hairiness varies.

Sawfly larvae (Hymenoptera) are also common defoliators. They look like caterpillars except that more body segments have a pair of legs. They feed together in colonies.

What to do About Defoliators

First, with local or regional expert help, determine if there is a need to do anything based on economic and biological analysis, and forest management goals and objectives. From an economic standpoint the value of the timber resource and the potential mortality should exceed the cost of preventing defoliation. Biologically speaking, spring defoliators need greater consideration for control measures than the spring/summer or summer defoliators. Your management goals or objectives may or may not dictate the need for actions to prevent defoliation. There are several options to consider.

Option • Do Nothing

This option is more appropriate for the spring/summer and summer defoliators. Forest management goals may also favor this option. Biological evaluation of the insect population could also suggest that you do nothing, especially if the population will collapse from natural causes. Economic analysis may also show that the resource value protected is less than the cost of treatments.

Option • Prevent or Suppress Defoliation

This option will more likely be selected when spring defoliators are involved, and when biological and economic analysis indicate the insect population and defoliation will increase the next growing season or that the resource is vulnerable and highly valuable. The primary tool of this option is insecticides, either biological or chemical, applied by air. Silvicultural tools include harvesting timber and doing timber stand improvement, which alter forest composition to reduce future defoliation and improve the health and vigor of residual trees. Occasionally, both insecticides and silvicultural treatments are needed. To help determine if prevention/suppression are needed, consult with your local or regional forest pest specialist.

Option • Monitor the Forest Insect Population

Many forest insect defoliators have parasites and predators that help to control them. Monitoring surveys can (1) determine if the parasites and predators are providing or will provide adequate control, and (2) help predict the next season's defoliation potential.

Option - Integrated Pest Management (IPM)

The above options, analysis, and surveys can be combined into an approach called *Integrated Pest Management* or IPM. Under IPM, information on the pest and the above options can be incorporated into the management plan for the particular forest. IPM encourages more careful consideration of all aspects of forest insect defoliators and their relationship to specific forest environments and their potential for modification.

Expert Help is Available

Contact forestry experts or your state forest pest specialist for current information and assistance with the forest insect defoliators that may threaten your area. The references listed below will provide additional information on forest insect defoliators of the central hardwoods and assist you in their identification.

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CENTRAL HARDWOOD NOTES

Oak Decline

Oak declines are complex plant diseases that result when trees are first stressed by environmental factors and/or living organisms and are then invaded and sometimes killed by opportunistic secondary organisms.

Predisposing stresses		**Mortality-causing secondary organisms**
Environmental	Biotic	
Drought	Defoliation by insects (e.g., gypsy moth)	Bark borers (Two-lined chestnut borer)
Soil flooding		Root pathogens (Armillaria)
Winter injury	Defoliation by diseases (e.g., oak anthracnose)	Bark pathogens (Hypoxylon)
Late spring frosts		
Highway deicing salt		
Air pollution		

Some of the characteristics of declining trees may be:

1. Reduced shoot and diameter growth; smaller leaves
2. Dieback of twigs, branches, and roots
3. Sprouts arising from latent or adventitious buds
4. Chlorotic (yellowish-green) foliage
5. Premature fall coloration
6. Reduced stored food reserves
7. Reduced resistance to attacks by opportunistic pathogens and insects
8. Degeneration of mycorrhizae
9. Death

In general, red oaks are considered more susceptible to decline than white oaks Of the red oaks, black, scarlet, and pin oaks are especially sensitive.

Decline is typically initiated by a stressful agent such as an extended drought, or a severe or repeated insect defoliation. These lower tree resistance to pathogens and insect invaders that “healthy” trees can normally resist.

Here are some ways to ameliorate oak decline under forest conditions:

1. Thin stands cautiously to reduce competition for moisture and nutrients among trees. (You may want to check with experts on your specific problem. Some research indicates that tree mortality following stress is often higher in managed stands than in unmanaged stands. Presumably, managed stands contain

larger, faster growing trees that suffer more severely from adversity because of their size, growth demands, etc. Also, regular harvesting may maintain abundant, vigorous populations of *Armillaria* in the soil. Thinning just before or just after defoliation can kill crop trees and should be avoided.)

2. Encourage those species best adapted to each site.
3. Maintain several species to lessen impact of loss of the particular species.
4. Whenever feasible for high value areas, remove dead and dying trees promptly to prevent buildups of secondary invaders such as the two-lined chestnut borer.

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CENTRAL HARDWOOD NOTES

Diagnosing Forest Vegetation For Air Pollution Injury

The purpose of this Note is to help you become more technically informed about air pollution when serious problems need to be diagnosed by pollution specialists. (Except for ozone, most of the information discussed does not attempt to describe possible air pollution damage caused by long distance transport. This complex problem is currently under intense study.)

Air may be polluted by many components ranging in size from dust particles to invisible gases. Sulfur dioxide and nitrogen oxides may be produced when coal or oil are burned and industrial processes may release fluoride, chlorine, ammonia, hydrogen sulfide, and numerous other compounds. Farming operations may release components in fertilizer and chemical pesticides.

Of the long list of pollutants only three are important in causing leaf or needle injury. They are ozone, sulfur dioxide, and fluoride. The remaining pollutants may cause injury, but the injuries are usually limited to areas very close to the pollutant source, e.g., chlorine injury on plants near a swimming pool.

Ozone

Of these three important pollutants ozone is the most widely spread in the United States and is the most harmful. Ozone differs from most other pollutants because it is formed in the environment when sunlight causes a chemical reaction between other pollutants-nitrogen oxides and hydrocarbons. High levels of ozone may be found in both urban areas near pollution sources and in rural areas many miles from pollution sources.

High concentrations of ozone for short periods most commonly cause small flecks or stipples on the upper leaf surface of hardwood trees. Flecks may be either white, yellow, or tan and, if many are present, the entire leaf surface may appear chlorotic and bronzed. Stipples are small, dark, pigmented dots on the upper leaf surface and may be either red, reddish brown, reddish purple, or black. Low levels of ozone for long periods also injure hardwoods. With the initial exposure few symptoms may appear, but with additional exposures a few flecks or stipple-like symptoms may gradually appear and coalesce to give the leaf a bronzed or yellow appearance. This may later be followed by premature foliage drop.

The most common types of ozone injury on conifers are chlorotic mottling and tipburn Chlorotic mottles usually develop as small patches of yellow tissue surrounded by apparently healthy tissue. Tipburn is the term used to describe the condition in which the needle tip dies and becomes reddish-brown. The tip may break off.

The responses to ozone of both hardwoods and conifers are general symptoms and are often influenced by many factors including leaf age, host genetics, and environmental factors.

Sulfur Dioxide

Sulfur dioxide is produced by burning coal and oil, smelting ore, manufacturing steel, and refining petroleum. Sulfur dioxide is not as widely spread as ozone because it usually comes from "point" sources such as smoke stacks. Thus, sulfur dioxide injury to forests tends to be restricted to small areas directly downwind from its source.

High doses of sulfur dioxide will cause the death of tissue at the edge of the leaf and between the leaf veins. The injured area may become light tan to white after drying. The leaf areas near the veins are seldom injured and remain green, giving the leaf a herringbone appearance. Injury caused by low doses of sulfur dioxide have a similar injury pattern, but the injury is slightly more diffuse. Chlorotic yellowing may be observed on the leaf's edges and in the area between the veins. Again, the veins usually remain green.

Sulfur dioxide injury on conifers is very difficult to diagnose because symptoms are very similar to injury caused by other stress factors. The needle tips-and in some cases the entire needle-become reddish brown. Injured needles may also fall prematurely.

Fluoride

Fluoride pollution is usually a local problem. Hydrogen fluoride gas is released during the manufacture of aluminum phosphate fertilizer and other products. Fluoride injury in hardwoods usually appears as yellow or dead areas near the leaf margin or tip. With continued exposure, discoloration progresses toward the base of the leaf. In conifers fluoride causes tipburn and death of the needle tips.

Other pollutants also cause injury. The most common injury found after exposure to high doses of pollutants are yellowing or dead spots on broad-leaf trees and tipburn on conifers. Many of the injury patterns are similar to those caused by environmental stress factors such as drought.

Is It Really Air Pollution?

Distinguishing between injury from air pollution and injury from other causes is a very difficult process that is best approached through a series of logical steps. One approach is to answer the following questions:

1. Is there a pollution source nearby capable of causing injury? Are the symptoms consistent with nearby pollution sources?
2. What are the characteristics of the landscape? Does the terrain provide a pathway from the source? Can the terrain be the cause of injury, i.e., flooded lowland?

3. What are the injury patterns and what tissue is injured? (This is important because many stress factors produce symptoms that look like air pollution injury.)
4. What is the distribution of the affected plants? Is the pollutant from a point source or is it broadly dispersed?
5. Are any insects or diseases present? These kinds of injuries can look like pollution injury. You may have to consult a pathologist or an entomologist.
6. How many species are affected? Biological agents usually attack one species or host, whereas pollutants usually affect numerous specimens. Also, certain plants are very susceptible to certain pollutants and can be used as biological indicators for that pollutant.
7. What is the recent history of pesticide use, fertilizer applications, and similar cultural treatments in this area? injury may have been caused by chemicals used in the vicinity.

Answering the above questions will not always insure correct identification of the cause of foliar injury observed in forests. But this information will be very helpful to air pollutant specialists who should be contacted as soon as serious problems are encountered.

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CENTRAL HARDWOOD NOTES

Grazing In Central Hardwood Forests

Woodland grazing is a major forestry and land management problem in parts of the central hardwood region. Most forest grazing is by cattle and, to a lesser extent, hogs in woodlands adjacent to pastures or feedlots. The practice is particularly common in the cattle producing areas of the Corn Belt where often 50 percent or more of the upland forest is grazed. Woodland grazing has minor benefits for livestock but exposes them to poisonous plants, and causes extensive and long-lasting damage to the forest. Livestock benefits are primarily shade, forage, and protection from wind in winter, while the damages to the forest are numerous. For additional information, see Note 11.04 Grazing *Effects on Soil and Water.*

Tree Seedlings and Saplings

Livestock browse and trample seedlings, and push over small saplings to obtain the foliage. This leads to reduced stocking and productivity of present stands, and changes species composition and lowers production and values of future stands. Livestock browsing is very selective, and depends on species palatability. Unfortunately, many of the palatable trees include the more valuable yellow-poplar, white ash, northern red oak, and white oak. Black walnut is a notable exception. The tabulation on the following page shows the preferences by cattle for understory shrubs and trees.

A grazed hardwood stand. Note the low stocking and poor quality of the overstory trees and the absence of litter, shrubs, seedlings, and saplings. (Harold Scholten)

Note seedling and sapling reproduction on the right side of the fence where grazing has been eliminated. (Harold Scholten)

Readily browsed under light grazing	**Browsed under moderate grazing**	**Browsed only under heavy grazing**	**Rarely browsed, even under heavy grazing**
Yellow-poplar	Black oak	Shagbark hickory	American hornbeam
White ash	Scarlet oak	Dogwood	Eastern hophornbeam
Sugar maple	Bur oak	Black walnut	Common persimmon
Red maple	Pignut hickory	Honeylocust	Pawpaw
American basswood	Bitternut hickory		Eastern redcedar
Northern red oak	Shellbark hickory		Osage-orange
White oak	American beech		Hawthorns
American elm	Black locust		Devils-walkingstick
Red elm	Black cherry		Gooseberry
Blackgum	Sassafras		Multiflora rose
Redbud	American sycamore		Blackberry
			Buckbrush

Long-term grazing means that the forest understory and eventually also the overstory will consist primarily of the less palatable species on the right side of this tabulation, and will contain few or none of the species on the left side.

Forest Productivity and Value

Grazing lowers forest productivity and value by (1) reducing individual tree growth, (2) reducing stand stocking and growth, (3) changing the species composition, (4) reducing wood quality, and (5) reducing sugar maple sap and syrup yields.

Livestock trampling compacts the surface soil and damages the fine absorbing tree roots. This reduces the tree's capability to absorb water and nutrients and leads to moisture stress, crown dieback, reduced growth, loss of vigor, and increased susceptibility to insects and diseases. Heavy grazing can reduce sapling diameter growth 25 to 50 percent. Stocking and growth of grazed stands gradually decrease as overstory trees die but are not replaced because seedlings and saplings are scarce. Species composition changes because the few seedlings and saplings that survive are primarily the less palatable species such as shagbark hickory, eastern hophornbeam, or honeylocust, rather than the oaks, ashes, elms, or maples normally found in the understories of ungrazed stands. Wood quality is also reduced by grazing. Decay organisms enter the trees through wounds to roots or lower boles caused by trampling, rubbing, or bark striping. The wood of trees in grazed stands may contain dark stains that preclude their use for high quality lumber or veneer. Sugar maple sap and syrup yields are reduced 25 to 50 percent by grazing.

This grazed stand is so open that a grass sod has become established. (Harold Scholten)

Wildlife Habitat

Many wildlife species utilize woodlands for food, cover, burrows, dens, or nest sites. The destruction of essential habitat features greatly reduces the number and kinds of wildlife that can live in a grazed forest. One study in Ohio showed that the mammal and bird populations respectively were 40 and 75 percent less in a grazed forest compared to an adjacent ungrazed forest.

Esthetic and Recreational Values

The presence of livestock and the changes caused by grazing may dramatically reduce the esthetic and recreational values of forests for most people. Grazing reduces wildlife populations, eliminates many woodland flowering plants and shrubs, and causes streambank erosion, reduces water quality, and destroys desirable aquatic habitats.

Poisonous Plants

Central hardwood woodlands contain more than 100 woody and herbaceous plants poisonous to livestock. Fortunately, most of these plants are unpalatable and are not eaten by livestock when enough suitable forage or feed is available. Some important poisonous plants of central hardwood forests are:

- White snakeroot
- Dutchman's breeches
- Squirrelcorn
- Poison-hemlock
- Spotted waterhemlock
- Ohio buckeye
- Dwarf larkspur
- Bracken fern
- Oaks
- Black cherry
- Black locust

White snakeroot is a very common and highly toxic woodland plant that can cause a potentially fatal livestock condition known as "trembles." Drinking milk from affected cows can cause the potentially fatal "milk sickness" in calves and humans. Dutchman's breeches, squirrelcorn, and dwarf larkspur are all also known as "staggerweed" because of their effect on livestock, particularly cattle. Dwarf larkspur is especially dangerous because it is readily eaten by livestock. Spotted waterhemlock has been called the most dangerous poisonous plant in the United States because it is abundant and extremely toxic.

The leaves, young shoots, and buds of oaks are poisonous to livestock in large quantities, and acorns (especially unripe acorns) are toxic to cattle. Black cherry leaves contain a harmless glucoside which rapidly converts to hydrogen cyanide when they wilt or are bruised. The leaves, pods, and seeds of black locust are poisonous, as are the leaves, buds, bark, and seeds of Ohio buckeye.

Benefits of Grazing

The benefits of woodland grazing are primarily shade, forage, and protection from winter wind. Shade reduces heat stress in livestock, and is especially beneficial in hot weather to cattle with elevated body temperatures associated with fescue poisoning.

Forage in grazed woodlands consists primarily of the grasses and sedges in open forests. Forage production in grazed woodlands ranges from less than 30 to more than 300 pounds dry weight per acre per year. In contrast, improved pastures in the Midwest produce from 3,000 to 10,000 pounds per acre per year. Woodland forage is also significantly poorer in protein, sugar, and digestable carbohydrate content than forage grown in open pastures.

In Summary

The best management for both livestock and the forest is to keep the two separate. If shade or winter protection are an important consideration when fencing between a pasture and a forest, leave small areas of trees in the pasture while protecting most of the forest. The increased income from a properly managed, ungrazed forest will usually more than offset the fencing cost and, in the long run, livestock, trees, wildlife, landowners, and their families, friends, and neighbors will all benefit from keeping livestock out of the forests.

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CENTRAL HARDWOOD NOTES

Principles Of Wildlife Habitat Management

Simply stated, habitat is where an animal lives and must include all the resources an animal needs to survive and reproduce. An animal's habitat has to provide five essential factors: food, cover, water, space, and interspersion. Habitat management is identifying which factors are scarce enough to limit populations, and then improving the habitat to remove the limiting factors. By putting your efforts on limiting factors you will get the greatest response in wildlife populations for the resources expended. You must accurately identify limiting factors, to avoid unnecessary efforts on nonlimiting factors.

Wildlife Habitat and Ecological Succession

Most habitat management consists of either increasing or decreasing certain plant communities, or reordering their composition because different wildlife species are adapted to particular plant communities. So habitat management is really managing successional stages.

Once the association between successional stages and wildlife habitat is understood, then broad management actions can be based on three questions:

1. What is the present successional stage?
2. What successional stage is needed by the wildlife species you want?
3. How do you move from the present stage to the stage you want?

Answers to questions 1 and 2 are relatively straight forward but require knowledge of ecological succession in your area, an inventory of the different communities, and some knowledge of the biology and ecology of the wildlife species to be emphasized. Answering question 3 is more difficult. Treatments to accomplish this task include prescribed burning, planting, mechanical and chemical treatments, and thinning and harvesting. You must decide which treatment is within budget, manpower, and environmental constraints. If early successional stages are maintained, frequent treatments may be required. On the other hand, maintaining climax communities may only require protection.

Interspersion and Edge

Interspersion is an essential habitat component that is often overlooked or underrated. Interspersion is the geographic distribution of an animal's habitat resources in relation to its cruising ability or mobility. For wildlife with a low cruising ability, the amount and quality of food, water, and cover in the habitat may not be as critical as how these resources are distributed. Many times habitat can be substantially improved by increasing the level of interspersion without changing the relative amounts of food, water, and cover.

Greater interspersion increases the amount of edge in a habitat. The number and kind of wildlife species is usually greater along edges than in either community forming the edge. When wildlife species associated with edges are being emphasized, management should be directed at increasing the amount and quality of edge. Rectangular shaped habitats have more edge per area than either circular or square shaped habitats. Edge quality should receive equal consideration. An edge formed by a forest stand and fescue pasture is lower quality for white-tailed deer and cottontail rabbits than an edge formed by a forest stand and an old field of bunch grasses, brush, and forbs. Further, abrupt edges are not as valuable as gradual transitions between communities. A transition zone is actually a separate habitat type. This zone may be used by wildlife that are not present in communities on either side.

The width of a transition zone can be increased by "feathering" the outside edge of a forest stand by removing the larger trees within 30 feet or more from the stand's edge and leaving scattered small trees and shrubs. Slash can be stacked on stumps, piles of rocks, or cull logs to provide wildlife with easy access under brush piles. If the edge is associated with an opening or field that is regularly plowed, mowed, or burned, the outside 30 feet or more can be set aside and treated only frequently enough to control invading woody species. Or several rows of plants selected for wildlife can be established along the edge of the field or opening.

Inherent Conflicts

Management goals are usually set to improve the habitat for a single wildlife species or groups of species. However, there can be conflicts inherent in these goals. Conflicts result because enhancement made to benefit some wildlife destroy habitat for other wildlife. For example, maximum habitat diversity is a common management goal. However, this approach could fragment contiguous stands of mature hardwood forest. While overall species richness would increase with increased habitat diversity and edge, species needing large blocks of forest may be eliminated. Some forest species have minimum habitat size requirements and will not occupy areas smaller than this critical size. Minimum size requirements must be accommodated if certain area-sensitive species are to be encouraged. The popular maximum diversity approach has been criticized because the value of individual wildlife species or special resource features may not be adequately considered.

When you consider diversity, it is important to remember the scale at which the concept will be applied. The lowest level is within a forest stand or small woodlot. The next level is the diversity within a compartment or management unit. The highest scale is the diversity within a large geographic area or region. Most managers are concerned with the smallest and next level of diversity. Usually the area and resources involved are not sufficient to completely avoid the inherent conflicts of fragmentation previously discussed.

However, resource managers of small tracts should consider the needs of individual species and special features in their prescriptions. Owners should be informed of these special needs and how their tracts can fit into a broader scheme for habitat management that includes neighboring tracts.

Some managers and most resource agencies have the opportunities to develop habitat management strategies at the highest diversity level. In these cases planning procedures should ensure that individual species and special resource features are considered in the alternatives. For large areas, the needs for both edge-sensitive and area-sensitive species can be met. For a region as vast and diverse as the central hardwoods, resource managers and land owners collectively need to be committed to a wide variety of management approaches to meet the needs of all wildlife species. It would be tragic to foster a "uniform" management that creates habitat for wildlife that may already be abundant at the expense of reducing habitat for species that are scarce.

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CENTRAL HARDWOOD NOTES

Wildlife Habitat Evaluation

To evaluate wildlife habitat you need to answer the following questions related to the three basic habitat components-food, water, and cover.

1. Is the area you are evaluating a single forest stand, shrubland, or grassland which will provide a single uniform habitat type? Or, are you evaluating a large forest management area made up of a number of stands whose age, density, species mix, etc., are (or could be) different and thus provide (or could provide) a number of different habitats?

The answer to this question will determine what wildlife species you can manage the unit for, and will also determine the type of evaluation procedure you should use. For example, a 40-acre woodlot could support a squirrel population nicely, but would only meet part of the needs of a deer population.

2. What single species or group of species do I want to evaluate the area for?

This is probably the most difficult question to answer. Yet, answering it is absolutely essential before you can evaluate the habitat. One must identify the species so the proper habitat characteristics can be evaluated. Even if you want a general assessment of a stand's potential for wildlife, you need to select a list of species you are interested in and evaluate the habitat value for each. There is no realistic way of averaging across species for a single 'wildlife" habitat value.

Many wildlife species have habitat requirements which overlap. So, selection of a particular species for your management objective may exclude some but not all other wildlife species from your area. Selecting white-tailed deer would not exclude squirrel or quail. Selecting bobwhite quail might, however, limit viable populations of squirrel or other species due to the greater difference in habitat needs.

3. Why am I conducting this evaluation?

The answer to this question will off en determine the information needed including the level of detail and accuracy. If the evaluation is part of an environmental impact analysis for a land management practice on a particular endangered species, then the species' habitat needs will dictate procedures. The procedures should provide sufficiently detailed answers to withstand judicial scrutiny. If the habitat evaluation is to provide a private landowner information on what a woodlot

"is good for," then the techniques employed can be less specific. The best habitat evaluation may be a simple 'walk-through" by the landowner and an experienced wildlife professional to provide a general idea of the habitat value of the land.

Evaluation Tools

Evaluating an area's capability to support a population of a given wildlife species means measuring habitat characteristics that are important to the well-being of that species. Habitat characteristics often include tree species, density, and age distribution; presence of snags or cavities; make-up of ground vegetation; distance to water; or special features such as caves. Measurements can be general such as present or absent; high, medium, or low density; or very detailed, precise quantities.

Key habitat characteristics can be combined mathematically, graphically, or subjectively to provide **a** habitat value. The habitat evaluation method can be a simple **1** -sheet questionnaire needing **general** categorical answers, or mathematical computations requiring substantial amounts of fairly precise data. Commonly used habitat evaluation techniques lie between these two extremes. If you need a detailed evaluation of the wildlife habitat on your property, you should seek professional assistance from the wildlife section of your state conservation agency; Federal agencies such as the Fish and Wildlife Service, Forest Service, or Soil Conservation Service; or a local university or college which has a forestry or wildlife extension program.

Habitat Suitability Index (HSI)

A habitat evaluation using a HSI results in an estimate of the value of the area for a wildlife species. It is a relative measure used to compare one piece of land (a single stand or uniform habitat unit) with another or with the theoretical optimum. It is not an estimate of the wildlife population size.

Habitat suitability procedures are available for many wildlife species and require measuring a number of habitat variables. The procedure for a particular wildlife species tells you which habitat variables to measure, how to measure them, and how to combine them to produce the final index. This index will indicate which variables may be limiting. So you may be able to improve the habitat for the species of interest by treating the stand to enhance the limiting variables. High index values indicate better habitat than low values.

Appendix 1 contains an example of how to use HSI for the eastern gray squirrel.

Pattern Recognition (PATREC)

This procedure provides an estimate of an area's potential wildlife population size by combining habitat variables with the known probabilities of animal presence or

absence. It is most appropriate for evaluating multiple stands (forest compartment or larger). As its name implies, it is based on recognizing the likelihood of a high or low population of animals being present given a certain pattern or arrangement of habitat types.

Again, you must first choose which wildlife species you want. The PATREC procedure for the chosen species will tell you which habitat variables to measure, how to measure them, and how to combine them to get the potential population estimate.

The value for each habitat variable measured provides a probability estimate of both high and low populations of the selected wildlife species in the area. This method also uses an overall probability of there being a high or low population of the wildlife species based on historical experience in this or similar areas. These probabilities are all mathematically combined to provide an estimate of the likelihood of there being a high or low population in the area. This final estimate is combined with historical high and low density estimates to produce a potential population estimate for the selected wildlife species in the area surveyed.

When you have the final estimate, you can then look at the variables and determine which ones might be improved by some treatment in order to increase the potential population.

Appendix 2 shows how to use the PATREC procedure adopted by the Mark Twain National Forest for the eastern wild turkey.

Habitat Evaluation

The procedures and the habitat values discussed are generally more readily available for popular game species and publicly sensitive endangered species, than for other species which have not had such high research or management focus. Having an evaluation procedure (HSI, PATREC, or other) is just one part of the evaluation process. You also need inventory data to determine values for habitat variables.

Habitat features such as average tree d.b.h., or stand age and density, can be obtained from standard forest inventories. Unique habitat features such as snags of a given size, ponds of a certain depth, etc., often require separate, specifically designed surveys. Unfortunately, most habitat evaluation procedures do not provide detailed habitat survey guidelines. The HSI procedures published by the U.S. Fish and Wildlife Service are a notable exception.

The habitat values provided by these evaluation procedures are more than relative comparisons between areas. The procedures can also be used to identify which habitat variable is most deficient in support of your selected wildlife species. By inserting different values for a given habitat variable that can be altered

through management while holding the value of all other variables constant, you can estimate where you can obtain the greatest wildlife benefit for management investments made.

The precision of the evaluation procedure depends on the precision of the habitat variable estimates. If only a general indication of wildlife value is needed, use rough, easily obtained estimates of habitat data. If the evaluation is more critical, then the habitat survey must be carefully designed to produce precise estimates of habitat conditions. In the latter case, the assistance of a natural resource professional (wildlife biologist, forester, field research scientist) is essential.

Finally, the user must realize that the habitat suitability index or potential population estimate provided by these evaluation procedures are indirect estimates. Interpretation of the resulting index or estimate must be tempered with a clear understanding of the limitations and assumptions within the evaluation procedure. And, realizing it is only an index or estimate, it should be only a part of the information used to make land management decisions for wildlife.

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APPENDIX 1

How to Determine Habitat Suitability Index for Gray Squirrels

Measure the following habitat variables:

- v1 = Percent crown cover of trees that produce hard mast that are 10 inches d.b.h. and larger (oaks, hickories, walnut, pecan, beech).
- V2 = Number of different tree species that produce hard mast.
- V3 = Percent crown cover of overstory trees in the overstory.
- V4 = Average d.b.h. of all overstory trees.
- V5 = Percent crown cover of shrubs.

Assume the inventory produced the following values for each variable:

- V1 = 25 percent
- v2 = 2
- V3 = 90 percent
- V4 = 12 inches
- V5 = 30 percent

Convert these values to indexes using figure 1. For this example, follow the dashed lines on the charts. This conversion provides the following indexes:

- V1 = 0.60
- v2 = 0.50
- v3 = 0.88
- v4 = 0.70
- v5 = 1.00

Combining the first 2 variables provides an index of winter food availability:

$$\sqrt{V1 \times V2} = \sqrt{0.6 \times 0.5} = 0.55$$

Combining the other 3 variables provides an index of cover:

$$\sqrt{v3 \times v4 \times v5} = \sqrt{0.88 \times 0.70 \times 1.00} = 0.78$$

The habitat suitability index is the lowest of the 2 values (0.55) that result from combining the variables, and indicates that winter food is the limiting habitat factor, and as a median value indicates that the stand can be considered moderate to good habitat for gray squirrels.

To increase winter food availability will require increasing the crown cover of hard mast species and/or the number of hard mast producing species. You cannot increase the number of hard mast species at this stage. However, a thinning that removes non-mast species would in the long run increase the crown cover of the hard mast producers and thus increase the index for winter food availability.

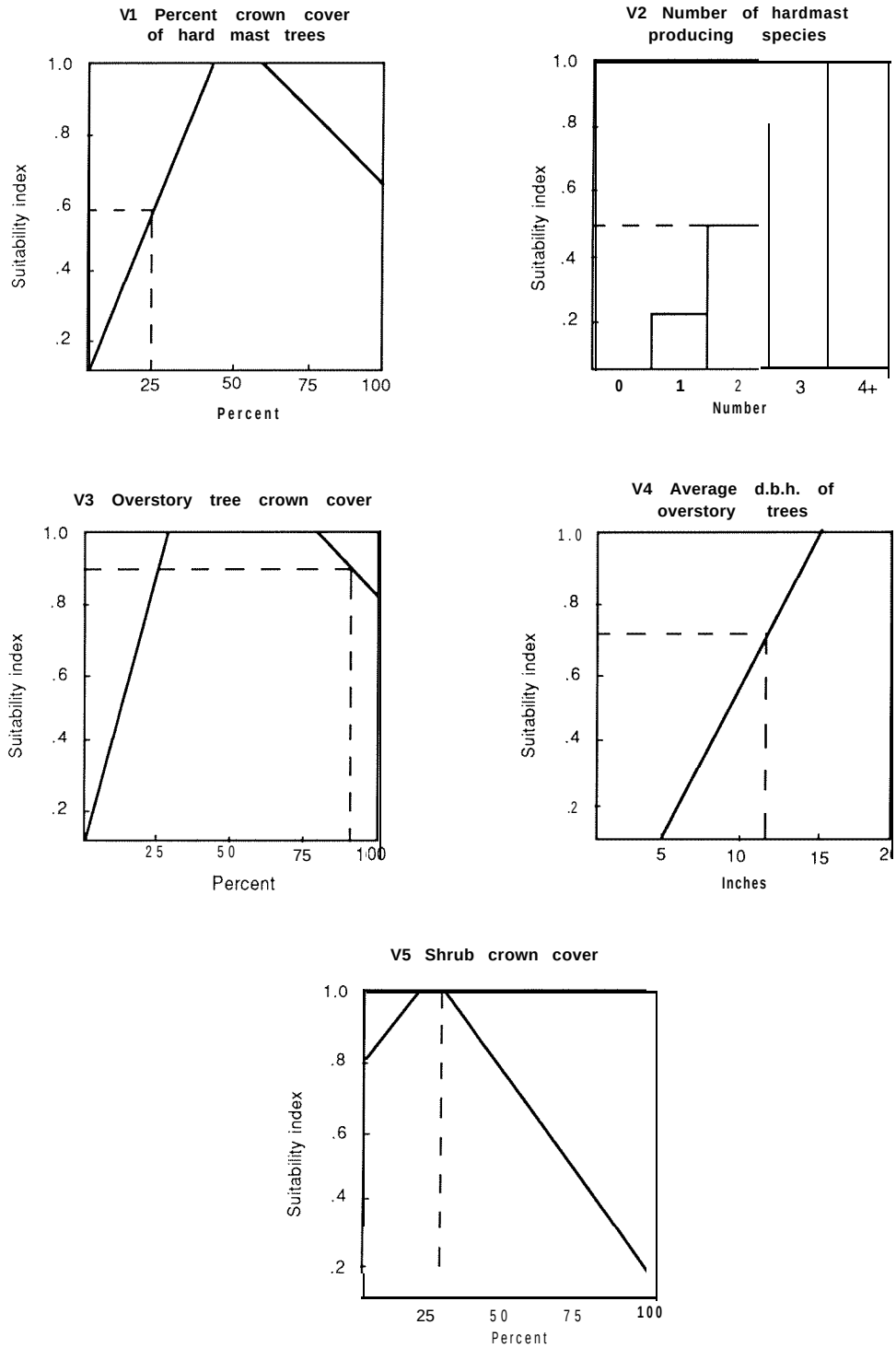

Figure 1 .--Habitat suitability variables and indexes for gray squirrel.

APPENDIX 2

Pattern Recognition Procedure for Eastern Wild Turkey on the Mark Twain National Forest

This procedure requires measuring the 8 habitat variables listed in table 1.

Assume the habitat inventory provides the following values:

V1 = 50 percent
V2 = 50 percent
V3 = 35 percent
V4 = 100 percent
V5 = None
V6 = 100 percent
V7 = None
V8 = 100 percent

Then select the high and low probabilities from table 1 that correspond to the measured values. This produces the following tabulation:

	Probability	
Variable	High	Low
1	**0.15**	**0.25**
2	**0.15**	**0.30**
3	**0.15**	**0.30**
4	**0.50**	**0.10**
5	**0.05**	**0.50**
6	**0.05**	**0.50**
7	**0.05**	**0.50**
8	**0.40**	**0.10**

The calculations are performed as follows:

Multiply all of the high probabilities:
High = 0.15 x 0.15 . . . x 0.05 x 0.40 = 0.00000002

Multiply all of the low probabilities:
Low = 0.25 x 0.30 x 0.50 x 0.10 = 0.0000225

Divide High by High + Low
High probability = 0.00000002/(0.00000002 + 0.0000225) = 0.0009

Divide Low by High + Low:
Low probability = 0.0000225/(0.00000002 + 0.0000225) = 0.9991

Multiply the high and low probabilities by the respective historical population densities (table 1) and add the resulting values:

Population density = (0.0009 x 24) + (0.9991 x 8) = 8.01

The estimated potential population for the current habitat is 8 birds per 1,000 acres.

The potential population can be increased by manipulating some of the habitat variables to increase the high probabilities. In this case, there are several options that could be considered. We could convert some of the open areas from hay or pasture to cultivated crops or food patches and plant wildlife shrubs in others. This would increase the high estimates for variables 5, 6, and 7. We might also plant forest trees in some of the open areas to eventually reduce the total area in open and semi-open habitats.

Table 1 *.-High **and** low probabilities for eastern wild turkey habitat variables*

Variable	Class	Probabilities	
		High	Low
1[1]	Percent of the area in open and semi-open habitats (old fields, pasture, hay or crop land) excluding forest regeneration areas, by distribution class (poor, medium, well).		
	16-40 well distributed	0.50	0.10
	5-15 well distributed or 16-40 poorly distributed	0.25	0.15
	5-15 medium to well distributed or 41-65 well distributed	0.15	0.25
	41-65 medium to poorly distributed or More than 65 open or Less than 5 open	0.10	0.50
2	Percent of area in open and semi-open habitats without regard to distribution.		
	15-24	0.30	0.20
	25-40	0.50	0.10
	41-60	0.15	0.30
	Less than 15 or more than 60	0.05	0.40

(Table continued)

(Table continued)

Variable	Class	Probabilities High	Probabilities Low
3	Percent of total forested area in oak-hickory, oak-cedar, and oak-pine types 50 years of age or older.		
	Less than 30	0.05	0.40
	30-44	0.15	0.30
	45-59	0.30	0.20
	Greater than 59	0.50	0.10
4	Percent of area in oak-hickory, oak-pine, and pine in sawtimber-size stands with 20 to 30 percent ground cover of forbs, grasses, and low shrubs.		
	Less than 20	0.05	0.40
	20-39	0.15	0.30
	40-49	0.30	0.20
	Greater than 49	0.50	0.10
5	Percent of open and semi-open habitats in crop lands (cultivated).		
	15-29	0.15	0.30
	30-49	0.30	0.15
	50-60	0.50	0.05
	Less than 15 or greater than 60	0.05	0.50
6	Percent of open and semi-open habitats in hay or pasture, either cool or warm season grasses.		
	20-30	0.50	0.05
	31-40	0.30	0.15
	41-50	0.15	0.30
	Less than 20 or greater than 50	0.05	0.50
7	Percent of open and semi-open habitats in shrub-grass habitats.		
	1 O-20	0.50	0.05
	21-30	0.30	0.15
	31-40	0.15	0.30
	Less than 10 or greater than 40	0.05	0.50
8	Percent of total area within one-half mile of permanent water.		
	Less than 25	0.10	0.40
	25-49	0.20	0.30
	50-74	0.30	0.20
	Greater than 74	0.40	0.10
	Historical population probability	0.20	0.80
	Historical population density in birds per 1,000 acres	24	8

[1] How well the open lands are distributed (poor, medium, well) can be determined by diagrams available from the Wildlife Biologist, Mark Twain National Forest, 401 Fairgrounds Road, Rolla, MO 65401.

CENTRAL HARDWOOD NOTES

Treating Seedling And Sapling Stands For Wildlife

What you want to focus on during the seedling-sapling stage is understory development and species selection. By thinning newly regenerated stands you increase sunlight and therefore the abundance and nutritional value of herbaceous vegetation. Thinning allows you to favor understory species that provide browse, forage, and seeds for wildlife. Precommercial thinning in sapling stands should promote vertical and horizontal diversity. This will benefit both timber and wildlife as stands mature.

Precommercial thinning can be used to favor mast-producing species. Encourage a variety of trees and shrubs for a more diverse habitat. Maintain a wide spacing (greater than 10 x 10 feet) between selected crop trees to delay canopy closure. If canopy closure is held below 50 percent during the sapling stage, residual tree crowns will develop rapidly and a diverse understory will flourish. All competing trees within 5 feet of selected mast trees should be cut.

Strive to maintain a combination of some hard mast trees like oak and hickory, soft mast trees like dogwood and blackgum, and mast-producing shrubs in every 5-acre patch. The oak species having the most consistent acorn production should be favored during thinning operations; i.e., red oaks in the Appalachians and a mix of red and white oaks in the Ozarks. Thinnings should be made during winter in areas where deer use is heavy. Slash available as browse will reduce feeding pressure on seedlings.

Pile slash from thinnings loosely to provide cover. Also slash piles can be used to protect trees and shrubs susceptible to deer browsing. Additional cover can be provided by "half-cutting" trees that are 6 to 8 feet tall. Make cuts 3 to 4 feet above the ground half way through the stem and then push the top over to provide a living brush pile. Avoid livestock grazing. For additional guidelines see Note *6.03 Silviculture Treatments in Sapling Stands.*

Maintain 10 to 20 percent of oak-pine stands in pines, in blocks no larger than 2 acres. Pine clumps provide shelter and cover for many wildlife species.

"Daylight" roads (cut back roadside woody vegetation) in a 25- to 50-foot band to encourage sapling growth. Don't cut back the entire road border at the same time, but in stages to provide valuable habitat. Old log landings in seedling and sapling stands can provide valuable habitat. They should be cleaned of woody debris so they can be mowed once every 3 years. They can also be planted with legumes, but first test the soil so it can be properly limed and fertilized before planting. For additional information *see Note 9.08 Logging Roads and Log Decks for Wildlife Habitat.*

Openings are an essential ingredient of any forest stand being managed for wildlife including sapling stands. Openings should be 1 to 10 acres, irregularly shaped, and occupy at least 5 percent of the stand. Make them adjacent to roads or trails to improve access by wildlife. Openings on poor sites will last longer and cost less. Such sites include narrow ridges, southwest exposures, and natural frost pockets. For additional information *see* Note 9.11 *Wildlife Openings.*

Don't prescribe fires during the seedling and sapling stage until trees are old enough to tolerate a light burn. Although burning increases wildlife food and cover, it should not be done from May through June when wildlife is most vulnerable.

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CENTRAL HARDWOOD NOTES

Treating Immature Stands For Wildlife

Immature stands include those up to 60 years old or in the sapling, pole, and small sawtimber size-class. Immature stands, particularly in the sapling or pole stage, present a challenge to the wildlife manager. Compared to either younger regenerating stands or more mature stands, pole-size trees do not provide much mast or forage beneficial for wildlife (fig. 1).

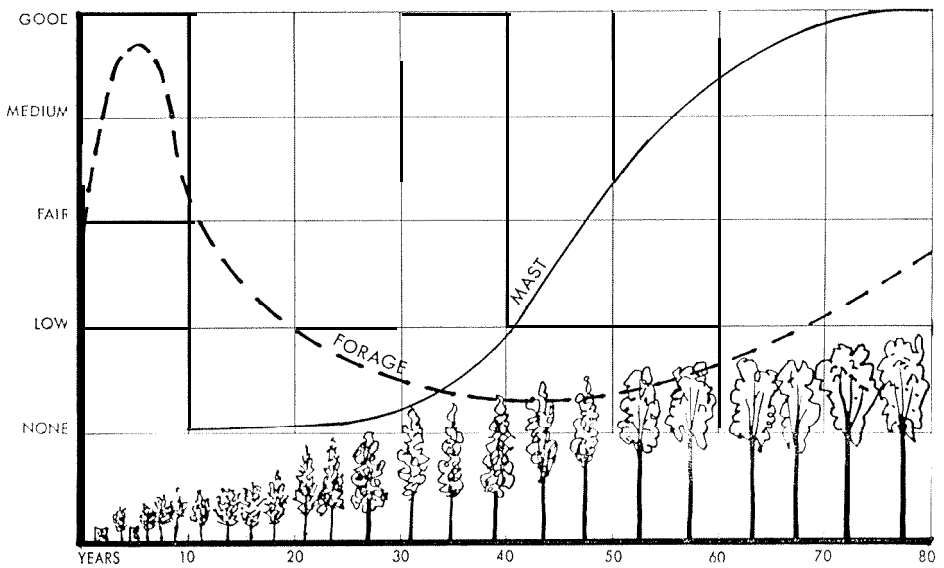

Figure 1 .-Relationship of mast and forage production to stand age for even-aged central hardwood stands.

There are good reasons for the scarcity of wildlife food and cover. Immature stands consist mostly of trees too young to produce abundant mast and too small to provide many dens. Although these stands are usually well-stocked, stem density in pole stands is well below that of seedling-sapling stands which provide the best cover for ruffed grouse, rabbits, and other small mammals. Slash left from the regeneration cut has decomposed by the pole stage. Blackberries, grasses, and forbs abundant in regenerating stands have been shaded out and the shade-tolerant undergrowth characteristic of mature stands has not yet developed. So immature stands tend to be deficient in five important habitat elements: herbage, browse, cover, mast, and cavities.

The options for treating immature stands are often limited by the small size and low value of the trees. Precommercial practices can be used, but in many cases it is best to do nothing and reschedule an examination in 5 or 10 years. The abundance of herbage, browse, mast, and cavities will increase as the stand matures. It is important to remember that in a managed forest the quality of wildlife habitat depends on the entire mosaic of a number of individual stands. It is not necessary to "improve" every pole stand when habitat is provided in nearby younger and older stands.

However, when thinning is practical it can increase herbage and browse, and release mast and cavity-producing crop trees. Thinning to promote understory development for wildlife requires heavier cutting than is usually done for timber production alone. In general, you should thin toward C-level stocking, rather than B-level (see Note 5.02 Stocking *Chaff* for *Upland Central* Hardwoods). Consider completely releasing the crowns of mast producers and den trees. The gap in the canopy around the 'wildlife crop tree" will also improve herbage and browse production.

When marking immature stands for thinning, do not discriminate on a species basis; work with what is available in each stand. Favor uncommon species over common ones, good form over poor form, vigorous trees over weak ones, mast producers over non-mast producers, and trees with dens or nests. Thinning at about lo-year intervals will promote understory development, and the temporary disturbances are not detrimental to wildlife.

Retain den and nest trees during thinnings. The best den and nest trees are alive and vigorous. They have internal columns of decay which formed where a large limb was lost or some other injury occurred. Active mammal dens often have fresh gnawing on the callous tissue around the entrance, and bird nest holes will have smooth, worn entrances. In young stands, trees left during the last harvest often provide the only large den trees. Save residuals that have the potential to survive until the next thinning, can produce mast, or have active dens or nests. All trees with mammal dens or woodpecker nests should be reserved from cutting.

Saving all den and nest trees will generally have little impact on timber volume or stand quality. For example, in Massachusetts oak stands, trees with dens and nest cavities accounted for an average of 3.8 percent of the total basal area. Most of the rough cull and rotten cull trees did not contain cavities and could be removed during timber stand improvement.

About half of the cavities in trees are not suitable for dens or nests where young animals can be reared. Although we do not place high priority on these trees, they should be cut only when there is a good silvicultural reason for doing so. Dead trees should be cut only when they can be used or sold.

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CENTRAL HARDWOOD NOTES

Treating Mature Stands For Wildlife

Stands older than 60 years or that are medium to large sawtimber size generally provide good wildlife habitat. Mature trees usually produce abundant mast and provide den sites (see fig. 1 in Note 9.04 Treating Immature Stands). The understory growth in these stands produces moderate amounts of browse and herbage Mature stands also provide opportunities for management because medium-to-large sawtimber-size trees are valuable for timber products.

Even-aged management (EAM) systems are often recommended for the oak-hickory, oak-pine, mixed mesophytic, and elm-ash-cottonwood forest types. EAM can produce quality sawtimber and abundant, diverse wildlife communities as well. Regular thinning through the life of even-aged stands will enhance the yield and value of timber products and in addition, thinning can promote tree species and vegetative structures beneficial for wildlife. Finally, EAM regenerates shade-intolerant trees that are a vital habitat component for many wildlife species inhabiting these forest types.

Thinning

To produce the most benefit for wildlife, thinning should favor mast producing trees and retain den trees. Cutting also increases understory, browse, and herbage production. Follow the prescriptions in the stocking guides for the particular timber type. Modify cutting guides to (1) retain active den trees, (2) leave unsalvable dead trees standing, and (3) favor mast producers over non-mast producers when other factors are equal.

The best den trees have the following characteristics:

1. A healthy crown and the potential to survive at least through the rotation and preferably longer.
2. A cavity entrance protected from rain.
3. Evidence of use, such as gnawing around the entrance, a smooth worn entrance, and fur or claw marks.
4. Multiple benefits for wildlife, such as mast production, multiple dens, or a combination of dens and woodpecker nest sites on large dead limbs.

Rotten culls in advanced stages of decline often have little value as cavity trees. Many do not contain dens and they usually will not survive long enough for new dens to form. Many of the best den trees are acceptable growing stock. The cavities are in the crowns; there is generally less than 20 percent total board foot cull; and they are expected to live for 10 or more years. Inventory your stands during the dormant season with the aid of binoculars to identify active den trees.

Preparing for the Next Stand

Technically, thinning does not provide for regeneration but in practice thinning late in the rotation may have the same effects as an initial shelterwood cut. So, cutting in mature stands can set the stage for the next stand by establishing advance regeneration and identifying exceptional trees that can be carried into the next rotation to benefit wildlife.

The shelterwood system is attractive for wildlife management because it provides a longer regeneration phase than a single regeneration cut. Until the shelterwood is finally removed, the stands contain both a mature overstory and a rich understory. Mast, browse, and forage are abundant, and undergrowth cover is often adequate for cottontails, ruffed grouse, and other species that usually live in younger stands.

At the time of the final harvest cutting, the shelterwood system can be modified by leaving some selected trees or providing special habitat. These trees are primary sources of dens, mast, and vertical structure during the first half of the rotation of the new stand. Some of them may be potential high quality timber trees, but those left for dens usually become wolf trees. Conflict with timber production can be minimized if den and mast trees are left as border trees in wildlife openings, along streams, or as permanent trail and corner markers.

Trees to be left should show the promise of responding to release. In general, this means good form, reasonably well pruned, and in the 6- to 12-inch d.b.h. class, rather than badly suppressed individuals. For mast production, it is probably best to leave small groups of trees of the same species, rather than isolated individuals. Within a mixed oak stand, leaving a higher number from the red oak group than the white oak group provides the most stable mast supply. A good rule of thumb is a ratio of four red oaks to one white oak. Also, leaving two or more soft mast (fruiting) trees such as black cherry, blackgum, or mulberry can help offset a hard-mast failure.

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CENTRAL HARDWOOD NOTES

Enhancing Wildlife Habitat When Regenerating Stands

Forest regeneration cuttings affect wildlife habitat more drastically than most forest management practices because a mature forest stand is replaced by a young sapling stand. Regeneration cuttings quickly provide habitat for many wildlife species but they also influence wildlife use of the new stand and adjacent areas throughout the rotation. Retaining snags, cavity trees, potential snags, and den trees in regeneration areas and excluding certain areas from harvest will benefit many wildlife species. (See Note 9.07 Stand Size, Distribution and Rotation Length ***for*** Forest *Wildlife,* for other important factors affecting wildlife.)

Overstory Composition

The regeneration method you use influences the species composition of the new stand (see Note 2.04 Choosing a Silvicultural System). Even-aged silvicultural systems or group selection cuts are preferred for regenerating central hardwoods because they favor oaks and other intolerant species. They generally benefit wildlife as well. Mast is an excellent food for many wildlife species in this region, and acorns are especially important. A mixture of both red and white oaks is desirable. Other mast producing trees preferred by wildlife are American beech, hickories, and black walnut.

Cover is often the most important benefit provided by regeneration. For example, sapling and young pole stands provide cover for grouse and woodcock, but only if sufficiently dense. Abundant herbaceous and young woody vegetation in regeneration cuts also provide deer browse. Providing adequate regeneration will benefit both wildlife and timber production.

Slash

Excessive slash in regeneration cuttings hinders movements by deer and ground foraging birds such as ruffed grouse. Grouse prefer good visibility at ground level. If you have difficulty walking through a regeneration cut, or cannot see in most directions at ground level, slash may be too thick for these ground foraging species. Firewood cutting or controlled burning can be used to reduce slash in extreme cases. Moderate amounts of slash are tolerated by these species and provide cover and forage for other wildlife. However, areas of dense slash may protect desirable tree species from over-browsing. The forest practitioner will have to consider all management objectives when deciding upon slash reduction.

Snags and Cavity Trees

Snags and cavity trees are needed by as many as 90 wildlife species in central hardwood forests. The presence of snag- or cavity-using wildlife depends on the tree size or successional stage of the stand. For example, bluebirds and great-crested flycatchers will use cavity trees that are left in clearcuts while barred owls

and white-breasted nuthatches use mature stands. Other species such as the downy woodpecker, red-bellied woodpecker, and black-capped chickadee will use any stand with sufficient snags or cavities.

Leave some snags and live trees with cavities.

The recommended numbers of snags and live cavity trees you should leave in regenerated stands are shown in table 1. Retain the soundest cavity trees present. Give preference to live cavity trees. Consider snag and cavity needs for the entire rotation when making the cut. Many snags and cavity trees left when the stand is regenerated will blow down during the early part of the next rotation. Also, large cavity trees may take 100 to 150 years to develop, longer than the typical rotation age. By retaining some live, mature trees along with snags and cavity trees, you may meet some of the future cavity and snag needs of wildlife. If snags are too scarce, girdling is an inexpensive and effective method to create them.

Snag, cavity, and potential snag and cavity trees can be retained as individual trees or in small clumps. While individual trees may provide better wildlife dispersion, they are subject to wind, lightning, dieback, or mortality after cutting. Retaining one or two live trees with each snag or cavity tree may provide added protection. Alternatively, you can meet cavity and snag requirements by retaining clumps of trees, such as two 1/6-acre clumps or one 1/3-acre clump per 5 acres of regeneration. Some live trees could be retained in each group as potential cavity trees and protection from wind.

Table 1 .-Minimum and optimum numbers of snag and live cavity trees per acre for wildlife

D.b.h. (Inches)	Upland forest				Bottomland forest			
	Live cavity trees		Snags		Live cavity trees		Snags	
	Minimum	Optimum	Minimum	Optimum	Minimum	Optimum	Minimum	Optimum
6-10	1	≥2	1	≥2	5	≥ 9	1	≥2
10-19	2	≥4	2	≥4	7	≥14	2	≥4
>19	1	≥1	0	≥0	1	≥ 2	0	≥1

(Adapted from Titus 1983)

Exclusion From Harvest

Excluding designated stands from regular timber harvest will eventually provide old growth habitat for certain wildlife species. Distinctive features which make old growth valuable for wildlife include a well developed understory and subcanopy and many large cavity trees. Old growth stands and valuable wooded streamside habitats can be protected by excluding from timber harvest a strip at least 100 feet wide along each side of permanent water courses. The size of the area excluded from harvest will depend on your management objectives. If wildlife is to be considered at all, exclude at least five percent of the forest from harvest. For wildlife that needs old growth or mature forest habitat, you should exclude 15 percent or more. Consider stand size too. If the forest property is small, consider cooperating with neighbors, because small, isolated, old growth and mature stands will not provide the wildife benefits of large contiguous stands.

Management Objectives

Your management objectives should determine what practices you follow to improve wildlife habitat when stands are regenerated. If wildlife diversity is important, provide the optimum numbers of snags, live cavity trees, and old growth to meet current and future needs. If your objective is to feature wildlife that use seedling and sapling stands (such as ruffed grouse), retaining too many small clumps of trees can decrease regeneration density and provide poorer grouse cover. Or, if your primary objective is timber production, with wildlife secondary, snag and live cavity tree requirements can be met by using a single clump of trees 1/3-acre in area per every 5 acres of regeneration.

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CENTRAL HARDWOOD NOTES

Stand Size, Stand Distribution, And Rotation Lengths For Forest Wildlife

The key to managing forest wildlife is providing diverse habitats. Stand size, stand distribution, and rotation length determine how diverse habitats will be. Since the tenure of private forest owners is generally shorter than prescribed rotations, rotation recommendations serve more as guides to the amount and intensity of cutting needed to maintain desired habitat. In making silvicultural prescriptions, including stand sizes and distribution, we must consider the home ranges and habitat needs of desired species in meeting the wildlife objectives of private owners or land managers.

Wildlife of Young Forests

A wide variety of generally herbivorous and insectivorous species are adapted to young, dense, fast growing hardwood stands. Species such as ruffed grouse, woodcock, bobcats, cottontail rabbits, and many songbirds are the “pioneer” species or “opportunists” because they are associated with early successional forests-stands less than 40 years old resulting from intensive cutting, fire, disease outbreaks, or extensive wind damage. These species respond quickly and often become abundant when suitable habitat is created. They benefit most from small stand size, short rotations, and a variety of age classes.

Clearcutting, shelterwood, and group selection silvicultural methods create the diverse habitats needed for these species, especially in the oak-hickory association. Single tree selection is appropriate for streamside buffer zones or for shade tolerant tree species in the elm-ash-cottonwood type.

If commercial wood products (firewood, pulp, saw logs) and wildlife populations are your management objectives, rotations should be 60 to 80 years in scattered 2- to 20-acre irregularly shaped stands with an even distribution of 1 O-year age classes. On intensively managed good sites you should make cuts at 20- to 40-year rotations on 2- to 5-acre stands having an even distribution of 5-year age classes. On poor sites, rotations of 30 to 50 years may be more appropriate. Cuts should be made in a “checkerboard” pattern to maximize edge and distribution of different age stands.

If you have a choice, choose large stands for habitat management. They allow you more flexibility in shaping. Large stands with irregular shapes are more pleasing in the landscape and are also beneficial to wildlife. In large stands site changes are likely to be greater and the stand will be more diverse as it develops. Small stands are more geometric in shape and are more uniform in composition and structure since they contain fewer site changes.

Wildlife of Mid-successional Forests

These wildlife species tend to be habitat "generalists." They use a wide variety of habitat types from early to late successional forests older than 40 years. Some species depend on openings of herbaceous plants within the forest to provide palatable vegetation, insect food, and protective cover for young animals. Hard mast is generally an important food. Some species depend on well-developed understories for seasonal habitat. Select 10- to 25-acre stands then cut every 10 years over a rotation of 80 to 100 years to achieve a mix of different ages.

Wildlife of Mature Forests

Many species of mature forests need snags and/or cavity trees for life requirements. Another group of wildlife require dead and down trees and tree tops, hollow logs, and stumps. Species requiring cavity trees are also partially dependent on forest cover patterns. Some primary excavators and secondary cavity users require snag and cavity trees in dense forest with a canopy closure of more than 70 percent. Other cavity users prefer snags and cavity trees in semi-open and open canopies. Consequently, if you are going to provide for a variety of cavity users you must leave snags and cavity trees under canopies of various densities. Recommendations for snags and cavity trees are found in Note 9.05 *Treating Mature Stands* and Note *9.06 Enhancing Wildlife Habitat When Regenerating Stands.* To provide these habitats, a minimum of 5 percent of the commercial forest land (greater than site index 45) should be set aside as permanent old growth. If old growth wildlife species are to be emphasized, at least 15 percent of the area should be set aside. If the area set aside is small, be sure to protect snags and cavity trees before thinning and final harvesting in the adjoining commercial forest land.

The stands that are set aside must be held past pathological rotation age so that there will be large declining trees and a multi-layered structure. Rotations should be extended according to the dominant tree species. The white oak group can be held 150 to 200 years; the red oak group will begin to decline rapidly after 100 years. Ideally, areas designated for old growth should be at least 15 acres in size with a minimum width of 200 feet; optimum size for old growth areas is 300 acres.

When selecting stands to set aside as old growth, first consider stands more than 90 years old with large defective trees. If these are not available, select "old growth" from stands more than 50 years old. These have the potential to achieve the large tree, multi-layered midstory structure.

In summary, the effects of stand size, distribution, and rotation length vary widely for different wildlife species. The challenge is to design a balanced management program that best satisfies the landowner's objectives for wildlife, forest products, recreation, and aesthetics. Sometimes objectives will conflict with each other and the landowner needs to understand the various trade-offs or compromises necessary to manage forests for multiple resources.

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CENTRAL HARDWOOD NOTES

Logging Roads And Log Decks For Wildlife Habitat

Roads are essential to manage and use forest land. They can improve wildlife habitat and provide recreational opportunities. But roads are often controversial because they have so many different users-loggers, hikers, hunters, and off-road-vehicle drivers. Benefits to wildlife can be maximized and user conflicts minimized by careful planning and design. Decisions about gates, signs, and seasonal access should be made during the planning stage. Careful layout will ensure that sensitive habitats are protected and permanent improvements such as ponds and clearings are connected.

This Note covers the effects of log-truck and skidder roads on wildlife habitat. Note 11.03 Forest *Access* Roads, gives details about road design and construction. Note 9.11 Wildlife Openings, explains how to include roads in a system of wildlife clearings.

Logging Roads and Wildlife Habitat

Two rules should be followed when using roads to improve wildlife habitat. First, manage roads for herbaceous forage; and second, avoid sensitive habitats.

Most large tracts of central hardwoods can be improved for wildlife by developing permanent openings to provide forage. Truck roads and log landings are ideal for this purpose, and should be treated as wildlife openings. Manage truck roads and log decks for grass and legume crops as described in Note 9.11 *Wildlife Openings.*

In addition to providing forage, roads can add diversity in forest "structure" and plant species. Light entering the forest from the road stimulates the development of shrubs and understory plants along the forest edge. This effect can be enhanced by "daylighting" or felling trees for about a tree length on one or both sides of the road. Daylighted roads provide herbaceous cover, dense brush, and forest in close proximity. The rich mixture of plant species is attractive to many wildlife species.

Planting forage crops on skidder roads prevents erosion and enhances habitat. Skidder roads are not usually maintained between timber harvests but the effects of seeding will last for several years. Seeded skidder roads in regenerating or recently logged stands provide valuable travel routes for man and animals.

Sensitive habitats need to be protected during road building. Sensitive habitats are generally unusual habitats. They might include wetlands, stream banks, heron rookeries, bat caves, rare plant communities, or an exceptional stand of mast-producing trees. Careful field work during the design of road systems is the best insurance that sensitive habitats are identified and provided with adequate buffer zones.

Finally, you need to consider when and how to permit access. Even when roads improve wildlife habitat, they can have a negative effect on some wildlife populations by making them accessible to people. For example, in parts of the southeast, wild turkey populations are inversely related to the length of road per unit area. Roads actually provide brood rearing habitat, but they lead to increased poaching and harvest.

Access policy depends on wildlife management objectives and local conditions. Roads managed as wildlife openings are often best left for foot travel only. That policy protects the forage crops from damage by vehicles, and minimizes disturbance to wildlife. It also permits reasonable access if roads are no more than one mile apart. Even where deer harvest needs to be encouraged roads may be closed during spring and summer to protect cover crops and reduce disturbance during nesting and brood rearing seasons.

Roads and Pedestrians

Log-truck and skidder roads can be used to distribute foot travelers through the forest. In West Virginia, parking areas and forest roads had more impact on hunter distribution than habitat or game abundance. Roads can also be used to educate the public, highlight management activities, and provide a variety of recreational experiences.

Log-truck and skidder roads generally make good foot trails because they are infrequently used by vehicles. In fact, we usually want to keep vehicles off these roads except during management activities. Roads that are managed for wildlife forage provide opportunities to see wildlife and the landscape. Many “control points” used to establish roads-log landings, rock ledges, knolls, ponds, and streams-are attractive places to see wildlife, unusual plants, and land forms.

Consider the road system as a way of distributing hunters and hikers. Encourage use by providing parking, erecting signs, and maintaining forage crops. Appropriate signs can highlight natural features and effective management practices.

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CENTRAL HARDWOOD NOTES

Stream Corridor Management

The quality of streams and stream habitat for aquatic life and terrestrial animals in the central hardwood forest can be maintained or enhanced through careful protection, management, and re-establishment of streamside forests. Streams and aquatic animals rely on adjacent forests for:

- Shade
- Organic material to drive aquatic food chains
- Streambank stability from dense root systems
- Filtering erosion sediment from adjacent lands
- Fish cover and production of aquatic invertebrates from submerged tree branches or root wads.

Since streamside forests are the only buffers between streams and the land that drains into them, we need to assess land use in the watershed and the condition of the stream channel. Watershed condition largely determines water quality. High turbidity and excessive suspended sediment are often due to land use practices that fail to protect soils from erosion. Avoiding large scale regeneration cuts, leaving forested buffer strips on contours at regular intervals, careful engineering and placement of logging roads, and maintaining adequate streamside buffer zones can help protect streams from excessive bedolads of eroded silt, sand, and gravel.

Even streams with well-managed watersheds can have problems, however. An unstable stream, or one that is continually declining in quality, must be carefully assessed from a physical standpoint. Whenever possible, rely on the expertise of an aquatic biologist, fisheries biologist, or other trained person with experience in dealing with the physical and biological nature of flowing water.

How to Manage for Optimum Streamside and Aquatic Habitats

1. **Use undisturbed stream sections as a model**

   Compare the section to be managed with natural, undisturbed sections in the same general area to determine relative stability and possible management needs. Streams meander and dissipate energy when water flows downhill. Streams whose meander pattern and gradient are close to that of undisturbed conditions can be managed most successfully. Streams that have been straightened, have large debris jams, have had intensive land use changes, or excessive timber harvest on adjacent streambanks, are often unstable and difficult to manage. Don't attempt major changes in unstable streams without help from professionals experienced in stream management.

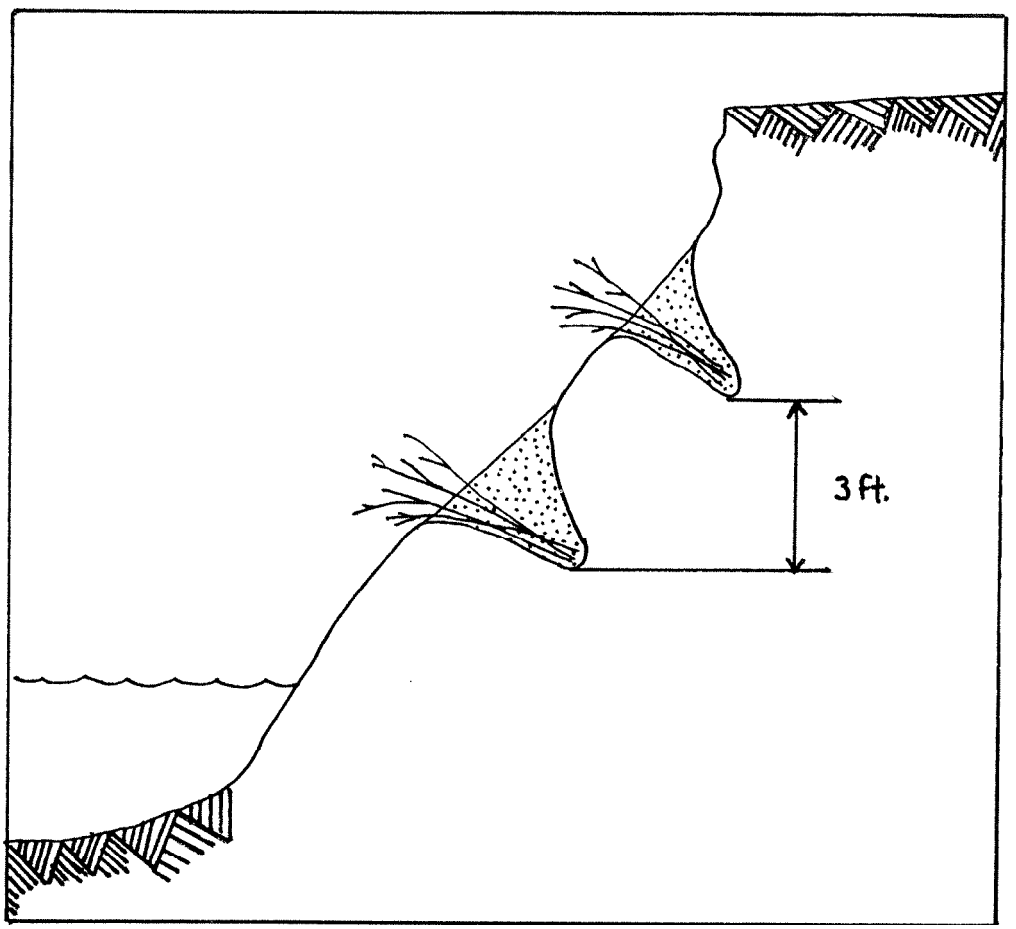
2. Plant bare areas

Revegetate bare streambanks that show little or no evidence of serious erosion or slumping. Use one or more of the following techniques:

a. Cuttings and live staking.-Use black willow and eastern cottonwood cuttings 12 to 18 inches long and 1/2 to 1 inch in diameter or stakes 18 to 36 inches long and 1 to 3 inches in diameter. Push or pound sharpened cuttings or stakes, buds pointing upward, into streambank soils 2 feet apart at least 1 foot above the elevation of the estimated low water level. Three inches of the cutting or stake should remain exposed. On vertical streambanks, stakes and cuttings should be planted with the tops pointing skyward, not flat. Planting is best done in February to April before buds break dormancy.

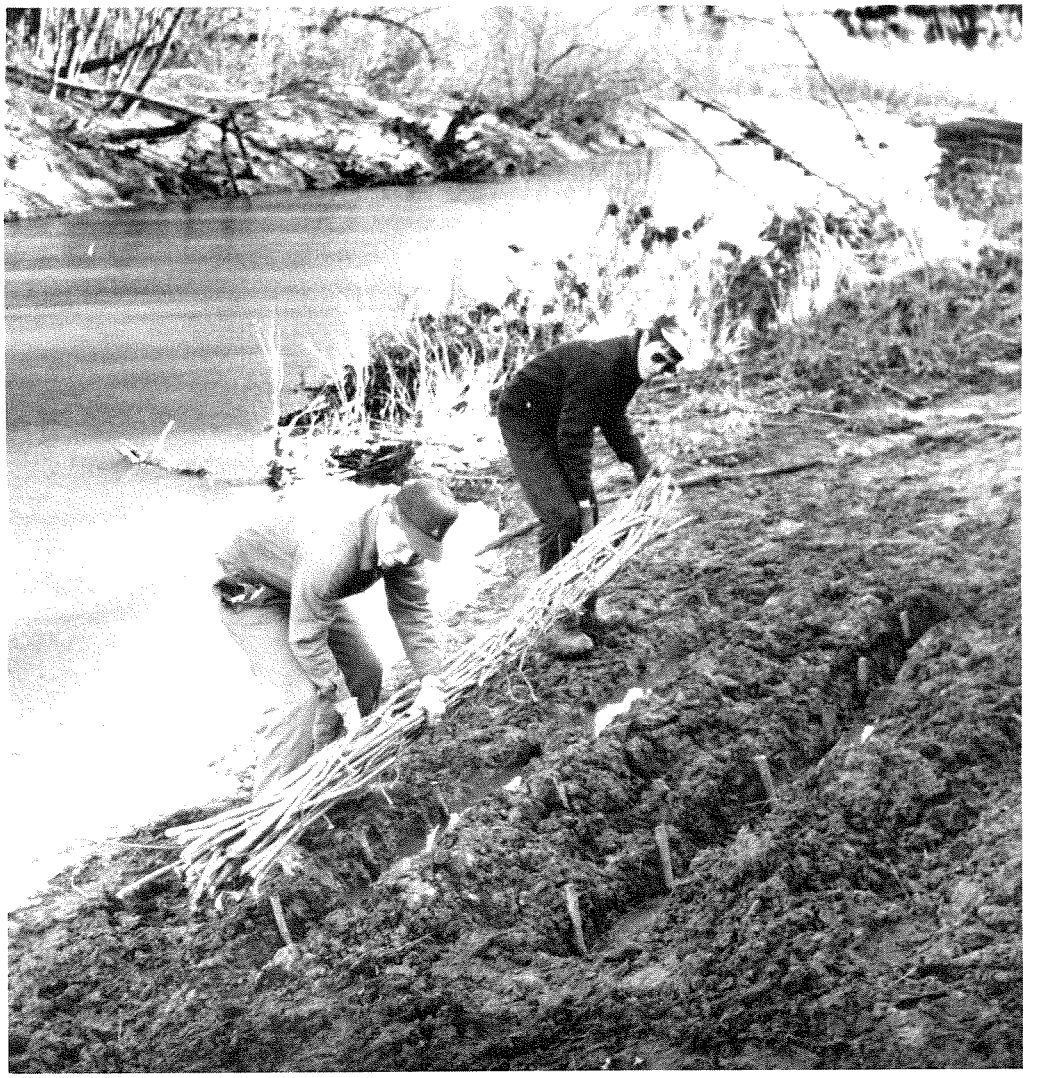
Pound in live stakes during dormancy (Missouri Department of Conservation).

b. Contour brush layering.-Place dormant cuttings 3/4 to 2 inches in diameter and 24 to 40 inches long in trenches 18 to 30 inches deep, dug at an angle at least 10 degrees vertical of the horizontal plane. Dig trenches 3 feet apart on contour. Branches placed in the trenches should be criss-crossed and be 3 to 6 inches thick when finished. Place fill soil back in the trench and tamp firmly. On streambanks to be reconstructed with heavy equipment, 6-to 8-foot-long tree whips and cuttings can be laid in 3- to 6-inch-thick mats, alternating with 3-foot layers of soil.



Dormant cuttings should be put in trenches 3 feet apart on contour

c. Wattling.-Arrange live black willow whips 1 -1/2 inches in diameter and 4 to 8 feet long in cigar-shaped bundles, branch ends alternating with butt ends. Compress the bundle into an 8- to 1 O-inch-diameter cylinder and tie. Dig a trench in the streambank and lay the willow bundle in it, with no more than 3 to 6 inches of the circumference exposed. Overlap the ends of successive wattles, stake them with live willow stakes, place the soil back in the trench, and tamp. Wattles can be placed on streambank contours or perpendicular to the stream's flow.



After placing the bundle in the trench, leave a little of it exposed (Missouri Department of Conservation).

d. Live dormant posts.-Cut live black willow posts 3 to 8 inches in diameter and 6 to 8 feet long, score (make a short cut with chain saw, hand saw, or hatchet) the lower half every 12 to 14 inches, and set them in post holes or drive them with a driver to a minimum depth of 3 to 4 feet. Recommended spacing is 2 to 4 feet between centers. About 1 foot of buried portion of the post must be above permanent water level for good root development and survival.

Score willow posts about every foot before setting (Missouri Department of Conservation)

Set or drive willow posts so that a foot of the buried portion remains above permanent water level (Missouri Department of Conservation).

3. Build structures as needed

Correct streambank erosion or slumping problems to improve stream channel stability, reduce sediment loads, and improve water quality for recreation and fish and wildlife habitats. While some lightly eroding streambanks respond to the revegetation efforts described above, often one of the following measures is needed to stabilize the base of a streambank's slope and provide temporary protection while vegetation becomes established. Structures suitable for forested areas include:

a. Tree revetments--bushy trees such as eastern redcedar or pin oaks fastened to the bank with earth anchors and cable to protect the bank at curves and where it is under pressure from high velocity currents.

b. Bank sloping-reduction of the slope of streambanks (2:1 or 3:1 horizontal to vertical) to provide a suitable slope for planting trees and/or for installation of structural bank protection.

c. Riprap-rock of appropriate size properly underlaid with a filter blanket (a layer of smaller size gravel beneath riprap designed to prevent the washout of fine soil or streambank material through the riprap) to protect streambanks.

d. Jetties---current deflectors of posts, pilings, rock, or other material that project into the stream. Consult with a person experienced in stream management or river engineering to prevent excessive impacts to the opposite bank and downstream areas.

These structures should be used in conjunction with revegetation treatments.

4. Get professional help

If streambanks are eroding severely or the stream is highly unstable, seek advice from stream management professionals.

5. Manage stream corridors

Improve streamside forests that are not regenerating naturally by planting tree species native to the area that are suited to the soils and site (see Note 3.05 Seeding and Planting Hardwoods). Streamside vegetation on both sides of a stream should be of mixed species and sizes with adequate forest floor vegetation and leaf litter and should not be grazed, cropped, or clearcut. Maintain a continuous forest cover at least 100 feet wide measured from the top of the bank.

6. Improve instream habitat if necessary

Evaluate instream habitat conditions with the assistance of an aquatic biologist or a fisheries management biologist. To insure a minimum of usable fish habitat, stream channels should have pools deeper than 3 feet, and 15 percent of the channel area should be comprised of rootwads, submerged timber, or boulders greater than 2 feet in diameter. Instream structures to increase fish cover and fish food production should follow the biologist's recommendations.

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CENTRAL HARDWOOD NOTES

Site Preparation For Wildlife

Site preparation-whether for timber and/or wildlife objectives--can influence the quality of wildlife habitat on the site and surrounding forest for the entire rotation period of the regenerated stand. The site preparation you select will help determine the species and numbers of wildlife that use the stand as the stand progresses from regeneration through maturity.

A wide spectrum of wildlife will benefit from site preparation methods that increase production of soft mast and browse immediately following stand harvest. Wildlife adapted to a mature forest will be favored by a stand dominated by species producing hard mast, particularly oaks.

Soft Mast

Wild grape, flowering dogwood, blackgum, blackberries, blueberries, and huckleberries, provide food for ruffed grouse, many song birds, squirrels, and small mammals.

Wild grape.-Retain clusters of wild grape at a ratio of 1/4-acre of grapevines per 10 acres of forest. On dry sites grapevines rarely interfere with reforestation, and need no treatment during site preparation. On high quality sites, the excess grapevines should be treated before regeneration, leaving no more than five vines per acre, plus the 1/4-acre clusters. For more information see Note 6.13 *Wild Grapevine Management.*

Dogwood, blackgum.-Preserve individual and clumps of seed-producing dogwoods and blackgum, particularly along edges of the regenerated stand. Dogwood should survive and produce seed throughout the early part of the rotation; blackgum may persist for the entire rotation.

Berry-producing shrubs.-These species become more productive in full sunlight following harvests until they are shaded heavily by the new forest. Avoid general application of herbicides harmful to these species.

Browse

Many hardwoods provide browse for white-tailed deer, the principal large herbivore in the central hardwood forest. No specific management is recommended for producing browse, but site treatments that encourage sprouting, such as burning and root shearing, will coincidentally improve the quality and increase the quantity of browse.

White-tailed deer browsing (Jay Hutchinson).

Japanese honeysuckle is an important food for white-tailed deer and ruffed grouse in southern portions of the central hardwood region. Avoid herbiciding honeysuckle if consistent with timber objectives. Honeysuckle rarely interferes with stand regeneration on poorer sites, particularly where it remains partially shaded on the edges of harvest sites. On good sites it may be a major problem. Burning will retard vine growth 1 or 2 growing seasons.

Hard Mast

Providing hard mast is a highly desirable long term objective, achieved by regenerating a forest dominated by oaks. White-tailed deer, black bears, wild turkey, eastern gray and eastern fox squirrel, and many species of small mammals rely heavily upon acorns for their winter food supply. Hickories are also important species that should be encouraged in new stands.

On drier sites, oaks can usually be regenerated after harvest by a variety of methods ranging from clearcutting to group selection if adequate advanced oak regeneration exists before harvest (see Note 2.05 Silvicultural Systems for *Oak-Hickory and Oak-Pine).*

On better sites (SI 80), however, competition from species less desirable for wildlife such as red maple, yellow-poplar, sweet gum, and striped maples may require specific site treatments before and/or after harvest to encourage oak. If there is adequate oak in the understory on good sites it must be encouraged to reach sapling size before the final harvest. Treatments should start 7 to 10 years before harvest. Herbicide undesirable understory and mid-story trees, opening the stand moderately to stimulate growth of existing oak seedlings. Oak saplings 8 to 10 feet tall compete favorably with pioneer species when released by harvest. Getting oak into the new stand without adequate advance reproduction requires special silvicultural treatment *(see* Note *2.05 Silvicultural Systems for Oak-Hickory and Oak-Pine,* and Note *3.06 Seeding and Planting Oak).*

Miscellaneous

Snags provide homes, perches, and feeding bases for cavity dwellers, raptors, woodpeckers, and songbirds. Preserve at least two snags per acre when possible, selecting the largest snags available.

Seed log landings, skid trails, and logging roads with herbaceous plants palatable to wildlife. Red, ladino, and white clovers provide green, leafy food during winter and early spring for ruffed grouse and wild turkey. Orchard grass is favored for grazing, and also provides habitat for insects eaten by turkey poults and ruffed grouse chicks in summer (see Note 9.08 Logging Roads and Log *Decks for* Wildlife Habitat, and Note 9.11 Wildlife Openings).

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CENTRAL HARDWOOD NOTES

Wildlife Openings

Openings provide important feeding areas for forest wildlife because herbaceous vegetation grows much more abundantly in the open than beneath a forest canopy. Herbage (grasses and forbs) is generally more nutritious and digestible than woody plant growth. Herbage is important in the diet of deer, especially in late winter and early spring. Voles and rabbits use openings year round, and these small mammals are eaten by many larger predators. Insects, a primary food of young wild turkeys and other birds, may be 25 times more abundant in clearings than in forest undergrowth. So, wildlife openings and the herbage and insects they provide are an important component of forest wildlife habitat. In addition, clearings and the roads and trails that connect them may provide scenic vistas and excellent opportunities for seeing wildlife.

The value of wildlife openings depends partly on undergrowth conditions in the adjacent forest. The amount of herbage in forest undergrowth is generally greater on good sites than on poor sites.

Thinning mixed hardwoods and elm-ash-cottonwood stands usually results in abundant herbage and woody undergrowth. In contrast, thinning oak-hickory and oak-pine stands usually produces more woody than herbaceous undergrowth. Thinnings and regeneration cuts provide important browse and some herbage for wildlife, but they are not equivalent to permanent wildlife openings in terms of herbage and insect production. For optimum habitat we usually recommend maintaining 5 to 10 percent of the management area in wildlife openings along with an active timber management program.

A good system of wildlife openings will include both agronomic forages and native plant communities. Domestic legumes and grasses provide high quality forage early in the growing season when little else is available. Native plant communities provide good cover, seeds and fruits, and abundant forage later in the growing season.

Distribution and Size

Ideally, wildlife clearings should be uniformly distributed through the management unit and connected by roads that have been planted to forage crops and incorporated into the opening management program. The best spots for new clearings are log decks, log roads, utility rights-of-way, poorly stocked stands, or regeneration failures.

The arrangement of clearings in the landscape and the total proportion of the management unit occupied by openings are as important as the size of individual clearings. A 1 -acre wildlife opening can be highly beneficial if: it is part of a system that includes larger clearings; it is within 600 feet of another opening; and it is connected to other openings by grassy roads or other corridors of herbaceous vegetation. Wild turkeys favor openings of 10 to 20 acres, but turkeys and other wildlife will use much smaller clearings. There are usually more opportunities for making small openings (1 to 3 acres) than large ones (10 to 20 acres). Systems composed of a few large openings and increasing numbers of smaller ones are effective in distributing high quality forage through a management unit.

Establishment

Once the trees have been removed, you need to establish the herbaceous community. If the natural ground cover is adequate, the grasses and forbs can usually be encouraged by lime and fertilizer. If the area has been heavily disturbed (log landing, skid trail) or is large enough for agricultural management, it should be seeded to a forage crop as soon as possible.

Mixtures of cool-season grasses and legumes such as birdsfoot trefoil, orchard grass, bluegrass, or quackgrass are generally recommended for planting in openings (see Note 9.13 Planting for *Wildlife).* These mixtures provide succulent forage through the growing season, and have proven to be effective in enhancing wildlife habitat. The species used depend on local site conditions and your management objective. Your local Soil Conservation Service Office and wildlife managers are the best source of specific planting recommendations. Management recommendations for forage crops are based on the needs of commercial agriculture, so the suggestions for lime and fertilizer applications usually exceed what is needed to maintain wildlife openings.

Whole-tree chipping has the potential for converting low value timber stands to wildlife openings. Because the stumps are sheared at ground level, the woody sprouts can be eliminated annually with “flailing-chain” mowers or herbicides applied to the stumps. Mowing will produce a “volunteer” herbaceous community. In 5 or 6 years the stumps will decay and the site can be disked and planted to forage crops if further development is considered necessary.

Maintenance

Periodic treatments are necessary to maintain forage species and prevent the invasion of woody plants. The keys to managing clearings are simplicity and flexibility. The acreage to be treated should be set in advance; prescriptions for individual clearings should be based on an annual inspection. The prescription should be based on the condition of the opening, the local wildlife populations, and your management objective. Heed the adage, “Don’t fix it if it isn’t broken.”

Agronomic forages require relatively intensive management-one or more annual mowings, periodic applications of fertilizer, and replanting. Native plant communities can often be maintained by mowing late in the growing season every 1 or 2 years and by burning in the spring at intervals of 3 to 5 years. Generally, you should not treat during the nesting and early brood rearing period-May and June for most of the central hardwoods area. Remember, it is almost always easier to keep an opening clear than to make a new one.

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CENTRAL HARDWOOD NOTES

Mast Importance, Production, And Management

Mast is a broad term that refers to the various nuts and fruits produced by woody plants. It is usually subdivided into hard mast (nuts) and soft mast (fleshy fruits). Forest tree and shrub mast is an important seasonal food for many forest wildlife species.

In the central hardwood region, the hard mast producers tend to be canopy trees while soft mast producers grow principally in the understory. The mast species in this region that are most important to wildlife include:

Hard Mast	Soft Mast
Oaks	Flowering dogwood
Hickories	Bush dogwoods
American beech	Viburnums
Black walnut	Hawthorns
Hazel	Persimmon
	Black cherry
	Other cherries
	Mulberry
	Sumac
	Wild grape
	Virginia creeper
	Greenbriar
	Spice bush
	Blackgum
	Poison ivy
	Sassafras

Most woodland game animals, including tree squirrels, white-tailed deer, wild turkey, and ruffed grouse use substantial amounts of mast. Productivity and body condition in several of these species have been linked to size of the acorn crop in a given year. A multitude of other mammals and birds also use hard and soft mast. The length of time an animal can utilize a particular kind of mast depends on the abundance of the mast-producing species, the size of the annual crop, and the feeding habits of the animal. Several species, such as tree squirrels and eastern chipmunks, gather and store hard mast so it is an important food source for longer periods for them than for non-storers such as white-tailed deer. It is important to know that there is intense competition among mast feeders for the mast crop in most years.

Production

Forest Types

Compared to the oak-hickory and oak-pine types, the mixed hardwoods and elm-ash-cottonwood types have significantly fewer mast-producing species. For wildlife it is especially important to modify stand prescriptions to retain mast-producing canopy trees and to encourage understoty soft-mast production when thinning or making intermediate cuts. In a given stand, the aggregate production of all soft-mast species frequently exceeds that of hard-mast species.

Production Variables

In general, mast production--especially hard mast-is unreliable. It varies greatly from year to year with little predictability. The black oak group (oaks with sharp-pointed leaf lobes), hickories, and black walnut are generally more reliable producers than the white oak group (oaks with rounded leaf lobes) and American beech. White oak, American beech, and northern red oak are very sporadic producers, tending to produce bumper crops some years and then to fail almost completely for the next several years.

In addition, insects generally damage or destroy more than 50 percent of the hard-mast crop; in some years it is 90 percent or more. The remaining sound nuts are often completely utilized by various mast feeders. This leads to concerns regarding regeneration of mast-producing species.

Several factors inherent in the individual tree strongly affect its ability to produce mast:

- Genetics-Some individuals are inherently better mast producers than others; some fail to produce any mast.
- Dominance and crown size-Dominant trees with large, well-developed crowns and edge or open-grown trees are better producers.
- Recent fruiting history-A bumper crop in one year reduces chances of significant production in years that immediately follow.
- Age-Hard mast production generally begins between 20 and 40 years of age, is greatest at mid age and size, and tapers off between 100 and 200 years, depending on species.

Certain physical or environmental factors also affect mast production:

- Light intensity-Production in almost all species increases with more light.
- Site-Better sites and soils produce larger mast crops.
- Rainfall-Lack of moisture reduces production.
- Frost-Freezing temperatures may destroy total annual production if they occur during flowering.
- Temperature-Warm early spring temperatures followed by cooler summer temperatures produce the best crops.

Recommendations For Management

1. Strive for as wide a mix of hard-mast producing species as possible to insure against total hard mast failure in any year. It is especially important to retain a good mix of white oak group and black oak group species.
2. Retain soft-mast species in the understory during thinning, selection harvesting, or clearcutting.
3. Maintain soft-mast producing vines during timber stand improvement and other release operations if they are not hindering timber crop trees.
4. Use thinnings that allow fullest crown development on mast-producing crop trees and that create maximum light penetration to the understory.
5. Create or retain wildlife openings in which mast-producing shrubs may be selectively maintained. Many soft-mast species are early successional. Rights-of-way should be similarly selectively maintained, with mast-producing shrubs encouraged on the right-of-way and mast-producing trees retained on the perimeters.
6. Extend rotation length (i.e., from 80 to 120 years) so that a higher proportion of the stands in a large forest property would be producing hard mast.
7. Under uneven-age management use group selection rather than single-tree selection for better light penetration for understory development.
8. Do not cut a hard-mast producing stand unless and until an adjacent stand of suitable composition is of mast-bearing age.
9. Exclude fire and grazing from mast-producing stands.
10. Make maximum effort to retain and release mast-producing trees, shrubs, and vines in intermediate treatments in areas having few mast-producing species. This applies especially to mixed hardwoods and elm-ash-cottonwood types.

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CENTRAL HARDWOOD NOTES

Plantings For Wildlife

Grains, forages, and other vegetation can be planted to provide critical habitat for desired wildlife species or to increase habitat diversity. Plantings may be in openings created in the forest (see Note 9.11 *Wildlife Openings)* or along the forest edge in cultivated or pastured fields if protected from domestic livestock. The first step in determining if and what type of plantings are needed is to evaluate the existing habitat on your land (see Note 9.02 *Wildlife Habitat Evaluation).* Some of the specific recommendations in this Note are based upon our experience in the southwestern part of the central hardwood region. Consult local or regional wildlife experts for species suitable for your area.

Two types of plantings can be used to complement natural habitat:

Food Plantings:

Annual Grains-Provide emergency high energy food when native foods are covered by ice and snow.

Forages-Provide nutritious food to complement native foods.

Perennial Fruit and Seed Producers-Provide soft mast and seeds.

Cover Plantings:

Provide escape, nesting, and winter cover.

The annual grain and forage plantings must be located in areas that can be plowed or disked and that have escape cover close by. The other plantings do not require tilling but may require control of unwanted, competitive vegetation.

Annual grains such as milo provide high energy food (Missouri Department of Conservation).

Dogwood provides soft mast (Missouri Department of Conservation).

To establish annual grains:

- Fertilize and lime according to soil test. If soil test is not available, use 800 pounds of 12-l 2-12 per acre (or equivalent) and 4 tons of crushed limestone per acre.
- Plow and/or disk as early in the spring as possible.
- Seed at the following rates:

Species	Seed/ acre Pounds	Seeding date
Milo	14	May-June
Corn	12	April-May
Mixture:		
Milo	8	May-June
German Millet	1	May-June
Soybeans	8	May-June
Lespedeza (Korean)	6	Overseed in February-March (the following year)

- Plant half of the area each year, leaving the other half to grow to native vegetation. Each year plant the half that was not planted the previous year.

To establish forages:

- Fertilize and lime according to soil test.
- Prepare seed bed in August or September.
- Seed at the following rates:

Species	Seed/ acre Pounds	Planting dates
Mixture:		
Wheat	30	Fall
Orchardgrass	2	Fall
Ladino clover	2	Fall
Red clover	2	overseed early the following spring
Lespedeza (Korean)	10	overseed early the following spring
Low fertility soils		
Orchardgrass	8	
Lespedeza (Korean)	15	
Ladino clover	0.5	

. After first year, mow two times each year (June and September).
- Top dress every 2 years with 100 pounds phosphate and 100 pounds potash.
- Light grazing in June that removes half of the current growth can be used instead of mowing.

To establish perennial seed producers and cover plantings:

- Prepare site by controlling competing vegetation.
- Plant in clumps to develop thickets or in rows to create travel lanes between habitat components.
- Control competition each year by mowing and/or using herbicides until plantings are established.
- Plant at the following spacings:

Species	Height	Spacing Between rows	Spacing Between plants	Desired sites	Use
	(Feet)	(Feet)			
Eastern red-cedar	30-60	10x6		Loam soils, abandoned fields, rocky hillsides, in full sun.	Soft mast, escape and winter cover
Sumac	2-6	3 x 2		Dry rocky hillsides and field edges.	Soft mast and loafing cover
Blackberry	3-6	3 x 1.5		Well-drained soils in full sunlight.	Soft mast loafing and escape cover
Blueberries	2-12	4x3		Well-drained acid soil in full sunlight.	Soft mast
Possumhaw (Deciduous holly)	8-20	8 x 4		Moist, well-drained soils to drier upland sites, creek banks, draws.	Soft mast
Downy serviceberry	15-30	10x 16		Rich upland soils to poorer upland soils; in partial shade.	Soft mast
Flowering dogwood Other dogwoods	20-30 8-15	14x8 Clumps 8x8		Well-drained soils in full sunlight or partial shade.	Soft mast
Hawthorne	8-15	10x6 Clumps 8x8		Adapted to old fields and woods border.	Soft mast, nesting and escape cover
Wild plum	1 0-30	10x6 Clumps 8x8		Deep, rich, moist bottom-land; adapted to upland sites, requires full sunlight.	Soft mast loafing and escape cover

To establish cover plantings of native warm-season grass:

- Prepare a plowed, disked, and cultipacked seed bed. Seedbed must be firm.
- Fertilize with phosphate, potash, and lime according to soil test.
- Plant during May or June.
- Seed at the following rates:

Species	Seed/acre (Pounds pure live seed)
Switchgrass	4
Big bluestem	7
Indiangrass	7
Mixture:	
Big bluestem	1.5
Indiangrass	1.5
Little bluestem	0.5
Sideoats grama	1

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CENTRAL HARDWOOD NOTES

Planning And Managing Recreational Opportunities On Large Ownerships

Properly managed, central hardwood forests can provide quality outdoor recreation experiences. If you manage a large ownership, a system known as the "Recreation Opportunity Spectrum" (ROS), used by the Forest Service and the Bureau of Land Management, can help you *define* the kinds of recreation opportunities on your land, help you collect and evaluate recreation data, and help you set management objectives so you can provide quality recreation.

The ROS provides a framework that divides recreational experience into six "settings," ranging from primitive to urban (fig. 1). For each setting there is a list of "attributes" that characterizes or helps define it. For example, attributes of the *roaded natural* setting include *user interaction-low* to *moderate* and *resource modification* evident (table 1). These attributes will help you zone your ownership according to the kinds of recreational opportunities a person can experience.

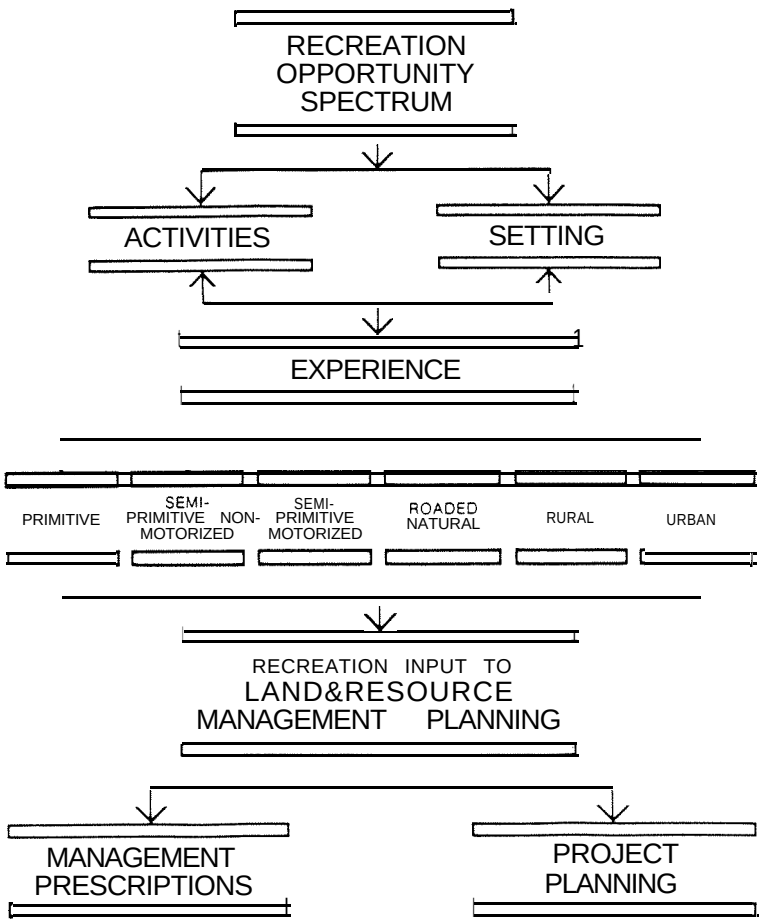

Figure 1 .--The Recreation Opportunity Spectrum framework.

Table 1 .-*Recreational settings and the attributes that characterize them*

Primitive
- -unmodified natural environment
- -fairly large size
- -user interaction very low
- -very few management controls
- -no motorized use

Semi-Primitive Non-Motorized
- -predominantly natural environment
- -moderate to large size
- -user interaction low
- -minimum management controls
- -no motorized use

Semi-Primitive Motorized
- -same as “semi-primitive, non-motorized” except motorized use is permitted

Roaded Natural
- -natural environment, but with sights/sounds of humans
- -user interaction low to moderate
- -resource modification evident
- -conventional motorized use provided/designed

Rural
- -substantial modified natural environment
- -sights/sounds of humans readily evident
- -user interaction moderate to high
- -considerable facility development
- -intensified motorized use and parking provided

Urban
- -natural appearing, but essentially urban environment
- -vegetation often exotic/manicured
- -large numbers of users
- -highly developed facilities
- -intensive traffic/parking development

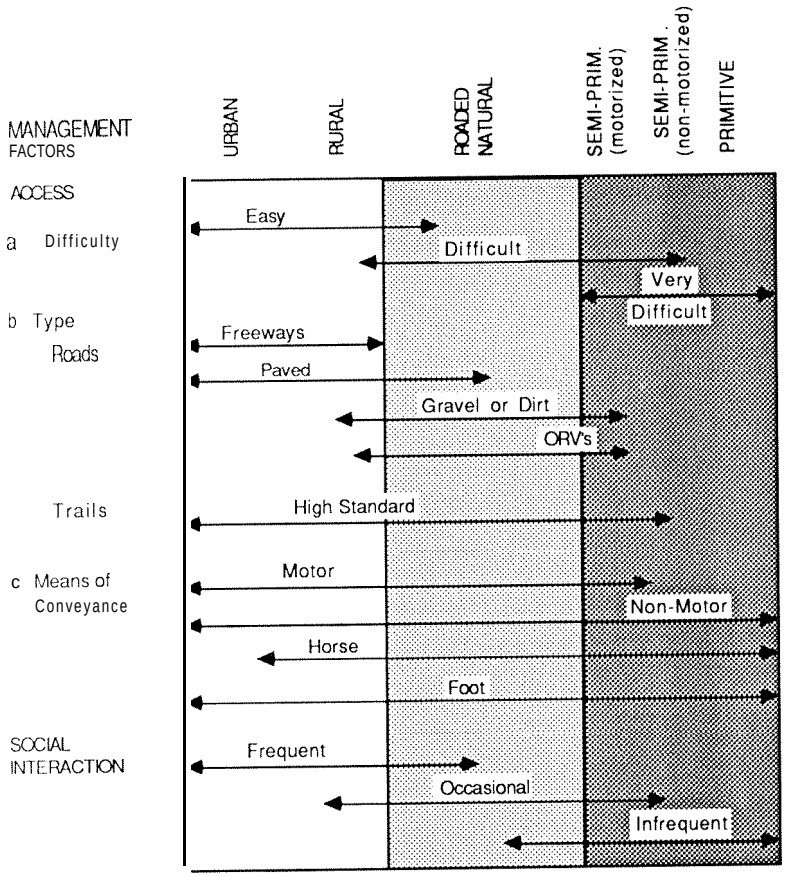

Figure 2.—Recreation Opportunity Spectrum settings.

The ROS framework also has “management factors,” which, together with the settings, form a grid (fig. 2). Only 2 of the 6 management factors are shown -- access and *social* interaction. *(Access* is subdivided into *difficulty, type--roads or* trails, and means *of* conveyance.) Figure 2 shows that access is “easy” in the urban and *rural* settings, “difficult” in the roaded natural through semi-primitive non-motorized settings, and “very difficult” in semi-primitive motorized through *primitive* settings. By glancing down the roaded natural column you can see the kinds of roads, trails, conveyance, and social interactions that are acceptable in a setting that is managed to be natural, but with roads.

How do you use the ROS system? First you should obtain a copy of the User’s Guide (see References). Next you would map all the cultural features (roads, trails, etc.) and then zone your land according to the settings and their attributes (table 1). (The remaining management factors are given and defined in the User’s Guide.) Then you should set your objectives for the land and develop the standards and prescriptions to maintain the kind of settings you want.

The ROS system will help you analyze how a management action such as timber harvest will alter one recreational use-say, fishing in a primitive setting-by increasing access, thereby creating use by mountain bikes or 3-wheelers, and a subsequent demand for more trails. The ROS gives you a way to portray these potential changes and evaluate whether they are desirable or inappropriate.

In summary, the ROS framework can help you:

1. Inventory, zone, and classify recreation settings, activities, and experiences.
2. Develop standards and prescriptions to maintain the kinds of recreation settings that you want.
3. Set management objectives and priorities to guide your decisionmaking.
4. Provide systematically for diverse, wide-ranging, quality recreation opportunities.

References

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CENTRAL HARDWOOD NOTES

Planning and Managing Recreational Opportunities on Small Ownerships

Demand for outdoor recreation in the central hardwood region continues to grow, though at a slower rate compared to the recent past. Meanwhile, land acquisition by public agencies has slowed, while some private forest lands are being converted to other uses. The result is increasing recreation pressure on a constant or declining land base. About a third of the noncorporate, private forest acreage is presently available to recreationists nationwide. Clearly, if you are a private forest landowner you have an opportunity to meet new recreation demands if you so desire.

Many landowners have decided that recreation by the public is inappropriate for their land and their objectives. Reasons include: vandalism, potential liability problems, and intrusion on privacy. On the other hand, many owners welcome recreationists as a means of improving public relations, as a source of income, or as a means to avoid vandalism or property damage.

Incentives are available in some states to owners who open their land to recreation. These incentives include tax breaks, protection from lawsuits, and/or payments from public access programs. Interested landowners should contact their state conservation agency or cooperative extension service for specific information about such programs.

Planning

Once a landowner has decided to open his or her land to recreation, the first step in the planning process is to inventory the resource. Determine land and water acreages and identify unique features of the area such as wetlands, bluffs, and areas with exceptional scenery. Note the distribution and abundance of fish and wildlife species. USDA offices in your county can provide assistance.

Landowners should also consider regional population and ease of access within the region. Both help determine the market area for any enterprise.

You must then decide what type(s) of recreation to offer. Alternatives include: hunting, fishing, hiking, cross-country skiing, snowmobiling-all requiring little capital investment. Owners also may wish to consider more intensive developments such as campgrounds and downhill ski areas. The decision concerning

level of development depends on your objectives, available capital, and potential markets. Information about potential markets is usually available from your state's comprehensive outdoor recreation plan. This plan identifies recreation needs, as well as current providers, by activity and region within the state.

You must also decide the appropriateness of charging a user fee. While fees result in additional revenue, they can be offset by collection costs, changes in liability, and potential losses of good will from opening land to recreation. Consider potential revenues and costs very carefully.

The final step in planning is to consider facilities. Activities like snowmobiling or hiking need few facilities. Trails can usually be constructed with available farm equipment or hand tools. Information about more intensive facilities are available from a variety of sources. Your local college may have a recreation-related program with faculty who are experts on the subject. Both state and federal agencies are sources of information. For example, the Soil Conservation Service has a booklet on the planning, design, and construction of farm ponds for wildlife habitat and farm fishing enterprises. The Park Practice *Program,* published by the National Park Service, includes a periodical entitled *Design* that includes plans for virtually every conceivable recreational structure. It is usually available from most libraries or agencies managing recreation resources.

Management

A major goal in managing recreation woodlots should be to maintain long term forest productivity while allowing recreational use. Human presence will impact the forest site. The key is to control the impact before costly maintenance is needed. For example, trail erosion in early stages is simple to repair with hand labor. More severe cases, however, may require the construction of check dams, plantings, or even trail closure.

Similarly, recreation areas and facilities that are kept clean and in good repair tend to have less vandalism, littering, and other forms of depreciative behavior. Conduct periodic inspections of facilities and routinely look for and correct potential danger from trees and other hazards.

Some modification of the recreation area may be appropriate. For instance, if wildlife is an important part of the recreation experience, wildlife habitat improvement may be appropriate. Information about such techniques for your area is available from wildlife and conservation agencies and organizations.

If fragile lands or endangered plant and animal species are present, you may wish to restrict permanent or seasonal access to such areas.

Managing a recreational enterprise will involve the same financial concerns found in other businesses that require careful financial management. Finally, good management requires responsiveness to customers and their changing needs. The result will be a more satisfied clientele-one that returns frequently.

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CENTRAL HARDWOOD NOTES

Visual Management of Central Hardwoods

People have become more aware and concerned with the appearance of forest landscapes. As a result, the appearance of the landscape is recognized as an important resource that needs to be managed along with wildlife, timber, and water. A visual management goal for central hardwoods is to maintain a natural-appearing landscape; one that reflects good forest husbandry and land ethics. This includes active management of the vegetation, using sound silvicultural and landscape management practices.

Areas needing the most attention are landscapes visible from major travelways, waterways, recreation areas, and other concentrated use areas. Likewise, areas and activities viewed at close range (foreground areas) are more sensitive than those farther away.

Landscapes having a variety of landforms, water bodies, open spaces, and vegetation will appeal to more people than those that lack variety. Vegetation management should aim to provide a combination of natural looking spaces, including groups of trees and plants of different sizes, densities, colors, and textures.

The following table describes the potential visual impact of various stand prescriptions and suggests what you should consider when planning and maintaining landscapes to be visually appealing.

Visual Resource Table

Even-Age Management

Provides visual variety as well as timber and wildlife benefits. With proper planning and implementation, you can minimize potential unsightliness.

Cutting Method and Visual Benefits	Potential Unsightliness	Applicable Landscape Design Actions (see detailed descriptions)
Clearcut	High	
Can result in positive visual benefits with proper planning, placement and execution. Provides spatial and vegetative variety, including structure, size and species. Provides temporary openings and vistas (choice ones can become permanent through maintenance).	Can produce sharp spatial contrasts in solidly timbered landscapes. May cause temporary color contrasts in disturbed soil. Harvest and site preparation slash off en contrasts with surrounding timber in form, line, color, and texture for about two growing seasons. Regeneration creates a solid mass of brushy young trees.	All
Two-stage shelterwood (fig. la)	Moderately High	
Effects are similar to clearcutting but in a subdued manner with an open, savannah like appearance after the first cut. When the shelter wood is removed, the new stand usually has sufficient structure to screen earlier harvesting. Final harvest impacts are less noticeable because of advanced regeneration.	Similar to clearcutting except shelterwood softens form, line, color, and texture contrasts. Final harvest may cause temporary unsightliness due to slash and possible damage to existing vegetation. Regeneration creates a mass of brushy young trees.	A, C, F, G, H, I, J, K,
Esthetic Three-St-Shelterwood (fig. 1 b)	Moderate	
For visually sensitive areas. More trees are left after each cut. Time period be-	Same as shelterwood except the additional cutting causes another, but less	A, C, F, G, H, I, J, K

tween each cutting is extended 20 to 30 years. The shelterwood gives the appearance of a natural overstory. Benefits are similar to a two-stage shelterwood but regeneration is taller, providing a better screen for final removal cut.	intensive disturbance. Regeneration creates a mass of brushy young trees.		
Two-Aae Manaaement (fig. lc)	Moderately Low		
Especially desirable for sensitive areas. Manage to maintain two distinct age classes, about 50 years apart. Maintains a continuous cover of trees and avoids complete overstory removal. Provides spatial variety and penetrating views into stands for a period after harvest. Encourages intolerant and midtolerant species.	Causes normal logging impacts such as color contrast in disturbed soil and slash for a short time.	A ,C, F , G, H, I, J, K	
Intermediate Thinning Cuts	Low		
Provides views into the stand. Hastens development of large trees.	Causes normal logging impacts, such as color contrast in disturbed soil and stash for a short time but these are muted by residual vegetation.	A ,F , G, H, I, J, K	

Uneven-Age Managenent

Provides a more natural appearing forest with a continuous timber stand in place, while benefitting timber and wildlife. The shift towards a stand composed of more tolerant species can add visual variety.

Cutting Method and Visual Benefits	**Potential Unsightliness**	**Applicable Landscape Design Actions**
Group Selection (fig. Id)	Moderately Low	
Provides a continuous forested appearance over a large area. Small cutting units can provide spatial variety, views, and vistas. Opening sizes vary from l/4 to 2 acres and are scattered throughout a stand giving variety in size and age.	Care is needed to schedule and locate cutting units to avoid monotonous and unnatural appearing landscapes. Although some additional roads may be needed because of more frequent cuttings (15- to 20-year intervals) residual vegetation will soften these impacts.	All
Single Tree Selection	Low	
Especially desirable in sensitive areas. Provides a continuous forest scene, with variety of tree species and sizes. Can add vegetative variety and spring and fall color. Can provide minor penetrating views after cutting.	Impacts associated with harvest cutting and stand improvement are minor and short-lived. Residual vegetation softens the impacts of slash and soil disturbance. More roads may be needed along with more frequent cuttings (15- to 20-year intervals) than with the even-age system.	A ,F , G, H, ,1 J, K

Figure 1 .-Cutting methods.

Landscape Design Actions

A - Plan comprehensively - Achieve a comprehensive visual effect by planning a travelway or viewing area rather than considering a stand at a time.

B - Make openings - Vary the size and shape of regeneration openings according to the scale and appearance of the surrounding landscape. Locate openings randomly with variable distances between them (fig. 2a)

C - Shape stand boundaries - Stand boundaries should appear natural. Stand openings should have free-form shapes and undulating edges that follow natural topographic features and vegetative changes (fig. 2a).

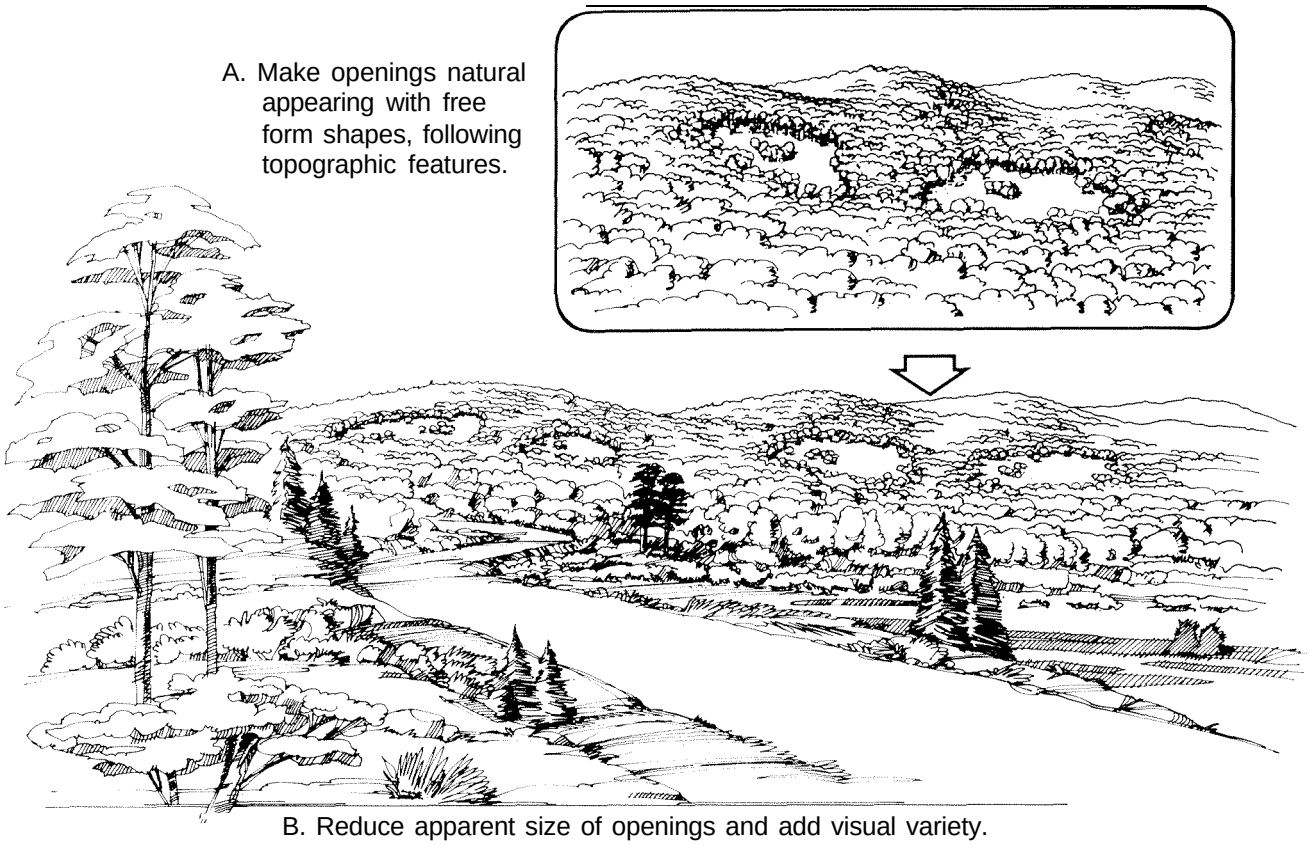
D - Soften large openings - Reduce the apparent size of openings and add visual variety and wildlife benefits, as follows (fig. 2b):

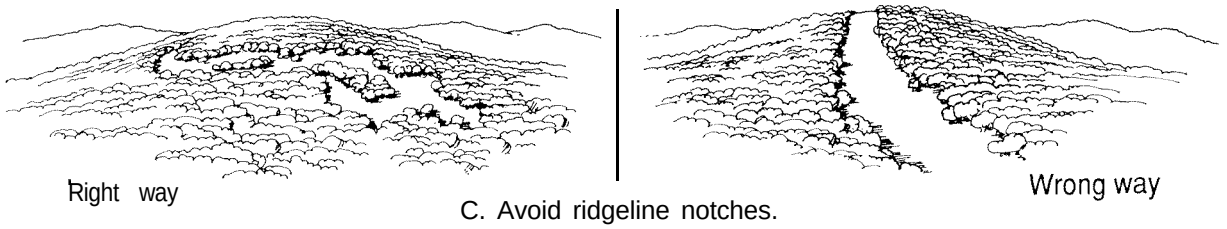
- Identify and protect special vegetation to be left on the area before harvesting and site preparation.
- Leave groups of trees, flowering trees, and shrubs.
- Utilize existing well formed and potential "character" trees to frame and soften openings.
- Extend peninsulas of vegetation from adjacent stands (fig. 2b).
- Leave groups or islands of vegetation, rather than single, scattered trees (fig. 2b).
- Leave groups of pine and/or cedar to provide visual variety, particularly during the dormant season.
- Avoid creating notch-like openings on ridge lines (fig. 2c).
- Clump snags and den trees for wildlife with other vegetation in the fore ground, or leave them along edges. Avoid leaving evenly distributed single trees in the foreground.

E - "feather" edges - Soften the sharp contrast. Edges should be feathered (partially cut) along the borders to create a transition in height and density between cut and uncut stands (fig. 2d).

F - Harvest during dormant season - This will reduce the strongly persistent leaf color contrasts in highly visible areas. It will also reduce undesirable soil color contrasts caused by construction and use of roads and skid trails.

G - Design roads and landings carefully - Keep the amount and construction standards of access roads, skid trails, and landing areas to a minimum. Locate to minimize visibility from travelways and use areas. Those no longer needed should be treated with waterbars as needed, and planted or seeded to reduce soil erosion and associated color contrast.





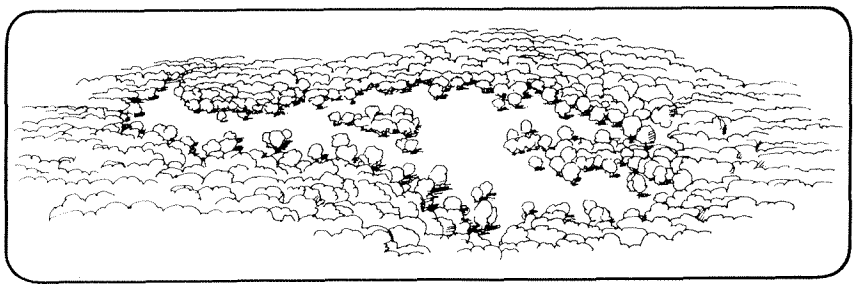


Figure 2.-Landscape design actions

H - Utilize whole *tree* - Close utilization of wood residues for charcoal or fuelwood can off en improve the looks of harvested areas.

I - *Treat* slash - Chip, lop, and scatter slash, or keep it low to the ground to improve appearance and to encourage rapid decay. This is especially important near roads, trails, and overlooks. The treatment can vary depending on the sensitivity of the area. Fell dead, dying, broken, and leaning trees in the foreground to reduce unsightliness.

J - *Reduce management time* - Because logging, thinning, road construction, etc., are unsightly, reduce their duration to a minimum.

K - Enhance *beauty* - Look for opportunities to create vistas, views of rock outcrop pings, water bodies, and other natural attractions.

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CENTRAL HARDWOOD NOTES

Factors Influencing Water Resources

Our Nation, as a whole, has an abundance of water with an average of 30 inches of precipitation each year. About 8.3 inches, or 1,200 billion gallons per day of this amount becomes streamflow. Only 55 percent of the average annual streamflow is generally available for use. Approximately 1,900 gallons per person per day or 420 billion gallons per day are used for domestic purposes, irrigation, and industrial uses. Demands are projected to increase at 2 percent per year. In addition, water is becoming more important for transportation and recreation. Considering that 80 percent of the Nation's valuable water supplies originate on forest and range lands, it is essential for resource managers to understand basic hydrologic relations and the impacts of management.

In the central hardwood region, average annual precipitation exceeds the national average and ranges from 30 inches in the northwest to nearly 50 inches in some southern areas. Average annual streamflow in the region varies from about 10 inches in the low rainfall areas to nearly 20 inches in the high rainfall areas. Groundwater supplies are abundant over most of the region and use is relatively low. Recreational benefits and uses of surface waters in the central hardwood region are important to many people.

Water Quality

Water quality refers to the physical, chemical, and biological characteristics of water. It is a product of climate, geology, physiography, vegetation, and human influences. If human influences are few, water quality is primarily related to the natural environment through which the water passes. Natural water quality varies considerably from place to place, depending on local factors, and it fluctuates due to seasonal and periodic events.

Forest ecosystems have the ability to stabilize natural water quality characteristics, and thus yield the highest quality water available for our use. In managing central hardwood forests, we must be careful not to let human activities adversely affect sediment, nutrient, and temperature levels of stream water. Basically, the effects of management relate to changes in the surface soil and vegetation.

The Water Cycle

Water is essentially a renewable resource, as are forests. It is renewable in that it passes through the endless moving process known as the "hydrological cycle." Most of the precipitation that falls in the central hardwood region is formed from water which evaporates from vegetation, lakes, rivers, and ground surfaces. A significant amount also originates as water vapor formed over the Gulf of Mexico, and is carried north by air currents. Precipitation may replenish soil moisture, move deep to groundwater reservoirs, or enter streams and move to the ocean. Less than 1 percent of the earth's water moves through the hydrologic cycle to supply the fresh water needs. The remaining 99 percent is in the oceans and polar ice caps.

Weather and climate are the primary factors that influence the distribution of precipitation and form and sustain lakes and rivers, create deserts, and produce floods and droughts. However, the distribution of water is also influenced by geology, soils, and vegetation, and their interactions with climate and weather.

Effects of Geological Features

Geologic erosion over millions of years has produced an organized stream system, which constantly changes from natural processes and human activities. In hilly or mountainous areas, the topographic divide between watersheds or basins is easy to establish, but in flat terrain it's extremely difficult to determine boundaries. Land forms have a significant role in the distribution and yield of water. Steep slopes provide greater stormflow yields at faster rates than gentle slopes. Relatively flat areas usually provide greater recharge to groundwater supplies. Topographic divides do not always represent the water divide since subsurface features may control subsurface water flow. Consequently, precipitation, pollution, disturbance, or use in one basin may affect streamflow or groundwater in another basin.

Effects of Forest Soils

Soils play an important role in determining the amounts and distribution, as well as the quality, of water coming from forested watersheds. Soils are largely the result of natural geologic weathering and erosion processes, but they can be greatly influenced by human activities. The amount and characteristics of the pore spaces are the primary factors affecting water movement and storage. The amount of pore space largely depends on soil texture, structure, and depth. Most forest soils have relatively deep litter and humus layers on the surface. The zone beneath these layers is the active zone for insects, worms, and small mammals and contains many large macropores. These upper soil horizons generally have very high infiltration rates and water storage capacities. Thus, most of the rain that falls infiltrates into these zones, and percolates to deeper horizons, the water table, and/or moves downslope through the macropores to stream channels with little or no erosion. Water movement in the deeper soil horizons is usually slowed because of higher clay content and smaller pores. Since the thickness or depth of soil varies widely in the central hardwood region, so does runoff.

The soil water deficit or difference between the available water-holding capacity and current water content of the soil is the primary factor that determines the amount of storm runoff. This deficit is created by water loss from the soil through evapotranspiration. Usually, the soil water deficit must be satisfied by rainfall before runoff occurs, even with very intense storms.

Effects of Forest Vegetation

The vegetative canopy and the litter layer protects the soil from erosion and recycles nutrients to maintain or enhance fertility. So silvicultural treatments have the greatest potential to change or manipulate water yield. As precipitation falls on forest vegetation, its velocity is reduced and part of it is intercepted by leaves, twigs, and stems. Some of the intercepted water flows down the stems (stemflow) to the ground. Canopy interception amounts to about 12 percent of annual rainfall,

but varies a lot by seasons, foliage changes, and storm characteristics. Some of the precipitation that passes through the forest canopy (throughfall) is intercepted by the litter layer, which protects the soil surface structure from raindrop impact and reduces evaporation losses. The remaining throughfall enters the soil. Most of the water that is intercepted by vegetation and litter is evaporated, but some of it may be used by plants. The vegetative canopy also withdraws a tremendous amount of water from the soil through transpiration and growth processes. A fully stocked central hardwood forest will use about three-fifths of the annual precipitation or 18 to 30 inches in these evapotranspiration processes. So manipulating the vegetative canopy can have a significant effect on water yield from a given watershed. For example, immediately after clearcutting, most of the vegetative interception and transpiration losses are eliminated, but evaporation from the soil surface increases slightly, especially as the litter decomposes. And runoff and deep percolation are increased.

The amount of increase in streamflow associated with silvicultural treatments varies with location of watershed, amount and distribution of rainfall, relative amount of vegetation removed, time since treatment, soil characteristics, and geological features. (A more detailed discussion of the effects of forest management practices on soils, water quality, and water yield is presented in Note 11.02 *Management Practices and Water Qualify.)*

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CENTRAL HARDWOOD NOTES

Management Practices And Water Quality

In the upland forests of the central hardwood region, most water quality changes associated with cultural practices are from the access roads and harvesting. Yet research shows that in the eastern United States, sediment yields from careful harvesting and site preparation on upland sites is actually less than from normal geological erosion-between 0.05 and 0.10 tons per acre per year for harvesting and site preparation compared to an estimated 0.18 to 0.30 tons for geological erosion.

Why Soil Erodes

Soil losses and sediment yields due to silvicultural activities generally occur when the protective litter layer is disturbed. Water from undisturbed forest lands is high quality because the canopy and litter layer protect the soil surface, and enhance soil biological activity. With the litter intact, water infiltrates the porous upper soil layers rapidly and rarely flows over the surface. Without this protective layer, however, raindrops detach soil particles and start eroding, transporting, and depositing sediments. Dislodged soil particles wash into soil pores, decrease soil porosity, and overland flow starts. Soil porosity is also reduced by compaction from heavy equipment used in forest operations, especially when soils are wet.

What About Nutrients?

More nutrients are lost following cultural treatments because fewer mobile nutrients are taken up, organic matter decomposes faster, and soil erosion increases. However, losses are usually low. Nutrient levels in streams do not change much and generally remain below the levels of natural geologic weathering and atmospheric inputs. Fertilization and fire may cause temporary, short-lived increases in stream nutrients.

Cutting Can Increase Streamf low

Changes in stand density or the forest canopy will change the water regime (fig. 1). The change in streamflow or water yield will be proportional to stand density reductions. Clearcutting may significantly increase streamflow from the harvest area because the amount of water lost to interception and used by vegetation in the evapotranspiration process is reduced. Reduced evapotranspiration increases soil water content and prolongs streamflow. Streamflow will last longer in the spring and begin sooner in the fall. Peak flows from moderate to small size storms occasionally increase as a result of timber harvesting. But newly harvested areas are usually small compared to entire drainage basins and do not contribute significantly to flood peaks. Generally, the increased flow during low flow periods is beneficial to other forest resources

Figure 1 -Streamflow increases after clearcutting as shown by this gauging station in a Clearcut watershed.

What About Logging?

Generally, the smaller the area harvested, the lesser the effect on water yield and quality. Instead of rubber-tired or crawler tractors use cable or helicopter logging on steep slopes, fragile soils, or where you want fewer roads. The key to protecting forest watershed values is to minimize soil disturbance and water channelling in logging roads and skid trails during harvests. A careless logger can cause water quality problems even with appropriate silvicultural treatments.

What About Site Preparation?

Site preparation often involves only selective treatment with herbicides or a light prescribed burn. If done properly, neither would significantly affect water quality or yield. Very hot fires will increase sediment and nutrient losses for a short time and will damage residual hardwoods. Prescribed fires to enhance regeneration or improve wildlife habitat will generally not degrade water quality or site productivity.

Best Management Practices

The following recommendations are designed to reduce soil disturbance and minimize the effects of timber harvesting and site preparation. More specific guidelines for best management practices may be available through state agencies.

1. Provide streamside management zones (SMZ's) along both sides of well-defined ephemeral, intermittent, and perennial stream channels and along the edges of lakes and other water bodies. The SMZ's should be wide enough to protect the area around the channels or shores from disturbance. State and federal guidelines or regulations provide specific SMZ widths depending on local criteria (call your state forestry agency). Some trees may be harvested from the SMZ's on a selective basis-up to 50 percent of the canopy. But skidding equipment or other vehicles should not be permitted in the zones. All treetops should be promptly removed from stream channels or other water bodies. In addition to protecting stream channels from disturbance, SMZ's help prevent excessive changes in stream temperatures, and protect aquatic organisms.
2. Select a contractor who will log carefully and who has equipment that will do the job properly without excessive damage to the site or residual trees.
3. During harvests skid uphill or away from stream channels to haul roads located on contours or ridge tops. Avoid skidding practices that channel water into streams.
4. Log only when soils are relatively dry. Wet-weather logging compacts soils and increases erosion.
5. After logging operations are completed, high erosion hazard areas such as landings, skid trails, and temporary access roads, should be disked or ripped, seeded, and fertilized based on local or regional recommendations.
6. Prevent water from collecting in landings and flowing down roads, skid roads, and skid trails. Water bars, outsloped roads, and revegetation immediately after logging will generally prevent excessive erosion. For minor soil disturbances, use cull logs and brush to disperse water until natural vegetation forms a protective cover.

7. if herbicides or pesticides are used follow label directions carefully, avoid spillage, and keep chemicals away from stream channels or water surfaces. Do not use chemicals in buffer zones.
8. Carefully examine logged areas a few months after harvesting and restoration are completed. Use logging residues, revegetation, or land treating equipment to stabilize any actively eroding areas.

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CENTRAL HARDWOOD NOTES

Forest Access Roads

In order to manage and use forest land, some type of access is needed. Today forest access means roads capable of providing access for tri-axle log trucks and skidroads for wheeled skidders (fig. 1). The bare soil exposed by road building is the major source of stream sediment from logging operations. Roads normally expose soil on about 10 percent of logged areas.

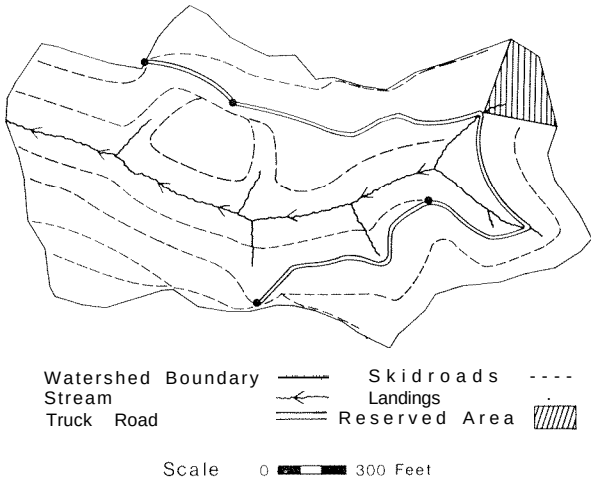

Figure 1.-An example of a forest road system meeting West Virginia Best Management Practice standards. It was used to remove approximately 1/2 million board feet of timber from a 96-acre Appalachian watershed.

The residual value of roads is often overlooked. Roads are the most lasting disturbance on logged areas and should be considered a permanent investment on forest land. Good roads not only provide access to a woodlot for posts, firewood, and future harvests, but may be used as access for hunters and other recreational uses. The importance of careful planning and layout cannot be overemphasized One steep section or soft spot can limit use of the road beyond for vehicles other than wheeled skidders. A good road system will meet users' needs without harming other resources (see Note 11.02 *Management Practices and Water Quality*).

Steps to a good forest access system:

1. Examine the area that can logically be served with the proposed road system until you are familiar enough to outline it on aerial photographs and topographic maps.

2. Determine the starting and ending points of the truck road.
3. Find out the elevation difference between the starting (e.g., county road) and ending locations (e.g. saddle on a ridge) to see if a road between the two points is feasible on an acceptable grade where maximums do not exceed about 10 percent.

$$\text{Road Grade percent} = \frac{\text{Elevation Difference X 100}}{\text{Horizontal Distance}}$$

4. If possible, lay out roads when the leaves are off. There is no substitute for walking over the area to be roaded It requires a lot of time to plan and layout a mile of truck road. Remember there is always a best road location. It is the responsibility of the road locator to put forth the effort to find it.
5. Locate control points. Control points are critical in determining road location. There can be obstacles you must avoid such as property corners, wet areas, underground gas lines or cables, and rock outcrops; or places the road should pass through, such as landing locations, and sites to cross streams. Keep roads and landings at least 100 feet from streams, the further the better.
6. After a proposed route is determined, flag a rough grade line (e.g., +5 percent or less) on this proposed location to see if it is feasible. Consider skidroad locations at this time too, so the entire road system can be tied together. Keeping forest access roads within acceptable grade limits is normally a problem in Appalachia, so major changes in the proposed road locations are sometimes necessary. Always remember: (a) road grades can be reduced if roads are lengthened, and (b) it is much more difficult to control water on steep roads. Keep rerunning the road grade line, always removing the old ribbon until you are satisfied that the road is in the best location. Locating a road properly the first time can avoid years of poor access and the difficulty and high cost of relocating.
7. Make sure the final road location is: (a) well flagged, (b) will provide access to the entire tract, (c) is environmentally sound, and (d) that a system of landings and skidroads can be tied into it.
8. Decide on the number and size of culverts. Use tables listed in the various erosion control references to determine culvert sizes. Culverts should be used on all live and intermittent streams and major seeps. Use at least 25 to 30 feet of culvert for truck roads. Deeper fills require longer culverts.
9. Space broad-based “dips” about 150 feet apart to control surface water (fig. 2). Where feasible vary the road grade to provide natural grade “breaks“ (where the grade suddenly changes) and reduce the number of constructed dips.
10. Lay out skidroads after the truck road. Use the same procedure striving for a maximum 15 percent grade and a minimum 150-foot spacing.

Figure 2.-A minimum-standard road showing a broad-based dip in the foreground.

11. Build truck roads and skidroads in dry weather if practical. Avoid skidding and hauling logs during rainy periods (when roads and trails may be damaged by excess water) and when surfaces are freezing and thawing.
12. Don't use broad-based dips on skidroads. The road surface is constantly being disturbed by dragging logs. Instead, use major grade breaks or grade changes to control surface water. Wheeled skidders can negotiate these sharper, deeper dips. Used gas-line pipe makes excellent culverts for seeps and streams on skidroads because it is highly resistant to crushing. Install 'water bars" to control water on skidroads as soon as logging is completed on them.

13. Seed roads and landings after logging to provide additional protection against erosion. Seeding also improves the appearance of logged areas and provides food for wildlife (see Note 9.08 Logging *Roads and Log Decks for Wildlife Habitat*).

A "minimum-standard" road that provides good access for several forest uses and is environmentally sound is described below (see References). The average cost per mile for this type of road (excluding gravel) is about $8,000. While gravel is costly it not only improves road utility but dramatically reduces soil losses from road surfaces.

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CENTRAL HARDWOOD NOTES

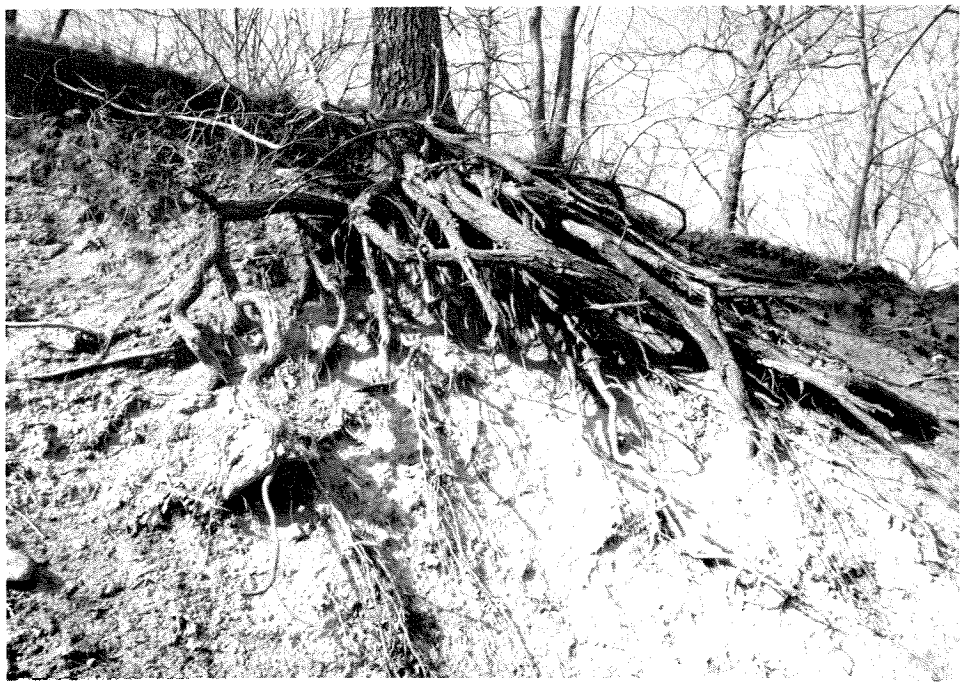
Grazing Effects On Soil And Water

In terms of animal nutrition and growth, there is little economic justification for grazing in hardwoods, though the trees do provide shade during hot weather. Some land managers who are not interested in growing hardwood timber see little reason to deny livestock full access to woodlands. And some grazing damage to soil and water probably is inevitable.

Litter on the forest floor is reduced by trampling and, along animal pathways, may be displaced sufficiently to expose mineral soil to locally serious erosion. Trampling compresses macropores in the upper few inches of soil, especially when soils are wet. Consequently, rates of infiltration and percolation are reduced, though seldom below the rates of the usual rainfall intensities. These effects do accelerate erosion, but soil losses exceeding 1 ton per acre per year rarely have been measured in carefully controlled experiments. Soil loss on the order of 1/20- to 1/1O-ton per acre per year is widely regarded as the geologic norm for the eastern forest region and losses ranging from 1 to 5 tons per acre per year are regarded as tolerable by the USDA Soil Conservation Service.

Through the years, forest owners and managers have been warned about the soil and water erosion caused by grazing. Indeed, such damage occurs but careful observation usually shows that active erosion is localized, commonly in places where too many animals have been restricted for too long on too small an area. This 'worst case" situation has tended to exaggerate soil loss as an incentive to get grazing animals out of hardwoods in order to optimize tree growth. To date, the far more common practice of widely dispersed grazing has not been shown to seriously accelerate erosion.

In earlier times, newly cleared forest sites often were cropped until some combination of depleted fertility and accelerated soil erosion rendered further cropping unprofitable. Without tillage, natural revegetation provided opportunity for grazing, which often continued throughout the entire course of succession from open fields to closed forests. Today, when people see animals grazing in a forest that has healed gullies or other evidence of former misuse, they conclude that current grazing accelerates erosion. True, the old gullies are there, but the discerning observer almost always finds them fully covered by litter and with trees growing in them-prima *facie* evidence that there is no overland flow and that there is little likelihood of erosion much above geologic rates. The healed gullies, the scars of practices long past, have been stabilized by decades of forest regrowth despite livestock roaming about in constant search of forage.



Too many animals on too small a space can cause active erosion such as on this grazed, steep slope (Harold Scholten).

Reduced water quality is unavoidable where animals have free access to forest streams. Deposit of body wastes directly into or close to water courses is an obvious source of pollution. Trampling stream banks and wading in channels increases the sediment load in streams. Fencing stream channels and immediate environs is an obvious way to maintain high water quality. Fencing not only protects the highly sensitive channels but establishes a filter strip to intercept sediment originating from upslope grazing.

Grazing harms most hardwoods through loss of foliage, small branches, bark, and by root trampling. It also reduces growth and makes trees more susceptible to decay, disease, and insects. Preferential browsing among small trees and seedlings alters stand composition, while heavy and prolonged browsing can eliminate all tree reproduction. The message is clear: don‘t graze stands if you want optimal hardwood reproduction and growth and no damage to soil and water.

In brief, forest grazing is rarely profitable in the central hardwood forest region. Where it is permitted, it will probably cause minor ill-effects on soil and water which can be minimized by fencing animals well away from streams or other water bodies. Most important, too many animals must not be confined for extended periods on too small an area (see Note 8.14 Grazing in Central Hardwood Forests).

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APPENDIX

Pesticide Precautionary Statement

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

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

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

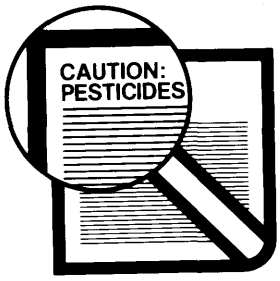
Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

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

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

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

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



APPENDIX

Index of Common and Scientific Names

Common name	Scientific Name
Plants	
American basswood	*Tilia americana* L.
American beech	*Fagus grandifolia* Ehrh.
American chestnut	*Castanea dentata* (Marsh.) Borkh.
American elm	*Ulmus americana* L.
American holly	*Ilex opaca* Ait.
American hornbeam	*Carpinus caroliniana* Walt.
Armillaria root rot	*Armillaria* spp.
Ash	*Fraxinus* L.
Autumn olive	*Elaeagnus umbellata* Thunb.
Beaked hazel	*Corylus cornuta* Marsh.
Big bluestem	*Andropogon gerardi* Vitman
Bigtooth aspen	*Populus grandidentata* Michx.
Birdsfoot trefoil	*Lotus corniculatus* L.
Bitternut hickory	*Carya cordiformis* (Wangenh.) K. Koch
Blackberry	*Rubus* L.
Black cherry	*Prunus serotina* Ehrh.
Blackjack oak	*Quercus marilandica* Muenchh.
Black locust	*Robinia pseudoacacia* L.
Black maple	*Acer nigrum* Michx. f.
Black oak	*Quercus velutina* Lam.
Black tupelo (blackgum)	*Nyssa sylvatica* Marsh.
Black walnut	*Juglans nigra* L.
Black willow	*Salix nigra* Marsh.
Blueberry	*Vaccinium* L. spp.
Bluegrass	*Poa* L. spp.
Boxelder	*Acer negundo* L.
Bracken fern	*Pteridium aquilinum* (L.) Kuhn
Buckbrush (western snowberry)	*Symphoricarpos occidentalis* Hook
Buckeye	*Aesculus* L.
Bur oak	*Quercus macrocarpa* Michx.
Butternut	*Juglans cinerea* L.
Canker stain	*Ceratocystis fimbiata* f. sp. *platani* Walt
Cedar elm	*Ulmus crassifolia* Nutt.
Cherrybark oak	*Quercus falcata* var. *pagodifolia* Ell.
Cherry, plum	*Prunus* L.
Chestnut oak	*Quercus prinus* L.
Chinkapin oak	*Quercus muehlenbergii* Engelm.
Clover	*Trifolium* L. spp.
Common persimmon	*Diospyros virginiana* L.

Coralberry ..... *Symphoricarpos orbiculatus* Moench
Corn ..... *Zea mays* L.
Cucumbertree ..... *Magnolia acuminata* L.
Devils-walkingstick ..... *Aralia spinosa* L.
Dogwood ..... *Cornus* L.
Downy serviceberry ..... *Amelanchier arborea* (Michx. f.) Fern.
Dutch elm disease ..... *Ceratocystis ulmi* (Buism.) C. Mor.
Dutchman's-breeches ..... *Dicentra cucullaria* (L.) Bernh.
Dwarf larkspur ..... *Delphinium tricorne* Michx.
Eastern cottonwood ..... *Populus deltoides* Bartr. ex Marsh.
Eastern hemlock ..... *Tsuga canadensis* (L.) Carr.
Eastern hophornbeam ..... *Ostrya virginiana* (Mill) K. Koch
Eastern redbud ..... *Cercis canadensis* L.
Eastern redcedar ..... *Juniperus virginiana* L.
Eastern white pine ..... *Pinus strobus* L.
European alder ..... *Alnus glutinosa* (L.) Gaertn.
Flowering dogwood ..... *Cornus florida* L.
Ganoderma root rot ..... *Ganoderma curtisii* (Berk.) Marr.
Elm ..... *Ulmus* L.
Green ash ..... *Fraxinus pennsylvanica* Marsh.
Gooseberry ..... *Ribes* L.
Greenbriar ..... *Smilax* L. spp.
Hackberry ..... *Celtis occidentalis* L.
Hawthorn ..... *Crataegus* L.
Hickory ..... *Carya* Nutt.
Honeylocust ..... *Gleditsia triacanthos* L.
Hypoxylon canker ..... *Hypoxylon mammatum* (Wahl.) J. Miller
Indian grass ..... *Sorghastrum nutans* (L.) Nash
Inonotus root rot ..... *Inonotus dryadeus* (Pers. Fr.) Murr.
Jack pine ..... *Pinus banksiana* Lamb.
Japanese honeysuckle ..... *Lonicera japonica* Thunb.
Korean lespedeza ..... *Lespedeza stipulacea* Maxim.
Larch ..... *Larix* L.
Little bluestem ..... *Andropogon scoparius* Michx.
Loblolly pine ..... *Pinus taeda* L.
Maple ..... *Acer* L.
Millet (German) ..... *Setaria* Beauv spp.
Milo ..... *Sorghum* Moench spp.
Mountain-laurel ..... *Kalmia latifolia* L.
Mulberry ..... *Morus* L.
Multiflora rose ..... *Rosa multiflora* Thunb.
Northern pin oak ..... *Quercus ellipsoidalis* E.J. Hill
Northern red oak ..... *Quercus rubra* L.
Nuttall oak ..... *Quercus nuttallii* Palmer
Oak ..... *Quercus* L.
Oak anthracnose ..... *Gnomonia quercina* Kieb.

Oak wilt ..... *Ceratocystis fagacearum* (Bretz) Hunt
Ohio buckeye ..... *Aesculus glabra* Willd.
Orchard grass ..... *Dactylis glomerata* L.
Osage-orange ..... *Maclura pomifera* (Raf.) Schneid.
Overcup oak ..... *Quercus lyrata* Walt.
Paper birch ..... *Betula papyrifera* Marsh.
Pawpaw ..... *Asimina triloba* (L.) Dunal
Pecan ..... *Carya illinoensis* (Wangenh.) K. Koch
Pignut hickory ..... *Carya glabra* (Mill.) Sweet
Pin oak ..... *Quercus palustris* Muenchh.
Pine ..... *Pinus* L.
Pitch pine ..... *Pinus rigida* Mill.
Poison-hemlock ..... *Conium maculatum* L.
Poison ivy ..... *Rhus radicans* L.
Possumhaw (deciduous holly) ..... *Ilex decidua* Walt.
Post oak ..... *Quercus stellata* Wangenh.
Quackgrass ..... *Agropyron repens* (L.) Beauv.
Quaking aspen ..... *Populus tremuloides* Michx.
Red clover ..... *Trifolium pratense* L.
Red maple ..... *Acer rubrum* L.
Red pine ..... *Pinus resinosa* Ait.
River birch ..... *Betula nigra* L.
Rock elm ..... *Ulmus thomasii* Sarg.
Sassafras ..... *Sassafras albidum* (Nutt.) Nees
Scarlet oak ..... *Quercus coccinea* Muenchh.
September elm ..... *Ulmus serotina* Sarg.
Serviceberry ..... *Amelanchier* Medic spp.
Shagbark hickory ..... *Carya ovata* (Mill.) K. Koch
Shellbark hickory ..... *Carya laciniosa* (Michx. f.) Loud.
Shoestring root rot ..... *Armillaria mellea* (Vahl. Fr.) Kumm
Shortleaf pine ..... *Pinus echinata* Mill.
Shumard oak ..... *Quercus shumardii* Buckl.
Siberian elm ..... *Ulmus pumila* L.
Sideoats grama ..... *Bouteloua curtipendula* (Michx.) Torr.
Silver maple ..... *Acer saccharinum* L.
Slippery elm ..... *Ulmus rubra* Muhl.
Sourwood ..... *Oxydendrum arboreum* (L.) DC.
Southern red oak ..... *Quercus falcata* Michx.
Soybean ..... *Glycine max* (L.) Merr.
Spicebush ..... *Lindera benzoin* (L.) Blume
Spotted waterhemlock ..... *Cicuta maculata* L.
Squirrelcorn ..... *Dicentra canadensis* (Goldie) Walp.
Striped maple ..... *Acer pensylvanicum* L.
Sugar maple ..... *Acer saccharum* Marsh.
Sugarberry ..... *Celtis laevigata* Willd.
Sumac ..... *Rhus* L. spp.

Swamp chestnut oak ..... *Quercus michauxii* Nutt.
Sweet birch ..... *Betula lenta* L.
Sweetgum ..... *Liquidambar styraciflua* L.
Switch grass ..... *Panicum virgatum* L.
Sycamore ..... *Platanus occidentalis* L.
Sycamore anthracnose ..... *Gnomonia platani* Edg.
Varnish or lacquer conk ..... *Ganoderma lucidum* (Leys. ex Fr.) Karst.
Viburnum ..... *Viburnum* L. spp.
Virginia creeper ..... *Parthenocissus quinquefolia* (L.) Planch.
Virginia pine ..... *Pinus virginiana* Mill.
Water oak ..... *Quercus nigra* L.
Wheat ..... *Triticum* L.
White ash ..... *Fraxinus americana* L.
White clover ..... *Trifolium repens* L.
White oak ..... *Quercus alba* L.
White snakeroot ..... *Eupatorium rugosum* Houtt.
Wild grape ..... *Vitis* L.
Willow ..... *Salix* L.
Willow oak ..... *Quercus phellos* L.
Winged elm ..... *Ulmus alata* Michx.
Witch-hazel ..... *Hamamelis virginiana* L.
Yellow birch ..... *Betula alleghaniensis* Britton
Yellow-poplar ..... *Liriodendron tulipifera* L.

Mammals, Birds, and Insects

Barred owl ..... *Strix varia*
Black bear ..... *Ursus americanus*
Black-capped chickadee ..... *Parus atricapillus*
Carpenterworm ..... *Prionoxystus robiniae* Peck
Columbian timber beetle ..... *Corthylus columbianus* Hopkins
Cottontail rabbit ..... *Sylvilagus floridanus*
Downy woodpecker ..... *Picoides pubescens*
Eastern bluebird ..... *Sialia sialis*
Eastern chipmunk ..... *Tamius striatus*
Eastern fox squirrel ..... *Sciurus niger*
Eastern gray squirrel ..... *Sciurus carolinensis*
Eastern tent caterpillar ..... *Malacosoma americanum* (Fabricius)
Elm bark beetle ..... *Hylurgopinus rufipes* Eichh.
Fall webworm ..... *Hyphantria cunea* (Drury)
Great crested flycatcher ..... *Myiarchus crinitus*
Gypsy moth ..... *Lymantria dispar* (Linneaus)
Living-beech borer ..... *Goes pulverulentus* Haldeman
Maple trumpet skeletonizer ..... *Epinotia aceriella* (Clemens)
Oak leaftier ..... *Croesia semipurpurana* (Kearfott)

Oak timberworm ..... *Arrhenodes minutus* (Drury)
Red-bellied woodpecker ..... *Melanerpes carolinus*
Red-humped caterpillar ..... *Schizura concinna* (J.E. Smith)
Red oak borer ..... *Enaphalodes rufulus* Haldeman
Ruffed grouse ..... *Bonasa umbellus*
Smaller European elm bark beetle ..... *Scolytus multistriatus* Marsham
Tree squirrels ..... *Sciurus*
Two-lined chestnut borer ..... *Agrilus bilineatus* (Weber)
Walnut caterpillar ..... *Datana integerrima* Grote & Robinson
Walnut shoot moth ..... *Acrobasis demotella* Grote
Whitebanded elm leafhopper ..... *Scaphoideus luteolus* Van Duzee
White-breasted nuthatch ..... *Sitta carolinensis*
White oak borer ..... *Goes tigrinus* (De Geer)
White-tailed deer ..... *Odocoileus virginianus*
Wild turkey ..... *Meleagris galloparo*

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Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.