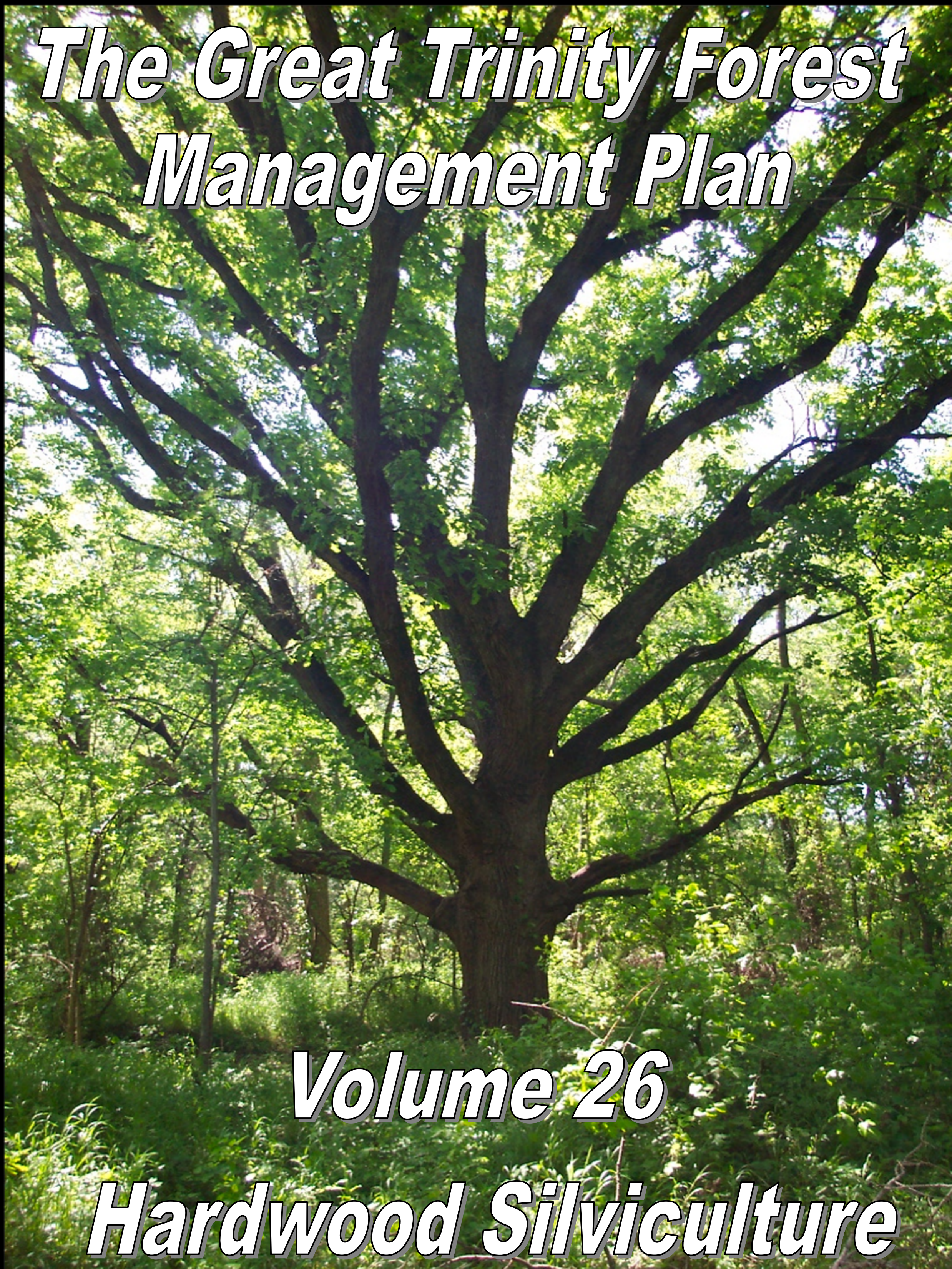
The Great Trinity Forest Management Plan



Volume 26

Hardwood Silviculture

GREAT TRINITY FOREST

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HARDWOOD SILVICULTURE

HOW to Prune Trees

(USDA Forest Service, Northeastern Area State and Private Forestry, NA-FR-01-95)

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Northeastern Area State and Private Forestry

HOW to Prune Trees

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Illustrations by Julie Martinez, Afton, MN

Introduction

The objective of pruning is to produce strong, healthy, attractive plants. By understanding how, when and why to prune, and by following a few simple principles, this objective can be achieved.

Why Prune

The main reasons for pruning ornamental and shade trees include safety, health, and aesthetics. In addition, pruning can be used to stimulate fruit production and increase the value of timber. Pruning for *safety* (Fig. 1A) involves removing branches that could fall and cause injury or property damage, trimming branches that interfere with lines of sight on streets or driveways, and removing branches that grow into utility lines. Safety pruning can be largely avoided by carefully choosing species that will not grow beyond the space available to them, and have strength and form characteristics that are suited to the site.

Pruning for *health* (Fig. 1B) involves removing diseased or insect-infested wood, thinning the crown to increase airflow and reduce some pest problems, and removing

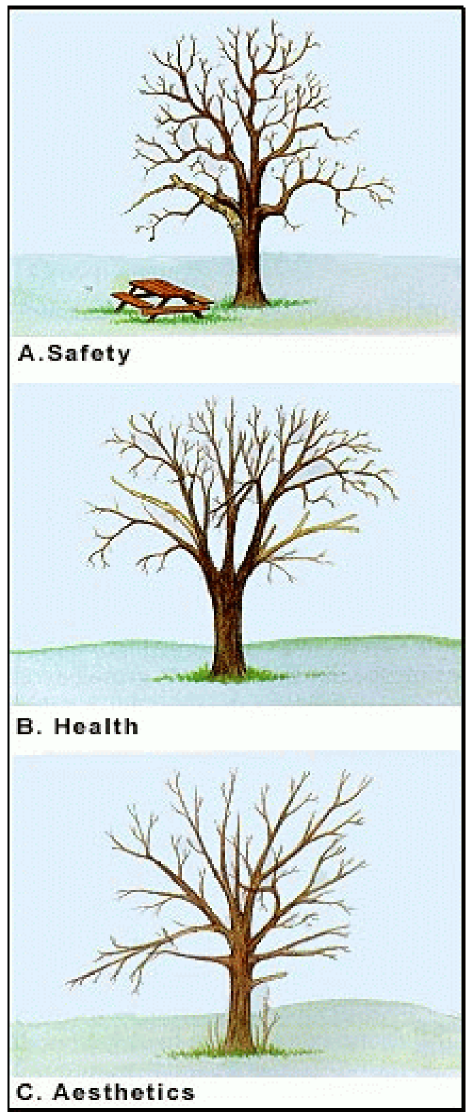


Figure 1. Reasons for pruning.

crossing and rubbing branches. Pruning can best be used to encourage trees to develop a strong structure and reduce the likelihood of damage during severe weather. Removing broken or damaged limbs encourage wound closure.

Pruning for *aesthetics* (Fig. 1C) involves enhancing the natural form and character of trees or stimulating flower production. Pruning for form can be especially important on open-grown trees that do very little self-pruning.

All woody plants shed branches in response to shading and competition. Branches that do not produce enough carbohydrates from photosynthesis to sustain themselves die and are eventually shed; the resulting wounds are sealed by **woundwood** (callus). Branches that are poorly attached may be broken off by wind and accumulation of snow and ice. Branches removed by such natural forces often result in large, ragged wounds that rarely seal. Pruning as a cultural practice can be used to supplement or replace these natural processes and increase the strength and longevity of plants.

Trees have many forms, but the most common types are pyramidal **(excurrent)** or spherical (**decurrent)**. Trees with pyramidal crowns, e.g., most conifers, have a strong central stem and lateral branches that are more or less horizontal and do not compete with the central stem for dominance. Trees with spherical crowns, e.g., most hardwoods, have many lateral branches that may compete for dominance.

To reduce the need for pruning it is best to consider a tree's natural form. It is very difficult to impose an unnatural form on a tree without a commitment to constant maintenance.

Pollarding and **topiary** are extreme examples of pruning to create a desired, unnatural effect. Pollarding is the practice of pruning trees annually to remove all new growth. The following year, a profusion of new branches is produced at the ends of the branches. Topiary involves pruning trees and shrubs into geometric or animal shapes. Both pollarding and topiary are specialized applications that involve pruning to change the natural form of trees. As topiary demonstrates, given enough care and attention plants can be pruned into nearly any form. Yet just as proper pruning can enhance the form or character of plants, improper pruning can destroy it.

Pruning Approaches

Producing strong structure should be the emphasis when pruning young trees. As trees mature, the aim of pruning will shift to maintaining tree structure, form, health and appearance.

Proper pruning cuts are made at a node, the point at which one branch or twig attaches to another. In the spring of the year growth begins at buds, and twigs grow until a new node is formed. The length of a branch between nodes is called an internode.

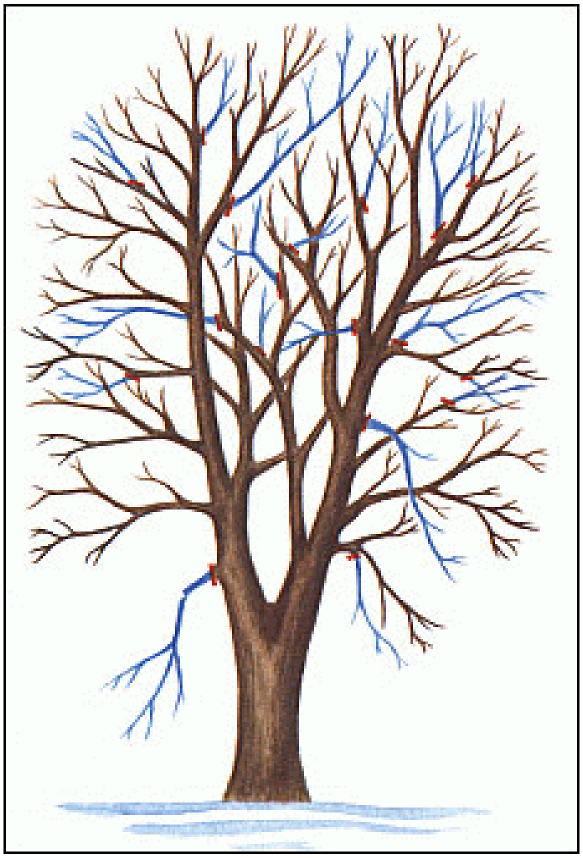


Figure 2. Crown thinning - branches to be removed are shaded in blue; pruning cuts should be made at the red lines. No more than one-fourth of the living branches should be removed at one time.

The most common types of pruning are:

1. *Crown Thinning* (Fig. 2)

Crown thinning, primarily for hardwoods, is the selective removal of branches to increase light penetration and air movement throughout the crown of a tree. The intent is to maintain or develop a tree's structure and form. To avoid unnecessary stress and prevent excessive production of epicormic sprouts, no more than one-quarter of the living crown should be removed at a time. If it is necessary to remove more, it should be done over successive years.

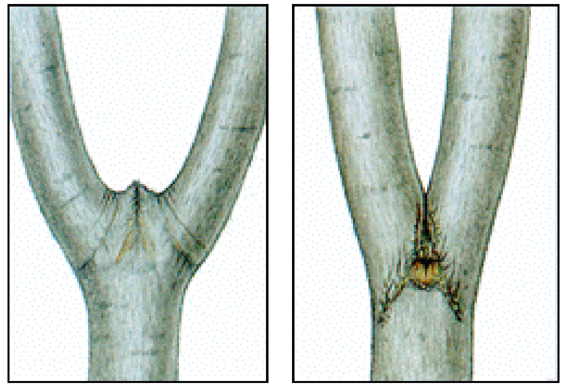


Figure 3. Types of branch unions.

Branches with strong U-shaped angles of attachment should be retained (Fig 3A). Branches with narrow, V-shaped angles of attachment often form **included bark** and should be removed (Fig. 3B). Included bark forms when two branches grow at sharply acute angles to one another, producing a wedge of inward-rolled bark between them. Included bark prevents strong attachment of branches, often causing a crack at the point below where the branches meet. Codominant stems that are approximately the same size and arise from the same position often form included bark. Removing some of the lateral branches from a codominant stem can reduce its growth enough to allow the other stem to become dominant.

Lateral branches should be no more than one-half to three-quarters of the diameter of the stem at the point of attachment. Avoid producing "lion’s tails," tufts of branches and foliage at the ends of branches, caused by removing all inner lateral branches and foliage. Lion’s tails can result in sunscalding, abundant **epicormic sprouts**, and weak branch structure and breakage. Branches that rub or cross

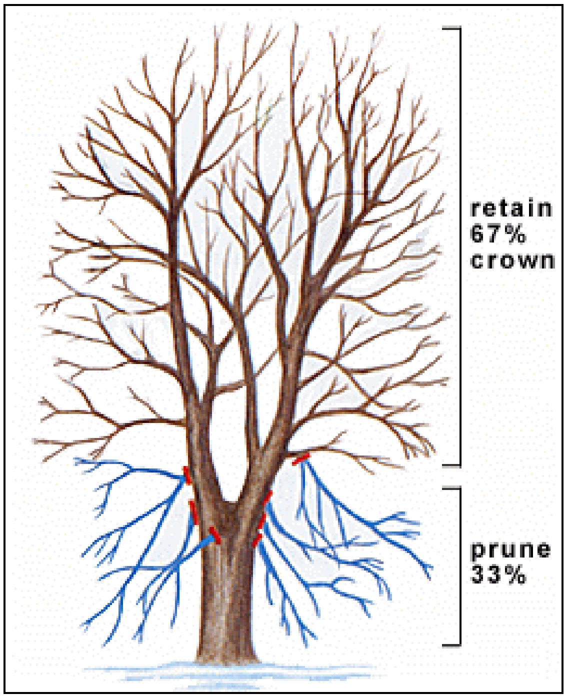


Figure 4. Crown raising - branches to be removed are shaded in blue; pruning cuts should be made where indicated with red lines. The ratio of live crown to total tree height should be at least two-thirds.

another branch should be removed.

Conifers that have branches in whorls and pyramidal crowns rarely need crown thinning except to restore a dominant leader. Occasionally, the leader of a tree may be damaged and multiple branches may become codominant. Select the strongest leader and remove competing branches to prevent the development of codominant stems.

2. *Crown Raising* (Fig. 4)

Crown raising is the practice of removing branches from the bottom of the crown of a tree to provide clearance for pedestrians, vehicles, buildings, lines of site, or to develop a clear stem for timber production. Also, removing lower branches on white pines can prevent blister rust. For street trees the minimum clearance is often specified by municipal ordinance. After pruning, the ratio of the living crown to total tree height should be at least two-thirds (e.g., a 12 m tree should have living branches on at least the upper 8 m).

On young trees "temporary" branches may be retained along the stem to encourage taper and protect trees from vandalism and sun scald. Less vigorous shoots should be selected as temporary branches and should be about 10 to 15 cm apart along the stem. They should be pruned annually to slow their growth and should be removed eventually.

3. *Crown Reduction* (Fig. 5)

Crown reduction pruning is most often used when a tree has grown too large for its permitted space. This method, sometimes called **drop crotch pruning**, is preferred to topping because it results in a more natural appearance, increases the time before pruning is needed again, and minimizes stress (see drop crotch cuts in the next section).

Crown reduction pruning, a method of last resort, often results in large pruning wounds to stems that may lead to decay. This method should never be used on a tree with a pyramidal growth form. A better long term solution is to remove the tree and replace it

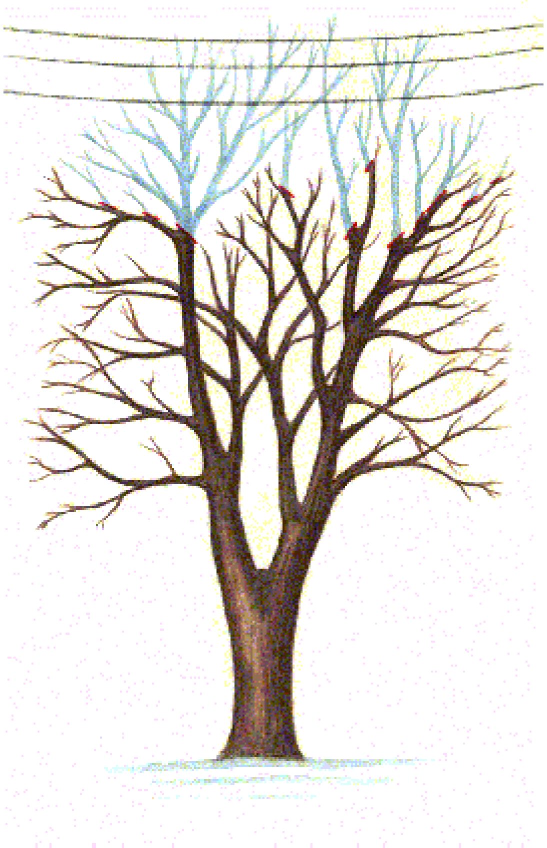


Figure 5. Crown reduction - branches to be removed are shaded in blue; pruning cuts should be made where indicated with red lines. To prevent branch dieback, cuts should be made at lateral branches that are at least one-third the diameter of the stem at their union.

with a tree that will not grow beyond the available space.

Pruning Cuts

Pruning cuts should be made so that only branch tissue is removed and stem tissue is not damaged. At the point where the branch attaches to the stem, branch and stem tissues remain separate, but are contiguous. If only branch tissues are cut when pruning, the stem tissues of the tree will probably not become decayed, and the wound will seal more effectively.

1. *Pruning living branches* (Fig. 6)

To find the proper place to cut a branch, look for the **branch collar** that grows from the stem tissue at the underside of the base of the branch (Fig. 6A). On the upper surface, there is usually a **branch bark ridge** that runs (more or less) parallel to the branch angle, along the stem of the tree. A proper pruning cut does not damage either the branch bark ridge or the branch collar.

A proper cut begins just outside the branch bark ridge and angles down away from the stem of the tree, avoiding injury to the branch collar (Fig. 6B). Make the cut as close as possible to the stem in the **branch axil**, but outside the branch bark ridge, so that stem tissue is not injured and the wound can seal in the shortest time possible. If the cut is too far from the stem, leaving a branch stub, the branch tissue usually dies and woundwood forms from the stem tissue. Wound closure is delayed because the woundwood must seal over the stub that was left.

The quality of pruning cuts can be evaluated by examining pruning wounds after one growing season. A concentric ring of woundwood will form from proper pruning cuts (Fig. 6B). **Flush cuts** made inside the branch bark ridge or branch collar, result in pronounced development of woundwood on the sides of the pruning wounds with very little woundwood forming on the top or bottom (Fig. 7D). As described above, stub cuts result in the death of the remaining branch and woundwood forms around the base from stem tissues.
When pruning small branches with hand pruners, make sure the tools are sharp enough

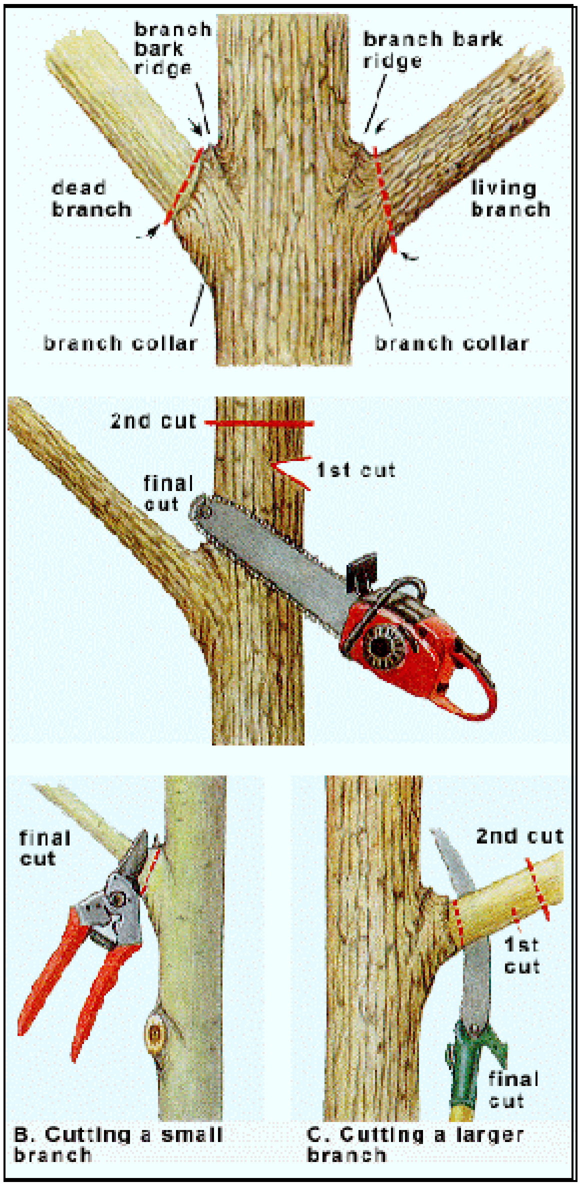


Figure 6. Pruning cuts

to cut the branches cleanly without tearing. Branches large enough to require saws should be supported with one hand while the cuts are made. If the branch is too large to support, make a three-step pruning cut to prevent bark ripping (Fig. 6C).

1. The first cut is a shallow notch made on the underside of the branch, outside the branch collar. This cut will prevent a falling branch from tearing the stem tissue as it pulls away from the tree.
2. The second cut should be outside the first cut, all the way through the branch, leaving a short stub.
3. The stub is then cut just outside the branch bark ridge/branch collar, completing the operation.

2. *Pruning dead branches* (Fig. 6)

Prune dead branches in much the same way as live branches. Making the correct cut is usually easy because the branch collar and the branch bark ridge, can be distinguished from the dead branch, because they continue to grow (Fig. 6A). Make the pruning cut just outside of the ring of woundwood tissue that has formed, being careful not to cause unnecessary injury (Fig. 6C). Large dead branches should be supported with one hand or cut with the three-step method, just as live branches. Cutting large living branches with the three step method is more critical because of the greater likelihood of bark ripping.

3. *Drop Crotch Cuts* (Fig. 6D)

A proper cut begins just above the branch bark ridge and extends through the stem parallel to the branch bark ridge. Usually, the stem being removed is too large to be supported with one hand, so the three cut method should be used.

1. With the first cut, make a notch on the side of the stem away from the branch to be retained, well above the branch crotch.

2. Begin the second cut inside the branch crotch, staying well above the branch bark ridge, and cut through the stem above the notch.
3. Cut the remaining stub just inside the branch bark ridge through the stem parallel to the branch bark ridge.

To prevent the abundant growth of epicormic sprouts on the stem below the cut, or dieback of the stem to a lower lateral branch, make the cut at a lateral branch that is at least one-third of the diameter of the stem at their union.

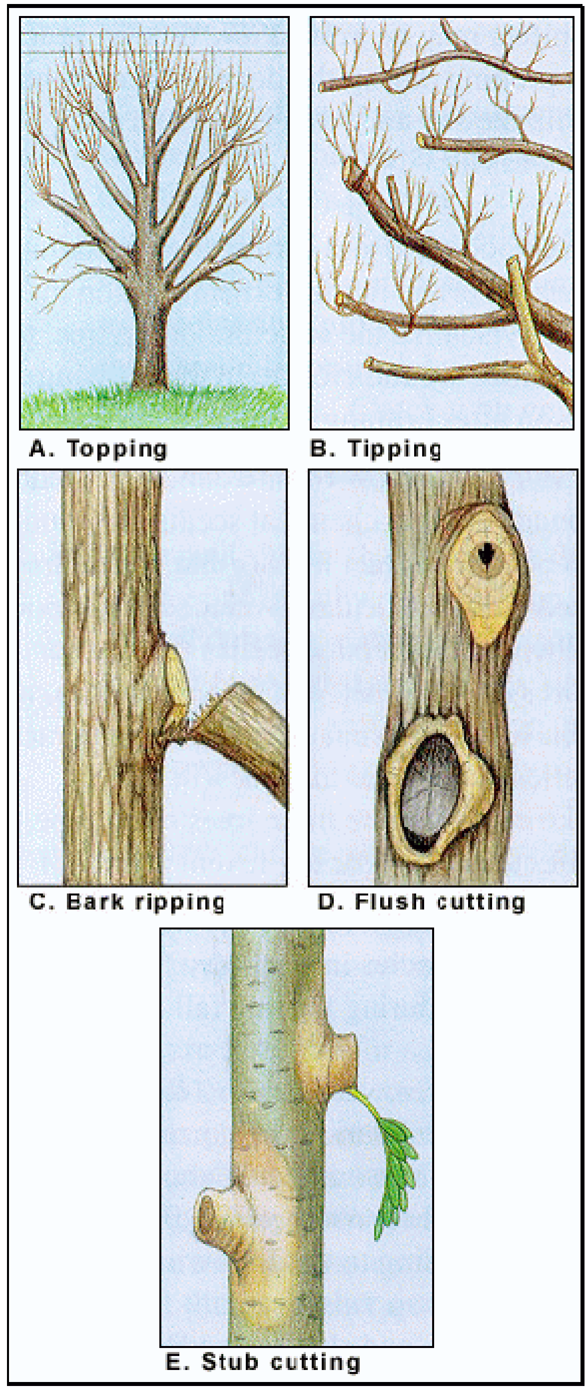
Pruning Practices That Harm Trees

Topping and **tipping** (Fig. 7A, 7B) are pruning practices that harm trees and should not be used. Crown reduction pruning is the preferred method to reduce the size or height of the crown of a tree, but is rarely needed and should be used infrequently.

Topping, the pruning of large upright branches between nodes, is sometimes done to reduce the height of a tree (Fig. 7A). Tipping is a practice of cutting lateral branches between nodes (Fig. 7B) to reduce crown width.

These practices invariably result in the development of epicormic sprouts**,** or in the death of the cut branch back to the next lateral branch below. These epicormic sprouts are weakly attached to the stem and eventually will be supported by a decaying branch.

Improper pruning cuts cause unnecessary injury and bark ripping (Fig. 7C). Flush cuts injure



stem tissues and can result in decay (Fig. 7D). **Stub cuts** delay wound closure and can provide entry to canker fungi that kill the cambium, delaying or preventing woundwood formation (Fig. 7E).

When to Prune

Conifers may be pruned any time of year, but pruning during the dormant season may minimize sap and resin flow from cut branches.

Hardwood trees and shrubs *without showy flowers*: prune in the dormant season to easily visualize the structure of the tree, to maximize wound closure in the growing season after pruning, to reduce the chance of transmitting disease, and to discourage excessive sap flow from wounds. Recent wounds and the chemical scents they emit can actually attract insects that spread tree disease. In particular, wounded elm wood is known to attract bark beetles that harbor spores of the Dutch elm disease fungus, and open wounds on oaks are known to attract beetles that spread the oak wilt fungus. Take care to prune these trees during the correct time of year to prevent spread of these fatal diseases. Contact your local tree disease specialist to find out when to prune these tree species in your area. Usually, the best time is during the late fall and winter.

Flowering trees and shrubs: these should also be pruned during the dormant season for the same reasons stated above; however, to preserve the current year's flower crop, prune according to the following schedule:

? Trees and shrubs that flower in early spring (redbud, dogwood, etc.) should be pruned immediately after flowering (flower buds arise the year before they flush, and will form on the new growth).

? Many flowering trees are susceptible to fireblight, a bacterial disease that can be spread by pruning. These trees, including many varieties of crabapple, hawthorn, pear, mountain ash, flowering quince and pyracantha, should be pruned during the dormant season. Check with your county extension agent or a horticulturist for additional information.

? Trees and shrubs that flower in the summer or fall always should be pruned during the dormant season (flower buds will form on new twigs during the next growing season, and the flowers will flush normally).

Dead branches: can be removed any time of the year.

Pruning Tools

Proper tools are essential for satisfactory pruning (Fig.6). The choice of which tool to use depends largely on the size of branches to be pruned and the amount of pruning to be done. If possible, test a tool before you buy it to ensure it suits your specific needs. As with most things, higher quality often equates to higher cost.

Generally speaking, the smaller a branch is when pruned, the sooner the wound created will seal. Hand pruners are used to prune small branches (under 2.5 cm diameter) and many different kinds are available. Hand pruners can be grouped into by-pass or anvil styles based on the blade configuration. Anvil style pruners have a straight blade that cuts the branch against a small anvil or block as the handles are squeezed. By-pass pruners use a curved cutting blade that slides past a broader lower blade, much like a scissors. To prevent unnecessary tearing or crushing of tissues, it is best to use a by-pass style pruner. Left- or right-handed types can be purchased.

Slightly larger branches that cannot be cut with a hand pruner may be cut with small pruning saws (up to 10 cm) or lopping shears (up to 7 cm diameter) with larger cutting surfaces and greater leverage. Lopping shears are also available in by-pass and anvil styles.

For branches too large to be cut with a hand pruner or lopping shears, pruning saws must be used. Pruning saws differ greatly in handle styles, the length and shape of the blade, and the layout and type of teeth. Most have tempered metal blades that retain their sharpness for many pruning cuts. Unlike most other saws, pruning saws are often designed to cut on the "pull-stroke."

Chain saws are preferred when pruning branches larger than about 10 cm. Chainsaws should be used only by qualified individuals. To avoid the need to cut branches greater than 10 cm diameter, prune when branches are small.

Pole pruners must be used to cut branches beyond reach. Generally, pruning heads can cut branches up to 4.4 cm diameter and are available in the by-pass and anvil styles. Once again, the by-pass type is preferred. For cutting larger branches, saw blades can be fastened directly to the pruning head, or a separate saw head can be purchased. Because of the danger of electrocution, pole pruners should not be used near utility lines except by qualified utility line clearance personnel.

To ensure that satisfactory cuts are made and to reduce fatigue, keep your pruning tools sharp and in good working condition. Hand pruners, lopping shears, and pole pruners should be periodically sharpened with a sharpening stone. Replacement blades are available for many styles. Pruning saws should be professionally sharpened or periodically replaced. To reduce cost, many styles have replaceable blades.

Tools should be clean and sanitized as well as sharp. Although sanitizing tools may be inconvenient and seldom practiced, doing so may prevent the spread of disease from infected to healthy trees on contaminated tools. Tools become contaminated when they come into contact with fungi, bacteria, viruses and other microorganisms that cause disease in trees. Most pathogens need some way of entering the tree to cause disease, and fresh wounds are perfect places for infections to begin. Microorganisms on tool surfaces are easily introduced into susceptible trees when subsequent cuts are made. The need for sanitizing tools can be greatly reduced by pruning during the dormant season.

If sanitizing is necessary it should be practiced as follows: Before each branch is cut, sanitize pruning tools with either 70% denatured alcohol, or with liquid household bleach diluted 1 to 9 with water (1 part bleach, 9 parts water). Tools should be immersed in the solution, preferably for 1-2 minutes, and wood particles should be wiped from all cutting surfaces. Bleach is corrosive to metal surfaces, so tools should be thoroughly cleaned with soap and water after each use.

Treating wounds

Tree sap, gums, and resins are the natural means by which trees combat invasion by pathogens. Although unsightly, sap flow from pruning wounds is not generally harmful; however, excessive "bleeding" can weaken trees.

When oaks or elms are wounded during a critical time of year (usually spring for oaks, or throughout the growing season for elms) -- either from storms, other unforeseen mechanical wounds, or from necessary branch removals -- some type of wound dressing should be applied to the wound. Do this immediately after the wound is created. In most other instances, wound dressings are unnecessary, and may even be detrimental. Wound dressings will not stop decay or cure infectious diseases. They may actually interfere with the protective benefits of tree gums and resins, and prevent wound surfaces from closing as quickly as they might under natural conditions. The only benefit of wound dressings is to prevent introduction of pathogens in the specific cases of Dutch elm disease and oak wilt.

Pruning Guidelines

To encourage the development of a strong, healthy tree, consider the following guidelines when pruning.

General

? Prune first for safety, next for health, and finally for aesthetics.

? Never prune trees that are touching or near utility lines; instead consult your local utility company.

? Avoid pruning trees when you might increase susceptibility to important pests (e.g. in areas where oak wilt exists, avoid pruning oaks in the spring and early summer; prune trees susceptible to fireblight only during the dormant season).

? Use the following decision guide for size of branches to be removed: 1) under 5 cm diameter - go ahead, 2) between 5 and 10 cm diameter - think twice, and 3) greater than 10 cm diameter - have a good reason.

Crown Thinning

? Assess how a tree will be pruned from the top down.

? Favor branches with strong, U-shaped angles of attachment. Remove branches with weak, V-shaped angles of attachment and/or included bark.

? Ideally, lateral branches should be evenly spaced on the main stem of young trees.

? Remove any branches that rub or cross another branch.

? Make sure that lateral branches are no more than one-half to three-quarters of the diameter of the stem to discourage the development of co-dominant stems.

- Do not remove more than one-quarter of the living crown of a tree at one time. If it is necessary to remove more, do it over successive years.

Crown Raising

- Always maintain live branches on at least two-thirds of a tree's total height. Removing too many lower branches will hinder the development of a strong stem.
- Remove basal sprouts and vigorous epicormic sprouts.

Crown Reduction

- Use crown reduction pruning only when absolutely necessary. Make the pruning cut at a lateral branch that is at least one-third the diameter of the stem to be removed.
- If it is necessary to remove more than half of the foliage from a branch, remove the entire branch.

Glossary

Branch Axil: the angle formed where a branch joins another branch or stem of a woody plant.

Branch Bark Ridge: a ridge of bark that forms in a branch crotch and partially around the stem resulting from the growth of the stem and branch tissues against one another.

Branch Collar: a "shoulder" or bulge formed at the base of a branch by the annual production of overlapping layers of branch and stem tissues.

Crown Raising: a method of pruning to provide clearance for pedestrians, vehicles, buildings, lines of sight, and vistas by removing lower branches.

Crown Reduction Pruning: a method of pruning used to reduce the height of a tree. Branches are cut back to laterals that are at least one-third the diameter of the limb being removed.

Crown Thinning: a method of pruning to increase light penetration and air movement through the crown of a tree by selective removal of branches.

Callus: see woundwood.

Decurrent: a major tree form resulting from weak apical control. Trees with this form have several to many lateral branches that compete with the central stem for dominance resulting in a spherical or globose crown. Most hardwood trees have decurrent forms.

Epicormic Sprout: a shoot that arises from latent or adventitious buds; also know as water sprouts that occur for on stems and branches and suckers that are produced from the base of trees. In older wood, epicormic shoots often result from severe defoliation or radical pruning.

Excurrent: a major tree form resulting from strong apical control. Trees with this form have a strong central stem and pyramidal shape. Lateral branches rarely compete for dominance. Most conifers and a few hardwoods, such as sweetgum and tuliptree, have excurrent forms.

Flush Cuts: pruning cuts that originate inside the branch bark ridge or the branch collar, causing unnecessary injury to stem tissues.

Included Bark: bark enclosed between branches with narrow angles of attachment, forming a wedge between the branches.

Pollarding: the annual removal of all of the previous year's growth, resulting in a flush of slender shoots and branches each spring.

Stub Cuts: pruning cuts made too far outside the branch bark ridge or branch collar, that leave branch tissue attached to the stem.

Tipping: a poor maintenance practice used to control the size of tree crowns; involves the cutting of branches at right angles leaving long stubs.

Topping: a poor maintenance practice often used to control the size of trees; involves the indiscriminate cutting of branches and stems at right angles leaving long stubs. Synonyms include rounding-over, heading-back, dehorning, capping and hat-racking. Topping is often improperly referred to as pollarding.

Topiary: the pruning and training of a plant into a desired geometric or animal shape.

Woundwood: lignified, differentiated tissues produced on woody plants as a response to wounding (also known as callus tissue).

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"How to Prune Trees" was written to help people properly prune the trees they care about. If you doubt your ability to safely prune large trees, please hire a professional arborist. Information in this publication can be used to interview and hire a competent arborist.

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

HOW to Recognize Hazardous Defects in Trees

(USDA Forest Service Northeastern Area, NA-FR-01-96)

HOW to

Recognize Hazardous Defects in Trees

United States Department of Agriculture

Prepared by Forest Service

Northeastern Area State & Private Forestry

NA-FR-01-96

Contents

Introduction

Trees add to our enjoyment of outdoor experiences whether in forests, parks, or urban landscapes. Too often, we are unaware of the risks associated with defective trees, which can cause personal injury and property damage. Interest in hazard tree management has increased in recent years due to safety and liability concerns resulting from preventable accidents. Recognizing hazardous trees and taking proper corrective actions can protect property and save lives.

A "hazard tree" is a tree with structural defects likely to cause failure of all or part of the tree, which could strike a "target." A target can be a vehicle, building, or a place where people gather such as a park bench, picnic table, street, or backyard.

This brochure was created to help home owners and land managers in recognizing hazardous defects in trees and to suggest possible corrective actions. We recommend that corrective actions be undertaken by professional arborists.

Because of the natural variability of trees, the severity of their defects, and the different sites upon which they grow, evaluating trees for hazardous defects can be a complex process. This publication presents guidelines, not absolute rules for recognizing and correcting hazardous defects. When in doubt, consult an arborist.

Inspecting Trees

Inspect trees under your responsibility every year. Tree inspections can be done at any time of year, leaf-on or leaf-off. To be thorough, inspect trees after leaf drop in fall, after leaf-out in spring, and routinely after severe storms.

Inspect trees carefully and systematically. Examine all parts of the tree, including the roots, root or trunk flare, main stem, branches, and branch unions. Be sure to examine all sides of the tree. Use a pair of binoculars to see branches high off the ground.

Consider the following factors when inspecting trees:

Tree Condition: Trees in poor condition may have many dead twigs, dead branches, or small, off-color leaves. Trees in good condition will have full crowns, vigorous branches, and healthy, full-sized leaves; however, green foliage in the crown does not ensure that a tree is safe. Tree trunks and branches can be quite defective and still support a lush green crown.

Tree Species: Certain tree species are prone to specific types of defects. For example, some species of maple and ash in the Northeast often form weak branch unions (page 5), and aspen is prone to breakage at a young age (50-70 years) due to a variety of factors, including decay and cankers.

Tree Age and Size: Trees are living organisms subject to constant stress. Pay particular attention to older trees, which may have accumulated multiple defects and extensive decay.

What to Look For

Hazardous defects are visible signs that the tree is failing. We recognize seven main types of tree defects: dead wood, cracks, weak branch unions, decay, cankers, root problems, and poor tree architecture. A tree with defects is not hazardous, however, unless some portion of it is within striking distance of a target.

Dead wood

Dead wood is “not negotiable”-- dead trees and large dead branches must be removed immediately! Dead trees and branches are unpredictable and can break and fall at any time (Fig. 1). Dead wood is often dry and brittle and cannot bend in the wind like a living tree or branch. Dead branches and tree tops that are already broken off (“hangers” or “widow makers”) are especially dangerous!

Take immediate action if...

- A broken branch or top is lodged in a tree.
- A tree is dead.
- A branch is dead and of sufficient size to cause injury (this will vary with height and size of branch).

Figure 1. Dead branches can break and fall at any time. (photo right)

Cracks

A crack is a deep split through the bark, extending into the wood of the tree. Cracks are extremely dangerous because they indicate that the tree is already failing (Fig. 2).

Take action if...

- A crack extends deeply into, or completely through the stem.
- Two or more cracks occur in the same general area of the stem.
- A crack is in contact with another defect.
- A branch of sufficient size to cause injury is cracked.

Figure 2. A serious crack like this one indicates that the tree is already failing! (photo right)

Weak Branch Unions

Weak branch unions are places where branches are not strongly attached to the tree. A weak union occurs when two or more similarly-sized, usually upright branches grow so closely together that bark grows between the branches, inside the union. This ingrown bark does not have the structural strength of wood, and the union is much weaker than one that does not have included bark (Fig. 3). The included bark mayalso act as a wedge and force the branch union to split apart. Trees with a tendency to form upright branches, such as elm and maple, often produce weak branch unions.Weak branch unions also form after a tree or branch is tipped or topped (page 15), i.e., when the main stem or a large branch is cut at a right angle to the direction of growth leaving a large branch stub. The stub inevitably decays, providing very poor support for new branches ("epicormic" branches) that usually develop along the cut branch.

Take action if...

- A weak branch union occurs on the main stem.
- A weak branch union is cracked.
- A weak branch union is associated with a crack, cavity, or other defect.

Figure 3. This weak branch union has failed, creating a highly hazardous situation.

Decay

Decaying trees can be prone to failure, but the presence of decay, by itself, does not indicate that the tree is hazardous. Advanced decay, i.e., wood that is soft, punky, or crumbly, or a cavity where the wood is missing can create a serious hazard (cover photo). Evidence of fungal activity including mushrooms, conks, and brackets growing on root flares, stems, or branches are indicators of advanced decay.

A tree usually decays from the inside out, eventually forming a cavity, but sound wood is also added to the outside of the tree as it grows. Trees with sound outer wood shells may be relatively safe, but this depends upon the ratio of sound to decayed wood, and other defects that might be present. Evaluating the safety of a decaying tree is usually best left to trained arborists (Fig. 4).

Take action if...

- Advanced decay is associated with cracks, weak branch unions, or other defects.
- A branch of sufficient size to cause injury is decayed.
- The thickness of sound wood is less than 1" for every 6" of diameter at any point on the stem.

Figure 4. This seriously decayed tree should have been evaluated and removed before it failed. (photo right)

Cankers

A canker is a localized area on the stem or branch of a tree, where the bark is sunken or missing. Cankers are caused by wounding or disease. The presence of a canker increases the chance of the stem breaking near the canker (Fig. 5). A tree with a canker that encompasses more than half of the tree's circumference may be hazardous even if exposed wood appears sound.

Take action if...

- A canker or multiple cankers affect more than half of the tree's circumference.
- A canker is physically connected to a crack, weak branch union, a cavity, or other defect.

Figure 5. The large canker on this tree has seriously weakened the stem.

Root Problems

Trees with root problems may blow over in wind storms. They may even fall without warning in *summer when burdened with the weight of the tree's leaves. There are many kinds of root problems to consider, e.g., severing or paving-over roots (Fig. 6); raising or lowering the soil grade near the tree; parking or driving vehicles over the roots; or extensive root decay.*

Soil mounding (Fig. 7), twig dieback, dead wood in the crown, and off-color or smaller than normal leaves are symptoms often associated with root problems. Because most defective roots are underground and out of sight, aboveground symptoms may serve as the best warning.

Take action if...

- *A tree is leaning with recent root exposure, soil movement, or soil mounding near the base of the tree.*
- *More than half of the roots under the tree's crown have been cut or crushed. These trees are dangerous because they do not have adequate structural support from the root system.*
- *Advanced decay is present in the root flares or "buttress" roots.*

Figure 6. *Severing roots decreases support and increases the chance of failure or death of the tree. (photo right)*

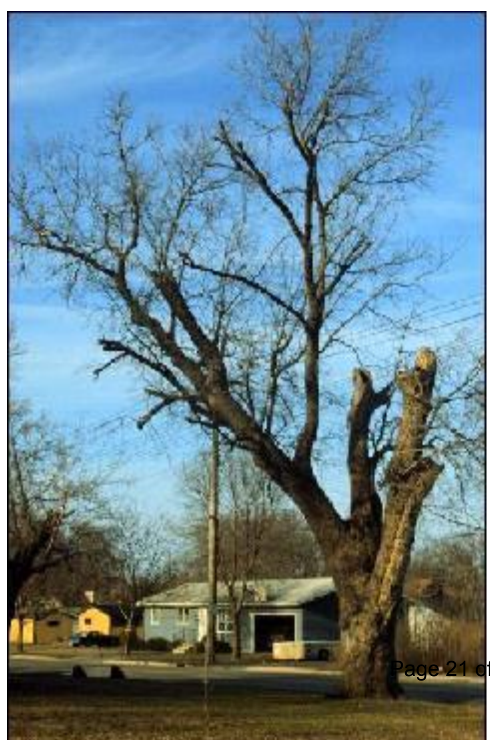

Figure 7. The mound (arrow) at the base of this tree indicates that the tree has recently begun to lean, and may soon fail.

Poor Tree Architecture

Poor architecture is a growth pattern that indicates weakness or structural imbalance. Trees with strange shapes are interesting to look at, but *may be structurally defective. Poor architecture often arises after many years of damage from storms, unusual growing conditions, improper pruning, topping, and other damage (Fig. 8).*

A leaning tree may be a hazard. Because not all leaning trees are dangerous, any leaning tree of concern should be examined by a professional arborist.

Take action if...

- *A tree leans excessively.*
- *A large branch is out of proportion with the rest of the crown.*

Figure 8. *This tree is decayed and badly out of balance because of poor maintenance. It is dangerous, and extremely unattractive! (photo right)*

Multiple Defects

The recognition of multiple defects in a tree is critical when evaluating the tree's potential to fail. Multiple defects that are touching or are close to one another should be carefully examined. If more than one defect occurs on the tree's main stem, you should assume that the tree is extremely hazardous.

Corrective Actions

Corrective actions begin with a thorough evaluation. If a hazardous situation exists, there are three recommended options for correcting the problem: move the target, prune the tree, or remove the tree.

Move the Target

Removing the target is often an inexpensive and effective treatment for correcting a hazard tree. Easily moved items like play sets and swings, RV's, and picnic tables can be placed out of the reach of the hazardous tree with little effort and expense.

If the target cannot be moved and a serious hazard exists, consider blocking access to the target area until the hazard can be properly eliminated.

Prune the Tree

A hazardous situation may be caused by a defective branch or branches, even though the rest of the tree is sound. In this case, pruning the branch solves the problem.

Prune when...

- *A branch is dead.*
- *A branch of sufficient size to cause injury is cracked or decayed.*
- *A weak branch union exists and one of the branches can be removed.*
- *Branches form a sharp angle, twist, or bend.*
- *A branch is lopsided or unbalanced with respect to the rest of the tree.*
- *A broken branch is lodged in the crown. Remove the branch and prune the stub.*

Pruning a tree properly early in its life is a good way to effectively avoid many potential problems when the tree is older and larger. When done correctly, routine pruning of trees does not promote future defects. If done improperly, immediate problems may be removed, but cracks, decay, cankers, or poor architecture will be the ultimate result, creating future hazards.

We recommend that the "natural target" pruning method be used. This pruning method is fully described in ***How to Prune Trees*** *(Bedker, O'Brien & Mielke, 1995).*

Remove the Tree

Before cutting a tree down, carefully consider the alternatives. The effects of removing a tree are often pronounced in landscape situations and may result in reduced property values. Tree removal should be considered as the final option and used only when the other two corrective actions will not work. Tree removal is inherently dangerous and is even more serious when homes and other targets are involved. Removal of hazardous trees is usually a job for a professional arborist.

Cabling and Bracing

Cabling and bracing does not repair a hazard tree, but when done correctly by a trained arborist, it can extend the time a tree or its parts are safe. Done incorrectly, it creates a more serious hazard. We do ***not*** *recommend cabling or bracing as treatment for a hazard tree unless the tree has significant historic or landscape value.*

Topping and Tipping--Poor Pruning Practices

Topping is the practice of pruning large upright branches at right angles to the direction of growth, sometimes used to reduce the height of the crown. Tipping is the cutting of *lateral branches at right angles to the direction of growth to reduce crown width. Both of these practices are harmful and should **never** be used. The inevitable result of such pruning wounds is decay in the remaining stub, which then serves as a very poor support to any branches that subsequently form. Trees that are pruned in this manner are also misshapen and esthetically unappealing (see Fig. 8).*

Conclusions

Evaluating and treating hazard trees is complicated, requiring a certain knowledge and expertise. This publication outlines some of the basic problems that may alert you to a hazardous situation. Never hesitate if you think a tree might be hazardous. If you are not sure, have it evaluated by a professional. Consult your phone book under "Arborists" or "Tree Service."

Remember that trees do not live forever. Design and follow a landscape plan that includes a cycle of maintenance and replacement. This is the best way to preserve the health of our trees and ensure a safe and enjoyable outdoor experience.

Suggested Reading

Albers, J.; Hayes, E. 1993. How to detect, assess and correct hazard trees in recreational areas, revised edition. St. Paul, MN: Minnesota DNR. 63 p.

*Bedker, P.J.; O'Brien, J.G.; Mielke, M.E. 1995. **How to Prune Trees**. NA-FR-01-95. Radnor, PA: USDA Forest Service, Northeastern Area State and Private Forestry. 30 pp. Also available on the Internet via FTP or the World Wide Web at: http://willow.ncfes.umn.edu.*

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How to Recognize Hazardous Defects in Trees was written to help people identify potential problems with trees. Trees with serious defects can pose an extreme hazard and should be treated with caution. The best way to correct a hazardous tree is to hire a professional arborist. Information in this publication can help to identify trees that require attention.

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Forest Soils & Site Index

(North Carolina Division of Forest Resources)

FOREST SOILS & SITE INDEX

Soil quality is the most important factor in forest management decisions. Soils will determine which tree species yields the greatest timber volume, the time to harvest, and ultimately, the investment a landowner must make to yield an acceptable economic return from forest management.

Soils vary greatly in their ability to produce merchantable volumes of pulpwood, sawtimber, veneer, poles, piling or other wood products in a reasonable period of time. The old saying "plant your sorry, worn-out acres to trees" has been followed by many an unwary landowner. In fact, as with any other crop, the better the land, the more productive the forest. Landowners must be aware of soil factors that affect forest production before investing in forest regeneration or management.

Site Index (SI)

The collective influence of soil factors will determine the site index for a particular tree species on a given soil area. Site index is the total height to which dominant trees of a given species will grow on a given site at some index age, usually 50 or 25 years in the Southeast. Dominant trees are the tallest trees in the stand. If it is stated that an area has a site index for loblolly pine of 70 feet at 50 years, then we expect loblolly seedlings planted on that area today to be 70 feet tall in 50 years. Index age and tree species must be stated when referring to site index because the site index of one species will be different from the site index of another species growing on the same area.

There is a close relationship between site index and timber yield. Volumes of merchantable wood increase with improvement in site index (Table 1.)

Table 1. Relation of site index (SI) to timber yield of managed loblolly pine

Site Index	**Yield at Age 40**	**Value**
70	6 MBF * + 26 cords **	$1,082 ***
80	14 MBF + 37 cords	$2,359
90	19 MBF + 38 cords	$3, 116
100	29 MBF + 36 cords	$4,602

* Thousand board feet (International Rule) of sawtimber per acre assuming recommended thinnings are completed.
** Cords of pulpwood per acre removed as thinnings.
*** Value per acre assuming $150 per MBF and $7 per cord.

Soil Factors

The following factors have a major impact on forest soil productivity and site index:

Topsoil Depth. The depth of the uppermost soil layer is a critical factor affecting tree growth. Topsoil is highest in organic matter and nutrients, is usually well aerated and drained, and allows maximum root growth and root penetration.

Soil Texture. The proportion of sand, silt and clay in the topsoil and subsoil layers is called texture. Sandy soils are normally very well drained and often lack nutrients due to constant leaching loss. At the other end of the spectrum are the pure clay soils comprised of very small, fine soil particles.

Subsoil Consistence Class. Consistency of the subsoil layer is another important factor in forest soil productivity. The combination of soil-sized particles and the physical and chemical properties of each individual particle type in a given soil determine the soil's consistence class.

Limiting Layers. A layer which restricts the downward penetration of a tree's root system will reduce tree growth in direct relation to the depth of layer. In rare instances, a limiting layer may increase site productivity, such as on sandy soils where the layer may retard leaching of nutrients and increase available moisture.

Fertility. Southern pines grow over a wide range of soil fertility levels. Fertilization is normally not recommended early in the rotation except in the case of a critical deficiency of a major nutrient such as phosphorus. A soil test prior to site preparation will alert a landowner to critical deficiencies.

Research has shown conflicting results in forest tree response to nitrogen fertilization, particulary early in the rotation. Growth may be suppressed if the fertilizer increases the growth of competing weeds. Best results from early fertilizer use arise in combination with herbicide or mechanical control of competing vegetation. Late rotation fertilization done 5 to 8 years before final harvest increased timber yields in many situations, but may not be economically practical.

Internal Drainage. Few tree species can grow in soils which are constantly wet. Drainage can be improved in some cases by tilling, ditching, or adding bedding as a site preparation method.
Measuring Site Index Site index can be determined by two methods: One method is to find on the area in question several dominant trees of the species of interest or a species with a known conversion factor to the species of interest. Using accurate age and height measurements, read the site index from a graph showing height over age curves for that species (Figure 1).

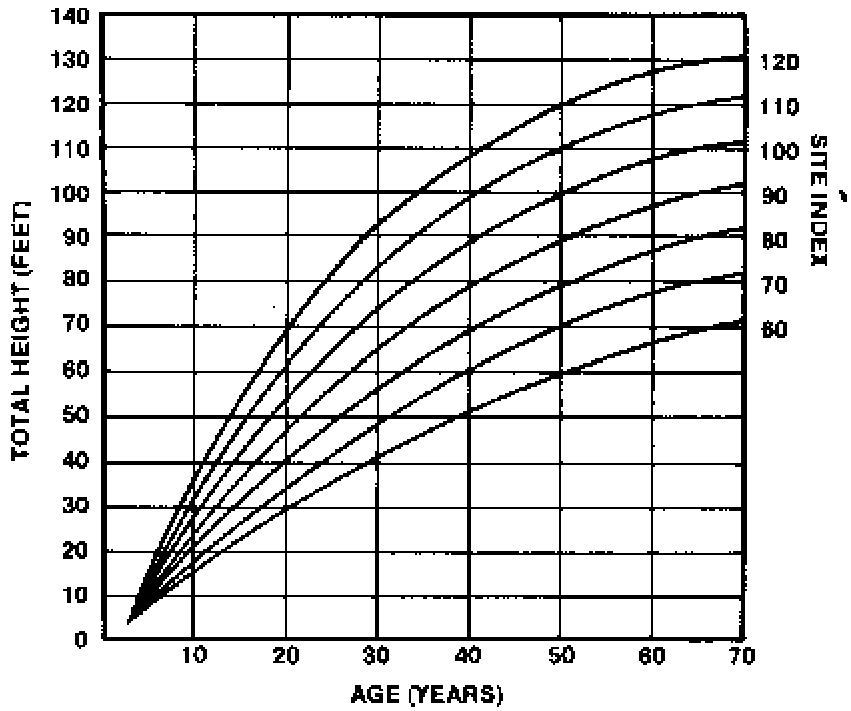

Figure 1. Site index curves for loblolly pine at index age 50 years in the Coastal Plain of Virginia, North Carolina and South Carolina. (These curves are based on stem analysis of 40 dominant trees in the middle and lower coastal plain.)

The second method of determining site index is based on physical characteristics of the soil. Tables giving site index by this system are available for several important species. Necessary information about the soil includes depth of the topsoil and plasticity of the subsoil. In deep sands, the depth to a finer-textured horizon and fine particle content of that horizon are used instead of topsoil depth and subsoil plasticity.

Site index can be calculated with reasonable accuracy for virtually any commercial tree species. A landowner should consult a professional forester to evaluate the site indexes for the tree species on a particular property. Site index information is included in the comprehensive soil surveys completed within the last few years or in progress in many counties. Your county Soil Conservation Service can provide information related to soil surveys.

Species Selection
Selecting the proper tree species to manage or plant on a particular site involves several steps.

1. Determine objectives. If timber production is the major objective, select a species that will economically produce timber products. If wildlife, recreation, aesthetics or other uses are the objective, select species accordingly. On many tracts, several uses may be compatible.
2. Select species with a proven track record in terms of growth and acceptance in the local market.
3. If two or more species could be selected and timber production is the major objective, select the species that will yield the greatest dollar return in the shortest amount of time. In most

cases, this means selecting the species with the highest site index.

Landowners should invest only in those species on those acres capable of producing acceptable economic return. Returns will vary with investment, species, and site quality. Foresters can provide information including site quality, yield and projected economic returns before deciding which, if any, species should be managed on a particular property.

Related Links

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Questions or comments about this site? Contact the webmaster.

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Site Preparation

Prescribed Burning

3/14/2003

Where Applicable:

Prescribed burning is one of the least expensive and oldest forms of site preparation. This technique can be used to prepare a site for planting or to prepare the seedbed for natural regeneration purposes.

Description:

Prescribed burning can be a beneficial management tool when used properly with trained personnel. However, due to the risk of escaped fire, accidents caused by smoke, and other liability concerns, it should only be performed by experienced individuals. Prescribed burning can be conducted by broadcast burning or windrow (pile) burning. Broadcast burning is burning conducted over the entire treatment area while pile burning is restricted to windrows or piles of debris. An acceptable burning plan should first be formulated with appropriate documentation prior to conducting the burn. This plan will detail all information regarding the planned prescribed fire and should be followed as closely as possible. The next step is plowing firelanes around the area to be burned. Depending on the size of this area, interior firelanes may be needed. Neighboring landowners, the TFS, and local fire department dispatch locations should be notified before a burn is started. Once the proper weather conditions (temperature, humidity, wind speed and direction, etc.) are available and the proper equipment (dozers, hand tools, etc.) and personnel are on site according to the burn plan, the fire can be started. Burning may be accomplished by backfiring, strip firing, or any number of other firing methods. All fires should be watched closely for spotting over the firelanes and completely extinguished before leaving the area.

Benefits:

Prescribed burning has many uses and benefits. It can be used to reduce hazardous fuels, to prepare sites for seeding and planting, to improve wildlife habitat, or to temporarily control competing vegetation. This operation can benefit the site in several ways. Most nutrients are returned to the soil in a more readily available form than they were prior to burning. This is an advantage over shearing and piling where nutrients are tied up in debris piles. Burning can be used to help control hardwoods less than 3” in diameter. However, the best vegetation control may be achieved using a combination of chemicals and burning. Burning also eliminates soil compaction and movement of soil caused by the use of heavy equipment with other site preparation methods.

Other Recommendations:

Burning season will be dependent on the goals of the burn. For example, to prepare a site for planting (debris reduction), burns should be conducted in late summer so that an optimal amount of slash is removed. The increased availability of nutrients following a prescribed fire may result in increased growth rates of competing vegetation. Herbicide applications for herbaceous weeds and grasses may be needed to reduce competition with young pine seedlings. Burning on steep slopes, deep sands, or other highly erodible soils is not recommended.

Cost:

Approximately $25-$50/acre depending on the size and shape of the tract, hazards present, fuel type and loading, amount of fireline needed, topography, etc.). The time needed to complete a burn will be dependent upon weather variables, possible burning ban delays, topography, size of tract, fuel type, etc.

3 in 1 plow

3/14/2003

Where Applicable:

The 3-in-1-combination plow is primarily used on cutover or clearcut tracts that contain large amounts of logging slash or small undesirable stems. This method of site preparation is extremely beneficial in low-lying areas or in areas that remain dry during most of the year. The four rotating disks located directly behind the subsoiler (ripping blade) cultivate a planting bed 12 inches above the normal ground level promoting root development. In wet, low-lying areas, this elevated bed prevents seedling mortality due to being submerged in water for extended periods of time. These cultivated beds also increase the soil's water holding capacity in excessively dry areas which allows for increased water uptake through the seedling's root system.

Description:

The 3-in-1 plow cultivates, fractures, subsoils, and beds the soil. The plow is most commonly pulled with a large crawler tractor that is equipped with a V-shear blade. The V-shear blade is used to push large debris to either side and shear stumps and residual non-merchantable trees. The combination plow contains a coulter wheel that cuts through pre-existing roots and stumps approximately 10 inches deep. The subsoiler follows the coulter wheel and fractures the soil 24 to 28 inches deep breaking any soil compaction that exists. Finally, the rotating disks cultivate the soil creating a planting bed approximately 12 inches above the ground level. This practice is usually applied between late-July and early-November allowing adequate time for the beds to settle.

Benefits:

Results from this practice will vary depending on the site's soil texture and water holding capacity. Most soils treated by this method will show an increased growth rate to varying degrees. The planting beds concentrate nutrients and water while the loosened soil beneath the beds allows for increased root expansion and development. The combination of these two benefits will increase seedling survival and growth on most any site, especially those more susceptible to soil compaction. This practice may result in a shortened rotation for pine stands allowing landowners the option of harvesting pulpwood and sawlog class material at a younger age. Shorter rotations should result in faster returns from the initial investment for landowners.

Other Recommendations:

This practice is not recommended on deep sands due to the coarse texture of these soils and low susceptibility to compaction. All Best Management Practices guidelines regarding site preparation should be followed and beds should be constructed along the contours of the land to minimize erosion hazards. Following the planting operation, it is usually recommended that a release spray containing an herbicide mixture sufficient to control the herbaceous weeds and grasses be applied.

<u>Cost:</u>

The cost of this practice can range from $160-$230/acre depending on tract size, amount of vegetation and slash cover, availability of vendors, etc.

Disking (Harrowing)

3/14/2003

Where Applicable:

This technique is applicable on sites suffering from light to moderate soil compaction from harvesting or past agricultural uses such as farming or grazing. This technique is also useful in incorporating organic matter into mineral soil on sites ranging from light to moderate vegetative/debris cover. Limitations include sites with debris or residual stems two inches or larger in diameter, excessive slope, extreme wetness, and large rock or other debris incapable of being disked.

Description:

Disking is accomplished by the use of a heavy track vehicle or rubber tired skidding tractors pulling a stronger, more robust version of the agricultural disk. It consists of a series of large-diameter, saucer-shaped steel blades joined at the center of an axle that allows them to roll when the implement is pulled. The concave blade surfaces face the leading end of the axle. The blade edges are sharpened, and usually serrated, to permit deeper penetration into the soil, cutting or breaking small stems and roots, and rolling over larger obstructions. Usually, two axles of the blades are set at a fixed angle to one another and pulled as a unit. Forestland disking should break a minimum of 6 to 8 inches of soil and should be done at least 2 months prior to planting to allow enough time for the soil to settle. After a proper site preparation burn, hand or wildland machine planting of seedlings can then be easily conducted.

Benefits:

This operation is beneficial in a number of ways. Disking is a cheaper alternative to heavier mechanical operations such as shearing and raking, where it can be utilized. Disking fractures compacted soils to improve root growth and development and allows for better aeration and moisture infiltration into the soil. Disking also reduces competition and incorporates organic matter into dryer soils where it will improve survival and early growth.

Other Recommendations:

Disking should be conducted during mid summer to mid fall followed by a prescribed-burn 6 to 8 weeks later after brown out. Disking should also be followed up with an appropriate herbicide application to help eliminate or control woody or herbaceous species in direct competition with seedlings for moisture and nutrients.

Cost:

Approximately $75-$125 per acre depending on tract size, vegetative cover, availability of vendors, etc. Contractors disk approximately 2-4 acres per hour depending on degree of vegetative/debris cover present and other landowner specifications.

Drum Chopping

3/14/2003

Where Applicable:

This technique is applicable on most any site ranging from light to heavy vegetative/debris cover. Limitations include sites with debris or residual timber six inches or larger in diameter, excessive slope, extreme wetness, and large rock or other debris incapable of being chopped.

Description:

Chopping is accomplished by the use of a heavy track vehicle pulling one or two large metal cylinders (drums) with longitudinal cutting blades. These drums are 6 to 16 feet in length and approximately 4 to 6 feet in diameter. They will have 8 to 16 longitudinal cutting blades that are evenly spaced around the drum. An average sized drum weighs approximately 4.5 tons when empty. If more weight is needed, water is added to the drum, where it can weigh 10 to 13.5 tons. One or two drums can be pulled behind a dozer to knock down and break trees and other vegetation. Chopping treatments break most small material into short lengths, pushing some into the surface soil with only local movement. Most material is concentrated near the soil surface, facilitating burning and decomposition of organic matter. The equipment generally covers the entire area in one direction, but "Double Chopping" at right angles, usually applied 6 weeks later, has the best results. A proper prescribed burn at least 60 days following this operation is typically conducted. Hand or wildland machine planting of seedlings can then be easily carried out on the property.

Benefits:

This operation is beneficial in a number of ways. Chopping is a cheaper alternative to heavier mechanical operations such as shearing and raking. Chopping is also less soil disturbing and in addition to improving planting access to the site, chopping incorporates some organic matter into the soil creating favorable growing conditions for young seedlings.

Other Recommendations:

Chopping should be planned during mid summer to mid fall followed by a prescribed-burn 6 to 8 weeks later after brown out. Chopping should also be followed up with an appropriate herbicide application to help eliminate or control woody or herbaceous species in direct competition with seedlings for moisture and nutrients. Drum chopping should not be performed on soil types that are at a high risk of compaction.

Cost:

Approximately $75-$125 per acre depending on tract size, vegetative cover, availability of vendors, etc. Contractors chop approximately 2-4 acres per hour depending on degree of vegetative/debris cover present and other landowner specifications.

Rake Only

Where Applicable:

Rake only is a method of mechanical site preparation used to pile or windrow debris after an intensive final harvest. This operation serves to facilitate planting operations and/or improve access for other more intensive site preparation equipment. This method can only be used if there is not a large number of stumps or standing stems present on site. If too many stumps or standing materials exist, shearing and piling, mulching or some other site preparation method would need to be used.

Description:

Rake only is accomplished by using a dozer with a rake blade to push debris into piles or windrows. The rake blade should be equipped with teeth on the lower edge to reduce the amount of large roots near the soil surface and minimize soil movement during raking. Once piled, the debris can then be burned. If piles do not take up a large amount of area or diversity for wildlife habitat is desired, these piles can be left and planted around. On slopes exceeding 7 percent, parallel windrows should be located no more than 150 feet apart with openings of at least 20 feet for every 150 feet of windrow. Ends of windrows should be at least 66 feet from property boundaries and residual stands. The Streamside Management Zones (SMZ's) along streams should be protected by planning the use of this equipment so as to minimize disturbance of these areas. Site preparation activities should skirt SMZ's and stream channels and any debris should be placed well above the ordinary high water mark of any stream, or body of open water. The recommended time frame for rake only is during the months of June through September.

Benefits:

Raking helps to reduce the amount of large roots near the soil surface minimizing residual sprouting thus reducing competition with planted pines. Regardless of the planting method used, ridding the site of debris will help facilitate a better planting job. Quite often sites that have been raked might also be wildland machine planted resulting in more uniform spacing and better survival.

Other Recommendations:

Care should be taken to disturb as little soil as possible during this procedure. As with any mechanical site preparation, this operation should be conducted so that windrows are pushed up along the contour of the land to help prevent soil erosion. Windrows should be as narrow as possible. Avoid this practice on steep slopes, deep sandy soil types, and other highly erodible soils. Extra care should be taken to avoid soil compaction on clayey soils and on wet sites.

Cost:

This operation normally costs approximately $80-$100 per acre depending on tract size, amount of debris, availability of vendors, access, etc.

Shear and Pile

Where Applicable:

Shear and pile is a method of mechanical site preparation that is used to rid the site of debris after a final harvest. This method is used when there is a large amount of debris or standing stems present on the site. If large amounts of debris do not exist, mulching, shear only, rake only or some other site preparation method might be used instead.

Description:

A combination of shearing and piling can be accomplished by using a dozer with a V-cutting blade to shear off remaining debris at the ground level. Once sheared, the debris is then raked into windrows. The rake blade should be equipped with teeth on the lower edge to reduce the amount of large roots near the soil surface and minimize soil movement during raking. Once piled, the debris can then be burned. If piles do not take up a large amount of area or diversity for wildlife habitat is desired, these piles can be left and planted around. On slopes exceeding 7 percent, parallel windrows should be located no more than 150 feet apart with openings of at least 20 feet for every 150 feet of windrow. Ends of windrows should be at least 66 feet from property boundaries and residual stands. The recommended time frame for shearing and piling is during the months of June through September.

Benefits:

Shearing and piling helps to reduce the amount of large roots near the soil surface minimizing residual sprouting thus reducing competition with planted pines. Regardless of the planting method, ridding the site of debris will help facilitate a better planting job. Sites that have been sheared and piled can be wildland machine planted and banded resulting in better survival, more uniform spacing, etc.

Other Recommendations:

Care should be taken to disturb as little soil as possible during this procedure and windrows should be as narrow as possible. As with any mechanical site preparation, shear and pile should be conducted along the contour of the land to help prevent soil erosion. This practice should be avoided on steep slopes, deep sands, or other highly erodible soils. The Streamside Management Zones (SMZ's) along streams should be protected by planning the use of this equipment so as to minimize disturbance of these areas. Site preparation activities should skirt SMZ's and stream channels. Any debris should be placed well above the ordinary high water mark of any stream, or body of open water. Extra care should be taken to avoid soil compaction on clayey soils and on wet sites.

Cost:

This operation normally costs approximately $160-$200 per acre depending on tract size, amount of debris, availability of vendors, access, etc.

Shear Only

3/14/2003

Where Applicable:

Shear only is a method of mechanical site preparation used to gain planter access after a final harvest. This method can be used if there is not a large amount of debris or standing stems present on site. If too much debris exists, shearing and piling, mulching or some other site preparation method would be needed.

Description:

Shear only is accomplished by using a dozer with a V-cutting blade to shear off remaining debris at the ground level. Most often the shearing is done on anticipated planting row centers. This could take one or two passes depending on the amount of debris present. During planting season seedlings can be planted in the middle of the sheared path by hand or wildland machine planters. The recommended time frame for shear only is from June through September.

Benefits:

Generally less soil is disturbed or moved by this method than by methods such as shear and pile or rake only making this practice more suited to steeper slopes and deep sandy soil types. Also, the shear only operation is less expensive than other site preparation methods and should allow access for a wildland machine planter resulting in a more uniform spacing, better survival, etc.

Other Recommendations:

Care should be taken to disturb as little soil as possible during this procedure by shearing vegetation off at or very near the ground line. As with most mechanical site preparation methods, shear only should be conducted along the contour of the land to help prevent soil erosion. The Streamside Management Zones (SMZ's) along streams should be protected by planning the use of this equipment so as to minimize disturbance of these areas. Site preparation activities should skirt SMZ's and stream channels. Any debris should be placed well above the ordinary high water mark of any stream, or body of open water. Many of the competing species on the site will likely resprout and the planting area will need to be broadcast, band, or spot treated with an acceptable herbicide mix to promote seedling growth and survival. Extra care should be taken to avoid soil compaction on clayey soils and on wet sites.

Cost:

This operation normally costs approximately $80-$90 per acre depending on tract size, amount of debris, availability of vendors, access, etc.

Spot Tillage

3/14/2003

Where Applicable:

This is one of the newest operations available for site preparation. It is perhaps best suited for urban forest situations, horticultural applications or in areas with steep slopes and other obstructions. However, there are limited areas where these treatments can be . Slopes over 20%, frequent gullies, high residual stumps and excessive harvest debris, all inhibit the use of tractor-mounted or trailing equipment. Spot tillage is noncontiguous cultivation of the soil in the exact spot where the tree will be planted. Spot tillage causes the least amount of site disturbance, and works in heavy debris areas.

Description:

Spot Tillage is accomplished by the use of a heavy track excavator that is fitted with an articulating arm. Cultivator disks (tillers) are mounted to the arm and turn at slow speeds and high torque. It can mix up logging debris and topsoil within one small diameter spot (4-5 foot diameter) up to 24-36 inches deep at a time creating a favorable micro site for the pine seedlings. Spot tillage should break a minimum of 20-24 inches of soil and should be done at least 3 months prior to planting to allow enough time for the soil to settle. Following this operation, hand planting of seedlings can then be easily conducted.

Benefits:

Spot Tillage is ideal for establishing trees on steep terrain as work can be done either up or down a slope. Erosion is minimized because harvest debris is left on the site as mulch and there is less site disturbance. Also, problems of compaction are addressed, with full cultivation possible to a depth of nearly three feet. The simplicity of the design makes it easy to add treatments like fertilizer and herbicide application at the time of preparing the site. In addition, as this operation is not dependent on the weather, site prep can be carried out at any time during the year. Therefore, fixed costs per acre are reduced through better plant utilization.

Other Recommendations:

Spot tillage should be conducted during mid summer to mid fall. Disking should also be followed up with an appropriate herbicide application to help eliminate or control woody or herbaceous species in direct competition with seedlings for moisture and nutrients.

Cost:

Approximately $175-$225 per acre depending on tract size, vegetative cover, availability of vendors, etc. Contractors disk approximately 2-4 acres per hour depending on degree of vegetative/debris cover present and other landowner specifications.

Subsoiling (Ripping)

12/15/2002

Where Applicable:

Subsoiling is used primarily as a method of mechanical site preparation for heavy soils on cutover and openland sites that have a compacted layer at or below the surface inhibiting root growth and development. This layer can be the result of mining for gravel, heavy grazing over long periods of time, or the mere presence of a hardpan or clay layer that restricts root growth to the upper layers of the soil surface.

Description:

Subsoiling is accomplished through the use of a rubber tired tractor on openland sites, a dozer or other heavy equipment on cutover sites that pulls a ripping bar through the soil to break up or fracture the soil structure to a minimum depth of approximately 18 inches. The recommended time frame for subsoiling is during the months of July through October when the soil is generally dry and crumbly. Adequate rainfall (2 inches or more) must follow this operation to settle the rip back in before the planting operation is conducted. Planting is generally conducted along the edges of or within the ripped lines.

Benefits:

This operation is most beneficial to newly planted seedlings in breaking through a hardpan allowing faster and deeper growth of roots through this layer. The fracturing of the rooting zone promotes better root growth and development over a shorter period of time allowing seedlings to become established faster. The disturbance along these rips provides a means of better infiltration of rainfall into the soil providing crucial moisture to newly planted seedlings and improves the overall quality and survival of the planting job in otherwise unfavorable conditions.

Other Recommendations:

Mowing is recommended prior to subsoiling on openland sites in order to reduce the amount of organic matter buildup on the ripping bar.

Cost:

$25-$75 per acre depending on tract size, soil properties, availability of vendors, vegetative cover, etc.

Mowing

3/14/2003

Where Applicable:

Mowing may be used as site preparation on pastures and/or light, semi-open fields prior to planting, by machine or hand. This practice is necessary when grasses or small saplings have reached heights or densities that will impede planter access, however it will do little to improve future growth and survival of seedlings. Mowing on sandy, well-drained sites should not create any future machine planting problems. However, mowing on wetter, tight soils may leave residual grass cuttings to mix with the soil during the machine planting operation. This can cause build-up on the planter's coulter, boot and packing wheels requiring frequent cleaning and is therefore not recommended. If possible, wet sites should be burned prior to planting or planted in their current condition. If the grass is extremely dense or canopied, burning is a better site preparation tool but should not be conducted on steep slopes, deep sands or other soils where erosion may be a problem.

Description:

Planting access problems due to weeds, grasses and small woody vegetation present in abandoned fields and pastures can be temporarily reduced with the use of a tractor and shredder. Mowing of these areas should be performed as necessary during the months prior to planting season to reduce the amount of residual stems and grass cuttings. Emphasis should be placed on proper timing of this treatment to minimize re-sprouting and re-growth between the mowing and planting operation.

Benefits:

Mowing helps to improve planter access to a tract of land potentially improving the quality of the planting job. Where possible, mowing followed by baling of improved pasture grasses is preferred. This serves to remove the grass cuttings and may provide additional revenue to the landowner or offset the costs of mowing. The quality of the grass and acreage involved will determine if baling is a viable option. Mowing also reduces moisture uptake by the grasses providing additional water to newly planted seedlings.

Concerns:

Mowing does not eliminate the need for herbaceous weed and grass control and should be applied accordingly, usually following the planting operation. In some instances, mowing grasses can actually increase their spread and growth creating more competition for seedlings. Mowing semi-open fields having scattered saplings and brush will not eliminate the roots but will leave sharp stems that could possibly puncture tractor or vehicle tires. Some landowners may choose to mow between rows of trees after planting for aesthetic purposes. However, this practice incurs additional expense and is recommended with extreme caution due to the high potential for seedling damage or destruction.

Costs:

Rates will vary depending upon acreage, equipment used and site conditions. Average costs will range from $15.00-25.00 per acre but the cost may be negligible for those who already own the necessary equipment.

Mulching

3/14/2003

Where Applicable:

Mulching is a relatively new method of mechanical site prep that can also be used to improve an existing stand of timber. This technique is applicable on most any site ranging from light to heavy vegetative/debris cover. Limitations include sites with excessive slope, extreme wetness, and large rock or other debris incapable of being mulched.

Description:

Mulching is accomplished by the use of a heavy rubber-tire or track vehicle with a large spinning drum mounted on the front. These drums are equipped with large hammer-like teeth that rip, tear, break, shred and splinter live woody vegetation, logs, stumps, and virtually anything else in its path down to the desired level. Some of this material may be incorporated back into the soil while the rest is distributed across the ground surface. This provides many of the same benefits mulching has traditionally been associated with as well as others. The equipment generally covers the entire area for best results but strips can be mulched in certain other situations according to landowner objectives. Hand or wildland machine planting of seedlings can then be easily conducted.

Benefits:

This operation is extremely beneficial to the landowner, the site, and existing or newly planted trees in several ways. Mulching carries much less liability than burning and can be conducted throughout the year while prescribed burning is limited to days with favorable burning conditions (no more burn ban delays). The mulched material increases the moisture retained in the soil (especially useful in droughty situations), distributes the nutrient rich organic matter evenly across the site, decreases soil temperatures (as compared to other methods of site preparation), and reduces erosion by aiding in soil stabilization. This method is highly competitive in price with other comparable site prep methods and can be economically used in areas where burning is not an option. These benefits should allow site prep and timber stand improvements on a year round basis facilitating access for planting and increasing the overall survival and growth of young trees on your property.

Other Recommendations:

Green living material usually mulches the best. Mulching should be planned as soon as possible following a harvest but can be conducted any time and should be followed up with an appropriate herbicide application to help eliminate or control woody or herbaceous species in direct competition with your trees for moisture and nutrients.

Cost:

Approximately $250/hour ($80-$250 per acre depending on tract size, vegetative cover, availability of vendors, etc.) Mulches approximately 1-3 acres per hour depending on degree of vegetative/debris cover present and other landowner specifications.

Bedding

3/14/2003

Where Applicable:

Bedding is perhaps the most widely used forest cultivation technique in the south. Bedding is usually conducted on relatively level cutover or clearcut tracts that have been sheared and piled and contain poor surface drainage. This practice is also applicable in low-lying poorly drained open fields where seedlings could be submerged in water for long periods of time. The elevated beds will lift the seedlings out of the excessively wet areas, improve rooting conditions, and increase seedling productivity allowing conversion of typically hardwood sites to productive pine plantations. This practice should be avoided on sites that may be subject to summer drought.

Description:

Bedding both disks and mounds the topsoil and nutrient-rich organic matter in long, continuous strips. The bedding plows have several scalloped disks that cut the soil and throw it into the center of the bed. A compaction roller then firms the bed into place. A crawler tractor usually pulls the bedding plow, although faster rubber-tired skidders are sometimes used. The beds should be elevated enough to allow planting of seedlings above standing water and should be oriented to channel excess water away from the planting site. Water outlets should be provided at locations that will minimize soil movement and water should be discharged onto a vegetated surface.

Benefits:

Bedding gives landowners the option of converting typically hardwood sites to more productive pine plantations. As mentioned, bedding concentrates topsoil nutrients while also increasing the soils water holding capacity. Bedding also provides for improved soil aeration allowing critical oxygen to young seedling roots. This combination results in increased growth and greatly increases seedling survival on poorly drained sites. Because of the increased growth rates, trees reach merchantable sizes in shorter periods of time. This shortened rotation will allow landowners the option of harvesting pulpwood and sawlog class materials at a younger age providing faster returns on their initial investment.

Other Recommendations:

Bedding should be done fairly close to planting season, otherwise the beds may lose shape and slump, particularly on wet sites. However, this practice should be applied at least six weeks prior to planting to allow for the freshly bedded soil to settle. Bedding alone does not improve areas with compacted subsoil. In fact, bedding on compacted soils may restrict future rooting of seedlings and interfere with drainage. These compacted soil types should be considered for alternate site preparation methods such as 3 in 1 plowing or ripping. Following the planting operation, it is usually recommended that a release spray containing an herbicide mixture sufficient to control the herbaceous weeds and grasses be applied.

Cost:

The cost of this practice can range from $80-$120/acre depending on the tract size, accessibility, availability of vendors, etc.

Fertilization

3/14/2003

Few forest soils provide an optimum supply of the nutrient elements essential for the growth potential of trees. Proper foliage or soil testing can identify the deficient elements necessary to produce optimum growth for a site. The nutrient elements most likely to be deficient are the NPK elements (nitrogen, phosphorus, and potassium, in that order of frequency of deficiency) found in most commercial fertilizers and chicken litter. There are a few cases in forestry in which benefit has come from fertilization with trace elements, some of which may be found in chicken litter.

Most common commercial nitrogen fertilizers used in forestry are urea compounds that are easily taken up by plants (Urea, Ammonium Nitrate, Diammonium Phosphate). Urea-formaldehyde compounds have the advantage of releasing the ammonium slowly while nitrate compounds are easily lost from the soil by leaching. The best time of the year to fertilize appears to be late winter or early spring. Fertilizing at mid rotation is usually done with around 200 pounds per acre of nitrogen and 25-50 pounds per acre of elemental phosphorous. Response will normally last 5-8 years and average results are approximately 0.5 cord per acre per year in increased growth. Fertilizing with 2-4 tons per acre of chicken litter in forest stands is becoming more common in the south but this is a relatively new practice.

In most cases it is best to restrict forest fertilization to the latter part of the rotation. A given amount of fertilizer seems to produce about the same amount of wood regardless of tree size and a given cubic volume put on large trees is worth more than the same volume put on small trees plus, your investment is carried for a shorter period of time. The supply of available nutrients is generally greatest just after the destructive events associated with regeneration. Deficiencies are most likely to set in after the stands have filled all the growing space and more and more nutrients are getting tied up in living and dead organic materials on the site. Fertilization is done at the time of planting or regeneration only if the deficiencies are very serious. Fertilization of young stands sometimes favors the competing vegetation more than the preferred trees so herbicide applications are a must.

Forest fertilization is normally done from the air with commercial fertilizers while chicken litter fertilization is normally conducted with ground spreaders. Special care should be taken to prevent direct application to water bodies in order to prevent eutrophication (algae blooms). Fertilizers are generally heavy enough that drift is usually not a problem. Cost will vary according to tract size, fertilizer type and source, availability of vendors, etc.

Fertilization is now becoming more commonplace in the South but before landowners jump on the fertilization bandwagon, the economics of its application should be carefully considered. Fertilization is an investment, done in hopes of improving output at a thinning or final harvest. The time value of money and inflation must be considered when evaluating the economic costs/benefits of fertilization.

Fertilization costs

Aerial Broadcast	
Early rotation	$40-60/acre
Late rotation	$65-75/acre
Hand application (at planting)	$15-40/acre

Herbaceous Weed Control

Aerial Broadcast

Where Applicable:

Aerial application of herbicide is used for the control of herbaceous weeds and grasses in areas recently planted with pine seedlings. Applications are generally made on improved pastures, old fields, cutover areas, and prepared sites where vegetation control is desired across the entire treatment area.

Description:

Aerial applications of herbaceous weed control are typically made by helicopter with accompanying fuel and chemical support trucks. After selecting the proper chemicals for the property based on the dominant species present, the company representative will usually delineate the treatment area boundaries with a Global Positioning System (GPS) unit. A suitable location for landing, refueling, and refilling the chemical tanks is then located on or within a reasonable distance from the property. The treatment area is aerial sprayed during the early periods of active growth (Feb-May) for herbaceous weeds and grasses using soil active and/or foliar active chemicals depending on the growth stage of targeted species. Great care should be taken to avoid application on non-target areas and operations should cease when wind speed exceeds 10 miles per hour. It is a violation of Federal Law to use these products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.).

Benefits:

This practice is extremely beneficial to young pines by eliminating competing weeds and grasses within the same growing zone. Eliminating these shallow rooted species increases the amount of available moisture, nutrients, and sunlight for seedlings. This helps to promo the growth and improve overall survival of newly planted seedlings during the first three critical years of establishment. Competition control results in more rapid growth of planted pines producing larger timber yields and shorter rotations for landowners.

Other Recommendations:

Best results are obtained when the application is made during the early stages of active weed growth (February- mid May) before an established root system is developed. A total of 5 to 10 gallons of spray solution should be applied per acre depending on vegetation density. Contact a herbicide specialist for a chemical prescription tailored specifically to your treatment area. It is recommended that you have a contract with the vendor and a guarantee on the chemicals used should the application be ineffective in controlling the target species. All Texas Forestry Best Management Practices for silvicultural chemicals should be followed.

Cost:

Aerial broadcast for herbaceous weed control ranges in cost from $40-$65/acre depending on tract size, vegetative cover, availability of vendors, chemical costs, application rates, etc.

Band Application

Where Applicable:

Herbaceous weed control by banding is primarily conducted in improved or native pastures and light semi-open fields. However, this method can also be performed on cutover tracts where adequate site preparation has been conducted.

Description:

The primary herbicides used in banding operations are imazapyr (Arsenal) and sulfometuron methyl (Oust). Other chemicals may be added to the tank mix for an additional cost to broaden the control of undesirable plant species. Bands are applied using rubber-tired tractors, ATV's, or backpack sprayers. Rubber tired tractors are equipped with rear-mounted spray tanks and booms with adjustable nozzles for treating several rows simultaneously. ATV's with rear-mounted tanks are also commonly used but normally spray only one row at a time. Backpack sprayers are sometimes used when acreage, tract location, or other factors make the use of other equipment impractical. Herbicides are generally applied in 3-4 foot wide bands. 4-foot bands or wider are preferred as encroachment of herbaceous material is delayed longer than with more narrow bands. Application is normally conducted in April-May with effectiveness reduced after June 1. It is a violation of Federal Law to use these products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.).

Benefits:

Application of herbicide by banding reduces competition between the newly planted seedlings and established herbaceous weeds and grasses. Water, and nutrients within the banded row that would otherwise have been utilized by the herbaceous material is made available to the pines. Although still dependent upon spring rains, summer weather and the quality of the planting operation, first year survival and growth is significantly improved through the use of this practice. Depending upon seedling spacing, improved pasture grasses may still be cut and baled for several years providing a continued source of revenue to the landowner. Band application of herbicides in comparison to broadcast applications reduces treatment cost.

Other Recommendations:

Consistent spacing of rows by the planting vendor will make herbicide application easier and more effective. If rows cannot be easily determined, then broadcast application by air or ground will be necessary resulting in increased application costs to the landowner. The hardest species of grass to control is Bermuda and should be actively growing before herbicide is applied. The later in the spring the herbicide is applied the better and even then, with abundant spring rains, the Bermuda grass may encroach by August. The problem with waiting until the Bermuda grass is growing is that the rows may be very difficult to locate and flagging may be needed. Goatweed (*Croton* sp.), shown in the picture above, is commonly one of the first herbaceous species to recover from herbicide treatment. Although it will readily become established in the treated rows, the limited amount of shade it produces will pose little threat to seedling survival and growth. All Texas Forestry Best Management Practices for silvicultural chemicals should be followed.

Cost:

Approximately $35.00-45.00 per acre for openland banding and $40.00-$60.00 for wildland banding depending upon tract size, location, availability of vendors, chemical costs, etc. In contrast, broadcast applications for complete coverage of the entire planting area will range between $50.00- 60.00 per acre.

Spot Treatment

Where Applicable:

This practice is used primarily as a method of chemical control for herbaceous weeds and grasses in areas recently planted with pine seedlings. Applic ations are generally made on improved and unimproved pastures, old fields, cutover areas, and prepared sites where partial coverage with the chemical is desired.

Description:

Spot applications of herbaceous weed control are accomplished through the use of a backpack or ATV-mounted sprayer pressurized with air. After selecting the proper chemical or mixture for control of the dominant undesirable species present, the vendor will spray herbicide around each seedling. Each chemical application “spot” should be a minimum of approximately 18-24” in diameter. The treatment area should be spot sprayed during the early periods of active growth (Feb-May) for herbaceous weeds and grasses using soil active and/or foliar active chemicals depending on the growth stage of targeted species. It is a violation of Federal Law to use these products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.).

Benefits:

Herbicide application is extremely beneficial to young pines by eliminating competing weeds and grasses within the same growing zone. Eliminating these shallow rooted species increases the amount of available moisture, nutrients, and sunlight for newly planted seedlings. This helps to promote seedling growth and improve overall survival during the first three critical years of establishment. Competition control results in more rapid growth producing larger timber yields and shorter rotations for landowners. Spot treatment is especially useful on smaller acreages, or where aerial or skidder operations are not feasible. This practice focuses on vegetation in the immediate area of young seedlings leaving untreated areas for soil stabilization, wildlife forage, cover, habitat, etc.

Other Recommendations:

Best results are obtained when the application is made during the early stages of active weed growth (February- mid May) before an established root system is developed. It is recommended that you have a contract with the vendor and a guarantee on the chemicals used should the application be ineffective in controlling the targeted species. All applicable Texas Forestry Best Management Practices for silvicultural chemicals should be followed.

Cost:

Approximately $40-$65/acre depending on tract size, vegetative cover, availability of vendors, chemical costs, application rates, etc.

Woody Site Preparation

3/14/2003

Aerial Site Preparation

Where Applicable:

It is often necessary to conduct site preparation operations on cutover sites, semi-open fields, and other areas with significant amounts of hardwood and/or brush competition. This serves to facilitate the planting of seedlings, and to increase growth while reducing seedling mortality. These sites can be treated mechanically, chemically, or with prescribed fire. However, given the high costs of some types of mechanical site prep and the liability concerns associated with the use of prescribed fire, chemical site preparation may often be the most viable alternative.

Description:

The most common method of application for site preparation herbicides is aerial application by helicopter or, less commonly, by light plane. Aerial application with fuel and chemical support trucks allows large areas to be treated in a short period of time and also facilitates even, complete coverage and application of the chemical. After making the proper prescription for the property, the herbicide vendor will usually delineate the treatment area boundaries with a GPS unit or otherwise mark the desired application area. A suitable location for landing, refueling, and refilling the chemical tanks must be located on or within a reasonable distance from the property. The property is then aerial sprayed during late summer or early fall (August-October) when woody species are sending their food reserves down to the roots. This will ensure proper kill of the targeted species.

Common site preparation herbicides for the control of woody vegetation include various formulations of the chemicals imazapyr (Arsenal, Chopper), glyphosphate (Accord, Accord Site Prep), and triclopyr amine or ester (Garlon 3a and 4, respectively). These chemicals act to inhibit enzyme production (imazapyr and glyphosphate) or to regulate growth (triclopyr) in woody plants. In order to facilitate adherence to the leaf surfaces of plants, these herbicides are often combined with a surfactant during the mixing process. It is a violation of Federal Law to use these products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.).

Benefits:

Chemical site preparation removes unwanted vegetation that would otherwise hamper planting efforts and possibly increase your costs. In addition, most site prep herbicides have some residual effect, which will aid in the initial establishment of young pines improving growth and decreasing mortality due to a reduction in competitive stress. Chemical applications from the air also eliminate the risk of erosion problems and soil compaction presented by other mechanical site preparation methods.

Other Recommendations:

Gallons per acre of spray solution applied will depend on vegetation density. Contact an herbicide specialist for a chemical prescription tailored specifically to your treatment area. It is recommended that you have a contract with the vendor and a guarantee on the chemicals used should the application be ineffective in controlling the target species. Great care should be taken to avoid application to non-target areas and applications should cease when wind speed exceeds 10 mph. All applicable Texas Forestry Best Management Practices for silvicultural chemicals should be followed.

Chemical site preparation is especially effective when followed by prescribed fire. Such an operation, which is also referred to as a brown and burn, serves to further eliminate hardwood competition and reduce debris improving planter access. Burning should not occur until at least 60 days after application to allow the herbicide to move into the roots of targeted species.

Additional Information:

For more information on forestry herbicides, including application rates, targeted species, and material safety data sheets (MSDS) contact your local herbicide vendor, chemical representative, or consult the online CDMS herbicide database on the Internet. The database has label and safe handling information for all major forestry herbicides. The CDMS web address is: **http://www.cdms.net/pfa/LUpdateMsg.asp**

Cost:

Chemical site prep cost ranges from $65-110/acre depending on tract size, location, vegetative cover, availability of vendors, chemical costs, application rates, etc.

Fall Combination Spray

Where Applicable:

It is often beneficial to conduct site preparation operations on cutover sites, semi-open fields, and other areas with significant amounts of hardwood, brush, and/or herbaceous competition. This serves to facilitate the planting of seedlings, and to increase growth while reducing seedling mortality. These sites can be treated mechanically, chemically, or with prescribed fire. However, given the high costs of some types of mechanical site preparation and the liability concerns associated with the use of prescribed fire, chemical site preparation may often be the most viable alternative.

Description:

The most common method of application for site preparation herbicides is aerial application by helicopter or, less commonly, by light plane. Aerial application with fuel and chemical support trucks allows large areas to be treated in a short period of time and also facilitates even, complete coverage and application of the chemical. After making the proper prescription for the property, the herbicide vendor will usually delineate the treatment area boundaries with a GPS unit or otherwise mark the desired application area. A suitable location for landing, refueling, and refilling the chemical tanks must be located on or within a reasonable distance from the property. The property is then aerial sprayed during late summer or early fall (August-October) when woody species are sending their food reserves down to the roots. This will ensure proper kill of the targeted species. Additional chemicals can be added during this fall application to control herbaceous competition the following spring. This is very beneficial in providing additional moisture and nutrients to young seedlings within the same rooting zone and eliminates the cost of a second application.

Common site preparation herbicides for the control of woody vegetation include various formulations of the chemicals imazapyr (Arsenal, Chopper), glyphosphate (Accord, Accord Site Prep), and triclopyr amine or ester (Garlon 3a and 4, respectively). These chemicals act to inhibit enzyme production (imazapyr and glyphosphate) or to regulate growth (triclopyr) in woody plants. When added to typical late season (fall) treatments, OustÒ (Sulfometuron methyl) controls weeds and grasses as they germinate during the fall, winter, and early spring. In order to facilitate adherence to the leaf surfaces of plants, these herbicides are often combined with a surfactant during the mixing process. It is a violation of Federal Law to use these products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.).

Benefits:

Chemical site preparation removes unwanted vegetation that would otherwise hamper planting efforts and possibly increase your planting costs. In addition, most site prep herbicides have some residual effect, which will aid in the initial establishment of young pines improving growth and decreasing mortality due to a reduction in competitive stress. Chemical applications from the air also eliminate the risk of erosion problems and soil compaction presented by other mechanical site preparation methods.

Other Recommendations:

Gallons per acre of spray solution applied will depend on vegetation density. Contact an herbicide specialist for a chemical prescription tailored specifically to your treatment area. It is recommended that you have a contract with the vendor and a guarantee on the chemicals used should the application be ineffective in controlling the target species. Great care should be taken to avoid application to non-target areas and applications should cease when wind speed exceeds 10 mph. All applicable Texas Forestry Best Management Practices for silvicultural chemicals should be followed.

Chemical site preparation is especially effective when followed by prescribed fire. Such an operation, which is also referred to as a brown and burn, serves to further eliminate hardwood competition and reduce debris improving planter access. Burning should not occur until at least 60 days after application to allow the herbicide to move into the roots of targeted species. Burning should be avoided on steep slopes, deep sands, or other situations with a high potential for erosion.

Additional Information:

For more information on forestry herbicides, including application rates, targeted species, and material safety data sheets (MSDS) contact your local herbicide vendor, chemical representative, or consult the online CDMS herbicide database on the Internet. The database has label and safe handling information for all major forestry herbicides. The CDMS web address is: **http://www.cdms.net/pfa/LUpdateMsg.asp**

Cost:

Chemical site prep cost ranges from $100-145/acre depending on tract size, location, vegetative cover, availability of vendors, chemical costs, application rates, etc.

Ground Site Preparation and Release Spray

Where Applicable:

Although no longer commonly practiced, application of herbicide by ground based heavy equipment (skidders or crawler tractors) may be used in circumstances where aerial application is not possible or practical. Examples of where ground application may be necessary include tracts too small or too hazardous to attract an aerial herbicide applicator, where scattered remaining hardwoods for wildlife or aesthetic purposes remain and cannot be sprayed around by air, as well as areas where drift of herbicide must be kept to an absolute minimum.

Description:

There are two basic types of spray equipment that may be mounted on ground-based equipment. These are mist sprayers and boom sprayers. Mist sprayers are designed to apply concentrated herbicide in a fine mist that is atomized in a powerful stream of compressed air. This allows for better penetration into dense vegetation. This type of sprayer is well suited for treating stands with a well-developed understory from ground level. Boom sprayers consist of a boom, which holds a series of nozzles over the spray area. The nozzles dispense the chemical. Boom sprayers are useful for treating agricultural areas and areas that have been thoroughly site-prepared.

Broadjet sprayers are an adaptation of the standard boom sprayer. They use a single large nozzle, or a cluster of small nozzles to replace the boom. Wick sprayers are another adaptation of the standard boom-type spray rig. Herbicide is applied through wicks attached to the spray nozzles. The advantage of this type of apparatus is that vegetation can be selectively treated because the equipment operator can see exactly where the chemical is being applied. It is a violation of Federal Law to use these herbicide products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.).

Benefits:

Application of herbicide through the use of ground equipment allows application of chemical site prep or release in areas or situations where aerial application is not feasible. Ground application also allows a degree of selectivity of targeted vegetation that is not possible with aerial application. Chemical site preparation removes unwanted vegetation that would otherwise hamper planting efforts and possibly increase your costs. In addition, most site prep herbicides have some residual effect, which will aid in the initial establishment of young pines improving growth and decreasing mortality due to a reduction in competitive stress.

Other Recommendations:

Gallons per acre of spray solution applied will depend on vegetation density. Contact an herbicide specialist for a chemical prescription tailored specifically to your treatment area. It is recommended that you have a contract with the vendor and a guarantee on the chemicals used should the application be ineffective in controlling the target species. Great care should be taken to avoid application to non-target areas and applications should cease when wind speed exceeds 10 mph. All applicable Texas Forestry Best Management Practices for silvicultural chemicals should be followed.

Chemical site preparation is especially effective when followed by prescribed fire. Such an operation, which is also referred to as a brown and burn, serves to further eliminate hardwood competition and reduce debris improving planter access. Burning should not occur until at least 60 days after application to allow the herbicide to move into the roots of targeted species. Burns should not be conducted on release sprays for stands of pine that have already been established.

Additional Information:

For more information on forestry herbicides, including application rates, targeted species, and material safety data sheets (MSDS) consult your local herbicide vendor, chemical representative, or the online CDMS herbicide database on the Internet. The database has label and safe handling information for all major forestry herbicides. The CDMS web address is:
http://www.cdms.net/pfa/LUpdateMsg.asp

Cost:

Costs for ground-based herbicide applications range from $60-90 per acre for release treatments and $80-130 per acre for site preparation treatments. Costs will vary depending on tract size, location, vegetative cover, availability of vendors, chemical costs, application rates, etc.

Woody Release and Timber Stand Improvement

12/14/2002

Chemical Release Treatments for Post Planting Control of Woody Brush Species in Young Pine Plantations

Where Applicable:

Application of broadcast herbicide for the mid-rotation or post planting control of woody brush species is often advisable on cutover and semi-open tracts of land. Hardwoods often establish themselves within a pine stand even after initial steps to remove them occurred at the time of planting. These hardwood sprouts will compete with young pines for moisture and sunlight inhibiting growth and survival. This practice is most suited to stands with ≥10% hardwood component.

Description:

Hardwood release is usually conducted during the late summer or early fall of the year a

Common herbicides for the control of woody vegetation include various formulations of the chemicals imazapyr (Arsenal), glyphosphate (Accord), and triclopyr amine or ester (Garlon). These chemicals act to inhibit enzyme production (imazapyr and glyphosphate) or to regulate growth (triclopyr) in hardwood tree species. In order to facilitate adherence to the leaf surfaces of plants, these herbicides are often combined with a surfactant during the mixing process. It is a violation of Federal Law to use these products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.). All applicable Texas Forestry Best Management Practices for silvicultural chemicals should be followed.

Benefits:

Chemical release operations remove unwanted vegetation in competition with young pines. Reducing the amount of hardwood competition present on the site may help increase survival and growth of newly planted pine seedlings by redistributing moisture, nutrients, and available light that would have otherwise been used by the hardwoods. Application of woody release is especially important to the survival of young pines during droughty periods, when seedlings are already stressed due to lack of adequate water.

Cost:

Release treatment costs vary from $60-80 per acre depending on location of the site, tract size, chemical costs, availability of vendors, etc.

Additional Information: For more information on forestry herbicides, including application rates, targeted species, and material safety data sheets (MSDS) consult the online CDMS herbicide database on the Internet. The database has label and safe handling information for all major forestry herbicides. The CDMS web address is: http://www.cdms.net/pfa/LUpdateMsg.asp

Timber Stand Improvement Using Basal Spray

Where Applicable:

Basal spraying is used in the deadening of undesirable vines, shrubs, and trees in a forest stand. Less desirable trees are removed to favor the growth of those that better satisfy the owner's objectives. The method can be used to remove hardwoods from a pine stand, but perhaps its greatest use is the removal of undesirable vegetation to improve the composition, growth, and quality of hardwood stands. Basal spraying is also suited for areas that are inaccessible to motorized equipment or sensitive areas where complete brownout is undesirable.

Description:

Each individual stem is treated using a combination of herbicides with a mineral oil carrier applied at ultra-low volume with a backpack sprayer. The lower 12 - 24 inches of the trunk are sprayed to the point of run-off with the chemical mixture. The technique is most effective on trees less than 4 inches in diameter. The intent is for the herbicide to penetrate the bark and slowly kill the tree and any basal buds that might sprout. It is a violation of Federal Law to use herbicide products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.).

Benefits:

Treatments can be performed for timber stand improvements (TSI) prior to a harvest while leaving individual plants and small areas for wildlife habitat. Standing dead trees provide various types of wildlife habitat such as perches, dens, and foraging trees for animals and birds.

Concerns:

Care must be taken when the herbicide is applied to minimize the amount that runs into the soil. This is important not only from an environmental quality standpoint, but also to avoid damaging non-target trees. The roots of an adjacent desirable tree can extend below the trunk of a tree being basal sprayed. If excess amounts of herbicide were applied to the treated tree, the adjacent desirable tree could absorb the herbicide and be killed or seriously damaged. All applicable Texas Forestry Best Management Practices for silvicultural chemicals should be followed.

Cost:

Basal spraying may not be desirable for large areas or where the vegetation is extremely heavy; however, it can be economical on smaller areas and where there are reasonably few stems per acre. Basal spraying cost ranges from $40 to $80 per acre. Cost can vary depending upon the number of stems per acre, chemical costs, availability of vendors, etc. Landowners can reduce the costs by performing the treatment themselves. They should have an applicator's license and knowledge of the vegetation to be treated.

Additional Information:

For more information on forestry herbicides, including application rates, targeted species, and material safety data sheets (MSDS) consult the online CDMS herbicide database at: http://www.cdms.net/pfa/LUpdateMsg.asp

Individual Stem Injection

Where Applicable:

Single stem injection is primarily used to reduce the competition of unwanted trees within managed stands. This practice is often used in combination with other herbicide applications or with prescribed burning to clean up areas not suitably addressed by the prior practice. Applying herbicides through injections can be used to improve the health and vigor of pre-existing stands or to remove unwanted trees within pure stands such as pine plantations. Stem injections should not be applied to trees or saplings less than two inches dbh (diameter 4.5 feet above ground) or in areas with more than 200 undesirable stems per acre. This practice is usually applied where broadcast application cannot be done, or where more selective control may be desired.

Description:

There are three ways to inject trees with herbicides; (1) injection at the base of the stem with a tube-injector, (2) injection higher up on the stem with a hypo-hatchet, and (3) the hack-n-squirt method (also done at breast height) in which the injection is made with a hatchet and the herbicide is sprayed into the cut with a squirt bottle.

Single stem injection is usually applied during the late summer and early fall (Late-August through Mid - October) when trees are actively translocating food and water reserves to the root systems. Common herbicides used for this practice include; Chopper, Arsenal, Accord, Garlon 3A, Tordon 101R, and Tordon RTU. Herbicide applications should be thorough and consistent in order to obtain control of vegetation on the site. A proper cut is essential in the application of this practice. The cut should be made in the form of a cup that can hold the herbicide until it can be taken in by the tree. Edges of the cup should not be torn, allowing the herbicide to leak onto the bark. The cup should also be deep enough to allow the herbicide to penetrate through the bark into the woody part of the tree. It is a violation of Federal Law to use these products in a manner inconsistent with their labeling (see specimen labels for general information, directions for use, precautionary statements, mixing and application instructions, etc.).

Benefits:

This practice is extremely beneficial to pre-existing and pure stands by eliminating unwanted, low quality, and poorly formed trees. Through the removal of these trees, the desired tree species can obtain more soil nutrients and water and also be provided more growing space. This practice often increases the growth rate and quality of the overall stand. Creating dead snags provides wildlife habitat (nest cavities, forage areas, predator perches, etc.) for certain animal species and may increase forage production by increasing sunlight to the forest floor.

Other Recommendation:

Inconsistent results may occur when the herbicides are injec

Cost::

The cost of this practice will vary ($60-70/acre) depending on the type of chemical used, vendor availability, chemical costs, whether the application is applied by a vendor or the landowner, the number of stems per acre, etc.

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Reforestation Practices- Estimated Costs

TEXAS FOREST SERVICE

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1-800-364-3470

REFORESTATION PRACTICES - ESTIMATED COSTS

Please note that all price quotes are based on past charges and should be considered as a reasonable **estimate** and not as the final actual cost. Your cost may vary depending upon location of your property, amount of acres, hazards, vegetative cover present, availability of contractors, etc. Using vendors or consulting foresters capable of conducting turnkey operations for multiple practices may help to lower costs.

Forestry Practice	Cost	Provider
Fireline construction	$15 / acre	Vendors
Boundary Line Marking	$150-$500 / mile	Vendors
Prescription Burning	$25-$40 / acre	Vendors
Site Preparation Methods		
Control Burn	$30-$50 / acre	Vendors
Chemical (Herbicides)		
Woody Site Prep		
Aerial	$90-$130 / acre	Vendors
Ground	$100-$150 / acre	Vendors
Fall Combo	$100-$145 / acre	Vendors
Woody Release & TSI		
Ground	$60-$90 / acre	Vendors
Aerial	$60-$85 / acre	Vendors
Basal Spray	$40-$80 / acre	Vendors
Individual Stem Inj.	$60-$70 / acre	Vendors
Herbaceous Weed Control		
Aerial	$40-$100 / acre	Vendors
Spot Treatment	$40-$65 / acre	Vendors
Openland Banding	$35-$65 / acre	Vendors
Wildland Banding	$40-$70 / acre	Vendors
Broadcast - ground	$60-$70 / acre	Vendors
Mechanical		
Disking (Harrowing)	$75-$125 / acre	Vendors
Drum Chopping	$75-$125 / acre	Vendors
Subsoiling (Ripping)	$25-$75 / acre	Vendors

3 in 1 plow	$160-$230 / acre	Vendors
Bedding	$80-$120 acre	Vendors
Shear and Windrow	$180-$275 / acre	Vendors
Shear only	$80-$120 / acre	Vendors
Rake only	$80-$100 / acre	Vendors
Mulching	$80-$250 / acre	Vendors
Spot Tillage	$175-$225 / acre	Vendors
Mowing	$15-$25 / acre	Vendors
Pesticides		
Gopher poisoning	$10-$15 / acre	Vendors
Pounce treated seedlings	$3.50 / M	Vendors/TFS
Town Ant Bait - Product Only	$15-$20/ 2 colonies	Vendors
Treats 2 average sized colonies		
Tree Planting		
Hand	$48-$75 / acre	Vendors
Openland Machine	$40-$55 / acre	Vendors
Wildland Machine	$60-$90 / acre	Vendors
Seedlings		
Loblolly Pines		
Bare Root	$39-$50 / 1,000	Vendors/TFS
Containerized	$150-$200 / 1,000	Vendors/TFS
Hardwoods		
Bare Root	$30 / 100	Vendors/TFS
Fertilization		
Broadcast		
Early rotation	$40-$60 / acre	Vendors
Late rotation	$65-$75 / acre	Vendors
Hand Application (at planting)	$15-$40 / acre	Vendors

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

How to Manage Oak Forests for Acorn Production

(USDA Forest Service, North Central Forest Experiment Station, March, 1994, TB-NC-1)

United States
Department of
Agriculture

Forest Service

North Central
Forest Experiment
Station

Technical Brief

From the
Silviculture and Ecology Upland Central Hardwood Forests Research Unit

March, 1994, TB-NC-1

HOW TO MANAGE OAK FORESTS FOR ACORN PRODUCTION

Paul S. Johnson, Principal Silviculturist

Importance of Acorns

Oak forests are life support systems for the many animals that live in them. Acorns, a staple product of oaks forests, are eaten by many species of birds and mammals including deer, bear, squirrels, mice, rabbits, foxes, raccoons, grackles, turkey, grouse, quail, blue jays, woodpeckers, and waterfowl. The population and health of wildlife often rise and fall with the cyclic production of acorns. Acorns' importance to wildlife is related to several factors including their widespread occurrence, palatability, nutritiousness, and availability during the critical fall and winter period. It would seem natural, then, that some oak stands and perhaps extensive forests be managed primarily for acorn production. Even though our knowledge of acorn production is incomplete, we have enough information to make reasoned decisions on the management of oak stands for acorn production.

What We Know About Acorn Production

Acorns of trees in the white oak group (subgenus Lepidobalanus) mature in 3 months; those in the red oak group (subgenus Erythrobalanus) require 15 months (two growing seasons). However, in both species groups, acorn production is relatively unpredictable from year to year. On the average, most species produce a good crop of acorns one year in three or four (Beck 1977, Christisen and Kearby 1984, Downs and McQuilkin 1944, Goodrum et al. 1971). In years of low or moderate acorn production, most acorns are consumed by insects. Moreover, the production of acorns differs among species. Some species are inherently better acorn producers than others, and different species tend to produce good acorn crops in different years. Although environmental factors unfavorable to acorn production such as late spring frost and summer drought tend to obscure inherent periodicity (cycles) in production, new evidence suggests that such periodicity occurs at 2-, 3-, and 4-year intervals for black, white, and northern red oaks, respectively (Sork et al. 1993).

Other factors being equal, trees of large diameter produce more acorns than trees of small diameter. However, in some species, production declines after the tree reaches a threshold diameter (fig. 1). Oaks with crowns fully exposed to light, such as dominant and codominant trees, produce more acorns than trees with crowns totally or partially shaded. In the white oak group, when one tree produces well, all of the potential acorn-producing trees in the population tend to produce well. In contrast, in the red oak group, some producers yield well in a given year while others do not. In addition, only a relatively small proportion of trees are inherently good seed producers. For example, among white oaks in Pennsylvania, only 30 percent of large, healthy trees produced any acorns even in good seed years (Sharp 1958) and an even smaller proportion produced a good crop in those years (Sharp and Sprague 1967).

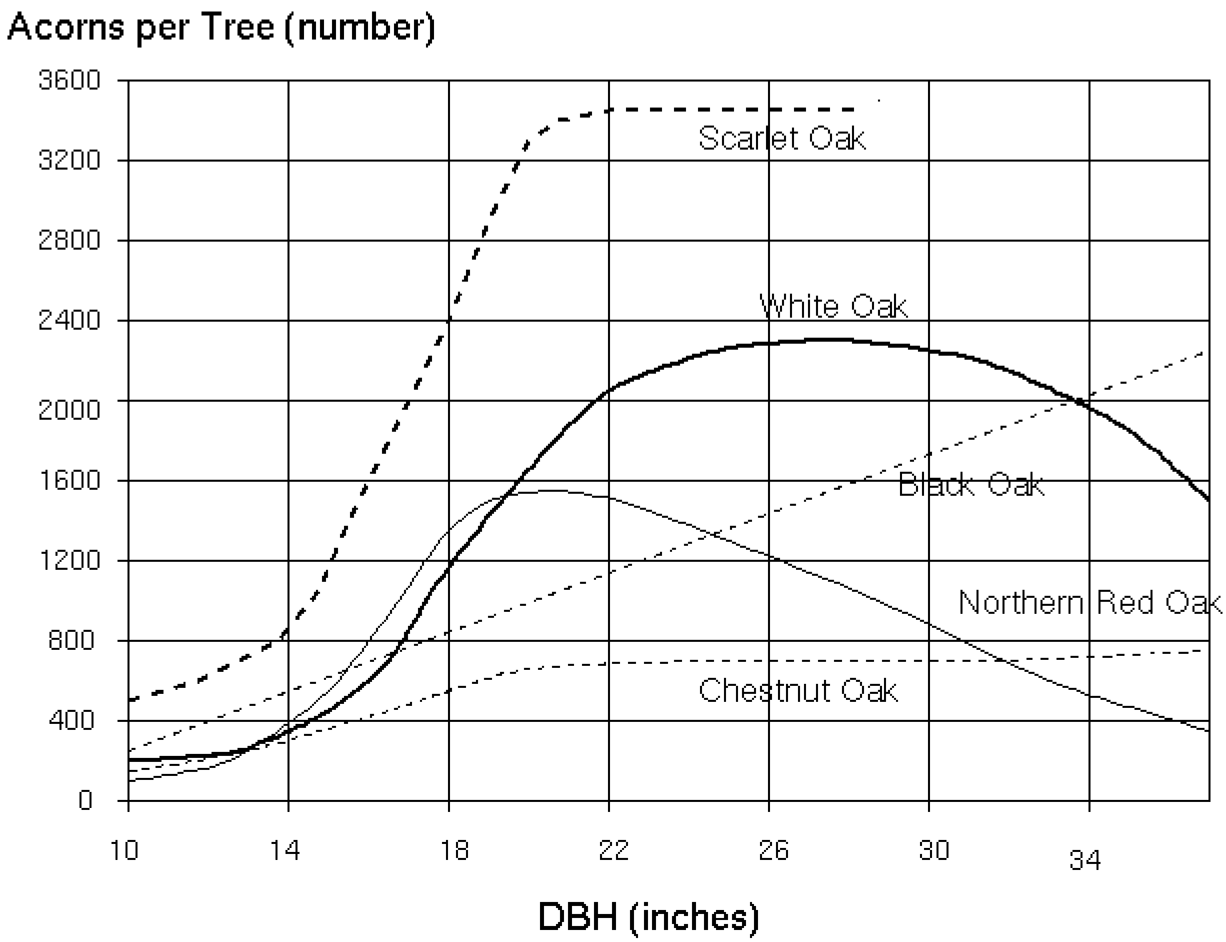

Figure 1. Average annual acorn production per tree in relation to d.b.h. in the southern Appalachians. (Based on a 7-year study: Downs 1944.)

Management Methods

Substantial gains in acorn production of established stands may be obtained by following these guidelines:

1. **Before the first thinning, identify and reserve the good acorn producers in each stand. To do this, you'll need to observe and keep records for 5 years or more. If that is impractical, roughly assess the acorn-producing capacity of individual trees by observing production during a single year in which a good to excellent acorn crop occurs for one or more of the major species present. However, in the red oak group, many good producers may be overlooked in a single year because not all trees of those species may produce well in the same year. Criteria for identifying good producers are given by Sharp (1958) (table 1). The best time to rank trees in the oak-hickory region is from August 10 to 25, before acorn predators begin to eat or cache many acorns. Acorns are best observed with binoculars on bright days when they are silhouetted against the sky (Sharp 1958).**

Table 1. -A ranking of acorn production for individual Trees[1]

Ranking	Average number of acorns per branch[2]	
Excellent	18+	24+
Good	12-17	16-23
Fair	6-11	8-15
Poor	<6	<8

[1]Adapted from Sharp (1958). Note that in any one year, excellent producers may not reach their potential because of unfavorable environmental factors.

[2]Based on the terminal 24 inches of healthy branches in the upper one-third of the crown.

2.
3. **During thinning, retain a mixture of oak species to minimize the impact of the large year-to-year fluctuation in acorn production in any one species.**
4. **Thin around the identified acorn producers to expose their crowns to full light on all sides. This facilitates crown expansion and increases branch density. Branch density increases acorn production per unit of crown area because of the increase in numbers (density) of acorn- bearing branches (Verme 1953). Among the potential acorn producers, dominant and codominant trees will be the most efficient producers. Area-wide thinning is not necessary because only 20 or fewer good seed producers are likely to occur per acre even in pure oak stands. But because these seed producers typically will be dominant and codominant trees, they may account for proportionately more basal area and stocking than their numbers alone indicate.**
5. **Increase or decrease the rotation (or in uneven-age management, maximum tree**

diameter) to include the tree diameter of maximum acorn production of the predominant species in each stand. For example, production in northern red oak peaks when tree d.b.h. reaches 20 inches and then it declines in larger trees (fig. 1). In contrast, white oak production is maximized at about 26 inches. Many other species, however, do not exhibit well-defined diameter-related peaks in production, at least within the diameter ranges that have been reported (Downs 1944, Goodrum et al. 1971). Large, senescent trees are usually poor acorn producers (Huntley 1983).

The above guidelines are similar to those presented by Beck (1989). They also are consistent with managing oak forests as life support systems.

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<u>Great Trinity Forest Management Plan</u>

HARDWOOD SILVICULTURE

Crop Tree Release in Precommercial Hardwood Stands

(Agriculture Extension Service, The University of Tennessee SP 559)

Agricultural Extension Service
The University of Tennessee
SP559

Crop Tree Release in Precommercial Hardwood Stands

Contents

Crop Tree Release in Precommercial Hardwood Stands

David Mercker, Extension Associate
Forestry, Wildlife and Fisheries

The length of time necessary to grow quality hardwood trees is perhaps the greatest deterrent preventing private landowners from practicing hardwood management. Valuable trees such as white and red oaks, cherry, ash, yellow poplar and black walnut require decades to reach financial maturity. This publication describes how to accelerate growth rates in your young hardwood forest, which is vital to keeping your interest alive during the critical and dynamic time between seedling establishment and final harvest.

Timber Stand Improvement (TSI) is a forest management tool used to enhance growth rates of timber and shorten the time required for hardwood crops to mature. TSI provides an opportunity for you to become actively involved in managing your timber, while increasing the possibility of a more favorable financial return.

Defining TSI and Crop Tree Release

TSI is controlling, manipulating and improving the growth, quality and species composition of a timber stand. One method of TSI is Crop Tree Release (CTR), the practice of deadening selected trees in younger, overstocked forests for the benefit of releasing desirable crop trees. Overstocked indicates a forest stand having more trees than is desired, causing the growth rate on individual trees to decline. CTR can be used to alter species composition within the forest, and to concentrate diameter growth on desirable, potentially valuable crop trees. When applied properly, CTR results in a faster-growing, healthier woodland composed of a greater percentage of more acceptable trees. Similar to the principles applied to gardening, CTR allows you to guide your forest, leaving it with well-spaced crop trees whose crowns are capable of rapidly responding to increased growing space. CTR can be first applied to younger, pre-commercial stands (trees that are too small for market), with diameters ranging from 4 to 8 inches (measured at 4.5 feet above the ground).

For clarification, CTR is not the practice of beautifying a forest. For example, clearing undergrowth to improve the appearance or visibility of a forest or cleaning up tree tops left after a timber harvest are cosmetic practices having little effect on the growth of your forest investment.

Other practices of TSI not addressed here include: improvement harvesting, fertilizing, deadening culls,

CTR allows you to guide your forest.

controlling wild vines, pruning and, to some extent, prescribed burning and site preparation.

Apply CTR on the Best Sites

Most hardwood forests could benefit from CTR to some degree, but the greatest benefit will be realized on more productive sites. This is where measurable growth response will occur and where returns on your investment will be realized more quickly. Sites with deep, fertile and moist soils, sites protected from hot and dry southwest winds, and sites where hardwood trees typically can reach a height of at least 70 to 75 feet tall in 50 years are the best choices. These sites are typically found along rivers, creeks and drainages, on north and east-facing slopes and in coves and ravines. Ridgetops and slopes with a southern or western exposure are drier and usually support less desirable species, such as blackjack and post oaks, blackgum, red maple, sourwood, elms and hickories.

The white and red oaks groups have traditionally commanded the highest price and should take top priority.

The condition of trees growing on a site can further indicate site quality. Trees found on better sites will have smooth, thin and tight bark. Their tree tops are expanding (rather than stunted or flat-topped) and they will often have long, merchantable, log length.

Select Stands with Desirable Species

Once the best sites have been located, desirable trees must be present. Not all of the best sites are composed of tree species worthy of CTR. Through past treatment (or mistreatment) of the forest, often the more acceptable and valuable trees have already been harvested. Many times, the residual trees were left because they were undesirable species with low market value or poor form. When this is the case, CTR is not recommended. Instead, regenerating the stand is the priority.

Species found within the white and red oaks groups have traditionally commanded the highest price and should take top priority. They are the mainstay of the Tennessee forest products industry and are likely to remain so. Speculating on the trends of future markets also can help you decide which species to favor. For example, market cycles periodically cause sharp increases in price for alternative species such as yellow poplar, black cherry, black walnut, maples and ash. Managing for a diversity of tree species can help you benefit from uncertain future timber markets. A mixture of tree species also offers diversity in wildlife food sources, particularly for smaller non-game species.

Likewise, markets fluctuate according to location. A study of the historical demand for wood products in your region, as well as seeking input from professional foresters, is essential before implementing CTR.

Use Correct Materials

A variety of tools such as hatchets, axes, hypo-hatchets and tree stump injectors have been used to conduct CTR, usually in combination with a systemic herbicide applied to the cut surface. Some herbicides can be applied directly to the base of thin-barked trees for their deadening, while others require for the bark and cambium to be severed and herbicide applied to the open cut. Following the label instructions is crucial. Contact your local University of Tennessee Extension Service for recommended herbicides.

Another reliable method, with regard to both effectiveness and efficiency, is the chainsaw. A light-weight but powerful saw complete with safety features and a 14- to 16-inch bar length is sufficient. Using a double-girdle method with the chainsaw will eliminate the need for herbicide (see procedure section). Other safety equipment, such as ear and eye protection, leg chaps, gloves and steel-toe boots are recommended.

Releasing Crop Trees

After the best sites and trees are found and your equipment is ready, you can begin releasing crop trees from unwanted competition. You'll need to locate those crop trees with good future growth potential. Availability of sunlight is the leading limiting factor of tree growth. When crowns of adjacent trees touch each other, growth rates are reduced. Thus, by deadening unwanted trees whose crowns are touching the crown of your crop tree, more space is created for expansion.

Condition your eye to locate trees needing release, not trees needing to be deadened. In other words, first find the crop tree, then ask, "Deadening which trees will improve my crop tree's growing condition?"

When selecting crop trees look for the following:

- Healthy trees — those with potential for further development;
- Trees with good form, relatively straight and with few forks;
- Better-grade trees (those with few knots);
- Those whose average age is between 15-30 years old (stands that are too young won't have reached proper height, and older stands might not successfully respond to the release); and,
- Those in the upper levels of the forest canopy.

The target is to release no more than 36 crop trees per acre. This equates to crop trees with an average spacing of 35 feet between each other. Spacing can be increased or decreased according to the stand conditions. For example, some 35-foot cells may not contain an acceptable crop tree, and that cell should be left. As a general guide, at least one-half of the 35 foot cells per acre should contain crop trees for the project to be justifiable.

You should deaden all trees whose crowns touch the crown of the crop tree on three to four sides. Special note: deaden only those trees whose crowns are affecting your crop trees. Those in-between or below and not affecting the crop trees should remain. The leftover trees help to protect crop trees from wind damage and epicormic branching (unwanted branching on the lower bowl often caused by sudden increases in sunlight).

Locate trees needing release, not trees needing to be deadened.

Procedure for Girdling Trees

Determine the trees to deaden. Using a chainsaw, turn the saw sideways and cut a complete girdle (ring) around the tree at a comfortable height (usually around 3 feet). Use proper safety procedures, as is outlined in your saw safety manual. Then, cut

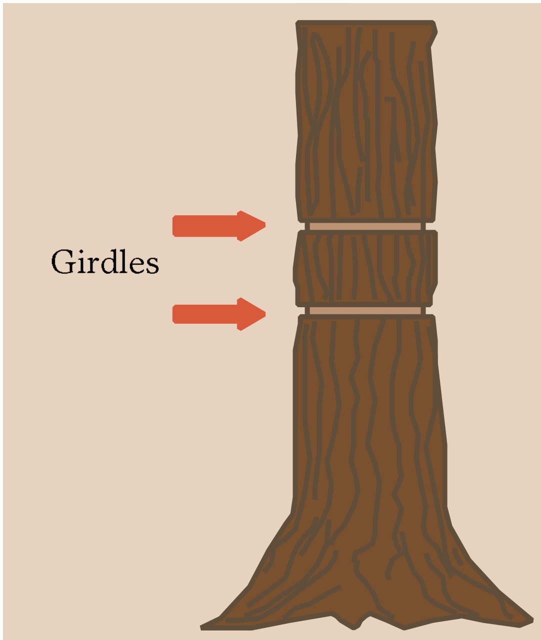

Figure 1. Girdles on a Hardwood Tree.

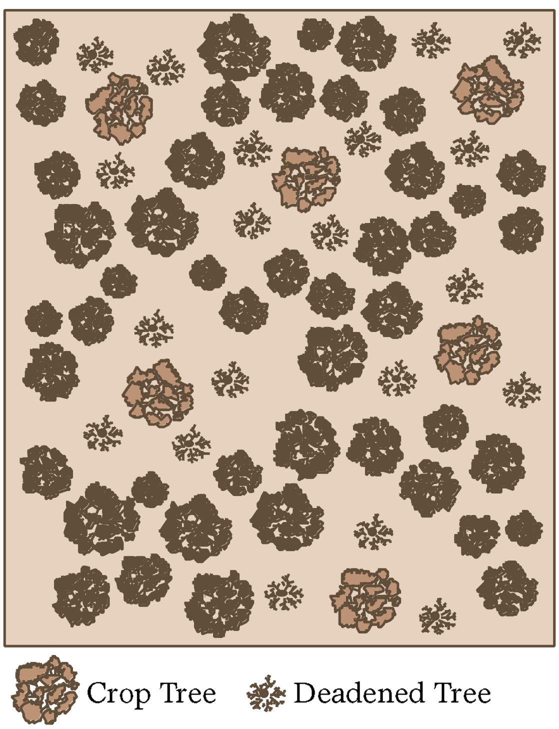

Figure 2. Aerial View of Released Crop Trees.

another girdle at least 6 inches above or below the first one. Each girdle should be cut completely through the bark and into the live wood at least 3/4 inch. Make sure that each girdle meets at both ends so the vascular flow of water is completely severed.

Wildlife Benefits from CTR

Trees may take up to a year to die, but once dead, limbs fall off creating "snags." Standing dead trees provide food (decomposing insects), as well as sites for nesting, roosting, denning and perching for many species of birds and mammals. Standing dead trees further benefit wildlife by allowing sunlight to reach the forest floor, increasing forage for deer and nesting cover for wild turkeys and many species of songbirds. Increased sunlight in the stand also allows the crowns of crop trees to expand, which increases mast production (e.g. acorns, beechnuts and cherries), further benefitting wildlife.

Why Deaden Trees If They Could Be Sold?

Younger stands of pine trees are commonly thinned by logging, thereby generating an income rather than an expense. Why can't the same early thinning be applied to hardwoods, as well? In some circumstances it can be feasible, particularly where markets allow and conscientious loggers are available; but in many cases, it's not. Several characteristics unique to pine stands lend well to early thinning:

(1) In Tennessee, the price for pine pulpwood is generally greater than for hardwood pulpwood. Normally,

loggers are more willing to purchase small pine trees for profitability.

(2) Pine plantations are usually in straight rows and on level terrain. Logging equipment can maneuver through pine stands easily, which keeps the logging production rate high and profitable. Hardwood stands, normally having grown up naturally (not planted), are mixed species with variable spacing and are often found on steeper terrain, making logging slow, difficult and expensive.

(3) Pine trees have flexible branches with conical-shaped crowns and can be felled and logged easily without causing excessive damage to residual trees. In contrast, logging younger hardwood stands often results in damage to the tops and bases of the very trees you are attempting to protect and release. For these reasons, manual CTR, rather than logging, should be considered in releasing your younger hardwood stands.

Conclusion

Private landowners are beginning to view their hardwood forests as a vital part of their farm assets. Demand for fine-quality hardwood products such as cabinets, flooring, furniture and veneer has increased and is expected to continue for the foreseeable future. As a result, prices have escalated, causing astute landowners to consider an active rather than an incidental approach to managing their hardwood crops.

The slow growth rates of hardwood trees have long been viewed as an obstacle to forest management. Through minimal investment, CTR is a way to energize your forest. Growth rate is enhanced, forest composition is improved, harvest rotation is shortened and revived enthusiasm for your forest investment results.

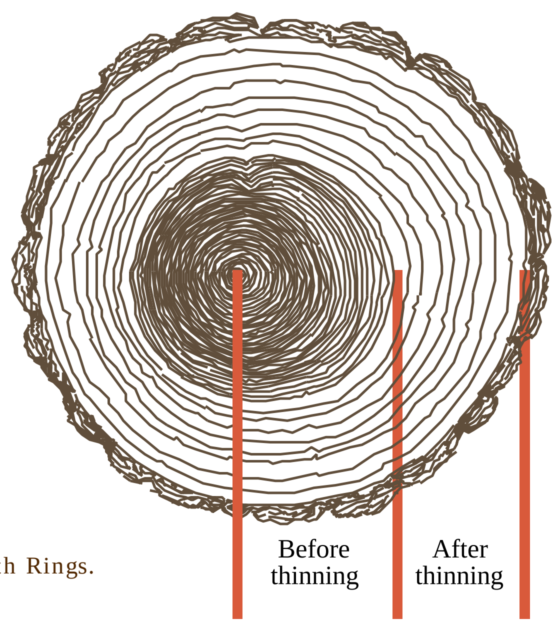

Figure 3.
Response of Annual Growth Rings.

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COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
The University of Tennessee Institute of Agriculture, U.S. Department of Agriculture,
and county governments cooperating in furtherance of Acts of May 8 and June 30, 1914.
Agricultural Extension Service
Charles L. Norman, Dean

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Do you have a Healthy Woodlot?

(Ontario Extension Notes)

EXTENSION NOTES

Ontario

DO YOU HAVE A HEALTHY WOODLOT?

The loss and fragmentation of the natural landscape in southern Ontario means that private woodlots, big and small, are more important than ever to human and environmental health and to the wildlife species that need forest habitat to survive. This Extension Note provides information on assessing and improving the health of your woodlot.

WHAT IS A WOODLOT?

A healthy woodlot provides habitat for a wide range of forest species. In addition to this important function, healthy woodlots can provide wood products and a host of other benefits. Woodlots that provide the best habitat for wildlife contain a mix of species, including conifers and hardwoods, and trees of all ages and sizes. They also have a good understorey of food-producing shrubs for wildlife and a dense layer of plants on the ground.

A woodlot is a community of trees and other plant species.

WHY ARE HEALTHY WOODLOTS SO IMPORTANT?

A few hundred years ago, southern Ontario was covered with immense forests interspersed with wetlands, savanna, prairies and other open areas. Through agricultural and urban development, the natural landscape has been reduced and fragmented. The small pockets of forest that remain provide fewer homes for plant and animal species that need large expanses of forest to survive. As a result, the wood thrush, the saw-whet owl, the blue-spotted salamander, the hoary bat and many other forest species are disappearing. Because the remaining patches of forest are so small, forest birds are also more vulnerable to predation and to nest parasites, such as the brown-headed cowbird which lays eggs in the nests of other birds

In many areas of southern Ontario, private woodlots are the only forested areas that remain to support forest species. They are also the only relief we have from the effects of urbanization. Like all forests, woodlots clean the air and water of pollution, prevent flooding and erosion, maintain a sense of nature in contrast to developed surroundings and provide green places for rest, relaxation and recreation. Healthy woodlots that contain a great number of different plant species play an important role in maintaining genetic diversity within plant species.

HOW CAN I IMPROVE THE HEALTH OF MY WOODLOT?

What you decide to do with your woodlot depends on your priorities and long-term goals. First take stock of what you already have in your woodlot. The size, relationship to other forests and sources of water, tree species and other aspects of your property will determine what you can accomplish in the future. Once you clearly know what you are working with, assess your priorities. Your priorities, for example, might be wildlife habitat, wood production and recreation, in that order. With your priorities in mind, set your goals. Achieving them may be as simple as leaving your woodlot and surrounding area alone for a period of time or encouraging natural regeneration.

Whatever your goals, a forest management plan can assist you in attaining them. If you need help with a management plan, contact a forestry consultant, your conservation authority or the Ministry of Natural Resources.

It takes time and energy to develop a healthy woodlot. Although you may not be able to do them all, here are some steps you can take to improve the health of your forested property.

1. **ENLARGE AN EXISTING WOODLOT OR CONNECT TWO WOODLOTS BY NURTURING NATURAL REGENERATION OR BY PLANTING TREES**
   Size is an important factor when it comes to supporting forest species. Bigger is better for most species and especially for neotropical long-distance migrant birds, such as the scarlet tanager and the cerulean warbler. These birds are threatened by the loss of forests that are large enough to provide secluded breeding areas.

   Consider how your woodlot fits into the landscape. Is it part of a larger forest? Are there other woodlots or natural areas nearby? If your woodlot is part of a larger forest, it might already play an important role in maintaining wildlife populations in your area. If you can expand it by nurturing natural regeneration or by planting, all the better. Connecting nearby woodlots by planting trees in open areas can transform a habitat-poor area into one that can support many more species.

   Encouraging the growth of natural regeneration in and around your woodlot is less expensive and requires less work than planting. It involves protecting seedlings and saplings of desired tree species from competition with other vegetation for water, sunlight and nutrients and protecting them from deer and rodents, which eat the bark of young trees. If you choose to plant trees, select native species that have been grown from local seed sources. To get the most from your planting investment, it is wise to seek professional advice regarding the specific site requirements of each species you choose to plant.

2. **MAINTAIN AND CREATE WILDLIFE TRAVEL CORRIDORS**
   Check to see if your woodlot is connected to other natural areas by lushly-vegetated fence rows, corridors of trees or other protected travel routes. Wildlife need safe travel corridors to find food, shelter, nesting sites and mates.

Wildlife, such as wild turkey, need protected travel routes.

You can improve existing corridors and create new ones by planting trees and shrubs between forested areas and between forested habitat and sources of water.

3. **PROMOTE NATIVE PLANTS**
A healthy woodlot contains native plant species, rather than non-native species. Non-native plants, such as Norway spruce and Norway maple, spread and displace native plants because they are usually prolific seed producers and have few insect or disease pests. Choose only native plants when planting forests or landscaping. Remove these non-native invaders listed below.

NON-NATIVE SPECIES

Norway maple	colonizes forests
European birch	invades bogs and other natural areas
glossy buckthorn	shades and crowds out native shrubs
dame's rocket	takes over moist forests and meadows
purple loosestrife	chokes out plants that provide food for wildlife
garlic mustard	invades shaded areas

4. **PROVIDE PROTECTIVE COVER FOR WILDLIFE**
Plant white spruce, white pine, cedar and other conifers which provide cover for deer, grouse and many other wildlife species. Conifers also add greenery during the winter months. To help small mammals, such as rabbits and weasels, construct brush piles from branches left over when the woodlot is thinned and trees are harvested.

5. **PLANT MAST SPECIES FOR FOOD**
When planting or choosing trees you want to grow in your woodlot for the future, be sure to provide plenty of black cherry, oaks, hickories and other mast species that provide nuts and fruits for birds and mammals.

Maintain at least seven mast trees in each hectare of forest.

6. **PROTECT AND NATURALIZE THE WATER'S EDGE**
Does your woodlot touch or include lake shoreline, streams, ponds, wetlands or other sources of water, food and aquatic habitat? If so, is the land-water interface shaded and protected by natural vegetation? The interface is one of the most important areas for deer, foxes and other large mammals that need protected access to water. These areas are also important sources of food for birds and mammals that feed on insects and amphibians.

Protect the water's edge from disturbances and, if necessary, plant native species to provide protective cover and food for wildlife. Red-osier dogwood, American highbush cranberry and other native shrubs are excellent sources of food and cover. They also prevent erosion by stabilizing the soil.

Poplars planted at the water's edge will stabilize the shoreline, and provide food and shelter for wildlife. In contrast, on the opposite bank, there is evidence of the shoreline being trampled, compacted and eroded by cattle.

Snags are standing trees that are dead and decaying. They provide habitat for many species.

7. **PROTECT SNAGS AND CAVITY TREES FROM LOGGING**
   Standing dead trees (snags) and older living trees with holes (cavity trees) are important elements of a healthy woodlot. Wildlife use them for feeding, nesting, denning and escaping from predators.

   Keep at least five snags and six cavity trees in each hectare of forest. Cut any trees that present safety hazards.

8. **LEAVE DECAYING LOGS, BRANCHES AND ORGANIC DEBRIS ON THE GROUND**
   Fallen logs and branches provide homes for small mammals, salamanders, snakes, insects and fungi. They also act as seed beds for some tree species and return nutrients to the soil as they decay.

9. **PROTECT LARGE CANOPY TREES AND SUPERCANOPY TREES**
   Large trees are sources of seed, shade, wildlife cavities and other important elements of forest habitat. They are also one of the features that people enjoy most. Leave a minimum of three large trees in each hectare of forest.

   Supercanopy trees are white pines and other conifers that poke above the forest canopy. They provide landmarks for migrating birds, roosting sites for raptors and safe havens for bear cubs to hide in. Leave at least one cluster of supercanopy trees in each four hectares of forest.

10. **CREATE NATURAL BUFFERS AROUND FORESTS**
    Plant native shrubs and ground covers around woodlots to act as a buffer between lawn and forest habitat. Lawns are biological deserts and should not be allowed to encroach upon natural areas.

11. **HARVEST CAREFULLY**
    If you intend to harvest trees, use methods that do as little damage as possible to the forest. Restrict forest operations to the time of year when the ground will best support heavy equipment. Winter, late summer and early fall are good times. Reseed or replant the disturbed areas of your forest. Keep access roads to a minimum. Also, protect tall conifers near wetlands and in areas that need conifer seed for regeneration.

Planting trees in open areas can transform a habitat-poor area into one that can support many more species.

Decaying logs provide habitat for wildlife and are a source of soil nutrients.

12. CONSIDER THE NEEDS OF WILDLIFE BEFORE DISTURBING NATURAL ENVIRONMENTS

Before you cut a forest or make a natural area, consider how the changes will affect wildlife. Will your changes disturb plant communities that provide food and shelter for wildlife? Will the changes isolate wildlife populations, making it difficult to find food, migrate or mate?

Wildlife species respond to environmental change in different ways. Habitat generalists, such as the white-tailed deer or the northern cardinal, which can live in a broad range of conditions and are relatively mobile, can move and adapt to environmental change. In general, the loss and fragmentation of forest habitat in southern Ontario has benefitted habitat generalists.

Habitat specialists, on the other hand, have more specific habitat requirements and have more difficulty adapting to environmental change. Some, like the woodland salamander, may persist in small patches of habitat while land-use changes occur around them. Others are more vulnerable and have difficulty surviving logging or other major habitat disturbances. Relatively immobile species, such as the wood frog, are particularly at risk.

As a general rule, it is important that woodlot owners avoid changes that could further reduce populations of habitat specialist species.

Bloodroot *(Sanguinaria canadensis* L.) is a perennial member of the poppy family. It is found in rich woods, blooming from March to June.

13. KEEP CATTLE OUT

As they graze, cattle trample the roots of older trees and compact the soil. In time, this suffocates the roots and kills the trees. Cattle also trample and eat undergrowth, making it difficult for forests to regenerate and exposing soil to erosion.

Careful use of trails protect woodlots from human damage.

14. LEAVE NATIVE PLANTS IN THE FOREST

Woodlots and natural areas are not the places to get plants for your garden. Natural areas are often the only place left for native wildflowers to grow. Most wildflowers, such as orchids, have specific habitat needs to complete their life cycles. Moving them may jeopardize the population and they probably won't survive in your garden anyway.

15. STICK TO THE TRAILS

To reduce the impact of human use, limit your travels to main trails. When developing trail systems, design entrances and paths carefully to minimize damage human traffic might cause.

16. RESTRICT PETS

Keep cats out of woodlots and other natural areas where they can prey on birds and small mammals. And keep your dog on a leash. Dogs can stress or kill both plants and animals.

17. AVOID FEEDING PEST SPECIES

If you live beside or near a natural area, ensure that your bird feeder is accessible only to animals that you want to attract. Avoid feeding the pest species in the chart that prey on or out-compete vulnerable native birds.

Use a tube-shaped silo feeder with small perches to discourage blue jays, grackles and starlings. To reduce the numbers of starlings, house sparrows and cowbirds at your feeder use sunflower and niger seed instead of corn and small grains like millet. Keep the area around the feeder clean so that the pest species have nothing to feed on. To keep squirrels away from the feeder, place it two to three metres high on a pole in an open area. A cone-shaped baffle halfway up the pole will also help to keep the squirrels away.

PEST SPECIES

house sparrow	a European species that competes with native birds
brown-headed cowbird	a nest parasite that lays eggs in the nests of other birds
blue jay	an expert nest raider
grackle	an aggressive bird that out-competes other species
starling	a European species that competes with native birds
squirrels	preys heavily on bird eggs and nestlings

WHERE DO I GO FOR HELP?

Here are some of the agencies that can provide advice and information on maintaining a healthy woodlot:

- Ontario Ministry of Natural Resources
- Ontario Ministry of Agriculture, Food and Rural Affairs
- conservation authorities
- municipal parks and recreation departments

You may also want to join a group that shares your concern for the environment. The following is a short list of organizations you might consider:

- Federation of Ontario Naturalists
- Canadian Wildflower Society
- Ontario Woodlot Association
- Ontario Forestry Association

The following extension notes and books are a good source of information on developing healthy woodlots:

- *The Old-Growth Forests of Southern Ontario*
- *Restoring Old-Growth Features to Managed Forests in Southern Ontario*
- *Managing Regeneration in Conifer Plantations to Restore a Mixed, Hardwood Forest*
- Lompart C., J. Riley, J. Fieldhouse, *Woodlands for Nature: Managing Your Woodland for Wildlife and Nature Appreciation.* Federation of Ontario Naturalists.1997.
- Hilts, S. and P. Mitchell, *Caring For Your Land.* University of Guelph. 1995.

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Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Treatments for Improving Degraded Hardwood Stands

UT Extension
SP680

Professional Hardwood Notes
Technical Information on Hardwood Silviculture for Foresters

Treatments for Improving Degraded Hardwood Stands

Wayne K. Clatterbuck, Associate Professor, Forest Management and Silviculture, University of Tennessee, Knoxville

Popular sentiment is that the small trees in the lower canopy when released will become the large trees of tomorrow. This assumption has been perpetuated in the diameter-limit harvests that have led to what we call high-grading today. The largest and best trees are repeatedly harvested leaving the smaller, inferior trees to perpetuate the next stand. In reality, the trees being released are probably of similar age as those being cut. The smaller, released trees did not have a chance to prosper in competition with the faster-growing, overstory trees. These released trees are incapable of continued growth with their small, spindly crowns. The consequence of removing only highly valued trees with each harvest is a hardwood resource with ever lower levels of economically valuable trees.

Degraded, low quality or problem hardwood stands generally result from the historic absence of markets for low-value trees. After many years of only harvesting the most valuable trees, millions of acres of degraded stands in the eastern hardwood region have little left to manage. These stands need silvicultural treatment to increase their value and productivity. Recent improvement in the markets for pallets, ties, chips and pulpwood increases the management options available for treating degraded stands.

Forest practitioners and landowners should understand why and how these problem stands were created so that fewer of these stands occur in the

Wayne Clatterbuck

Degraded stand with fire-scarred trees and trees with poor form.

SREF

TENNESSEE FORESTRY DEPARTMENT OF AGRICULTURE

COOPERATIVE EXTENSION SERVICE
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future. The goal of this publication is to explain why hardwood stands become degraded and to describe corrective measures for improving degraded hardwood stands.

Degraded Hardwood Stands

Definition

The term "degraded" in this manuscript includes all low-quality and problem hardwood stands. As a result of past practices, degraded hardwood stands usually contain trees that are crooked, rotten or diseased; are of undesirable species; are physically damaged from previous logging operations and are not growing at a satisfactory rate. Degraded stands also contain patches of too many or too few trees and regeneration of desirable species is lacking. Most importantly, degraded stands usually do not contain large volumes or numbers of desirable growing stock trees (Haymond and Zahner 1985). These degraded stands present great opportunities, but tough challenges for forest management (McGee 1982). The opportunity for improving these stands is considerable, as many acres now produce just a fraction of their potential.

It is assumed that usually, but not always, these stands have been cutover and only the best trees removed. But degraded stands also occur on low-quality sites or as a result of fire, insects or disease. It is always important to determine "why" a stand is degraded. If the degraded stand occurs on a poor site, careful planning of treatment is recommended because there is little that can improve tree growth on poor sites.

Wayne Clatterbuck

Damaged trees usually do not improve with growth as shown by this fire-scarred yellow-poplar on a good site.

How Did These Stands Become Degraded?

A cause of degraded hardwood stands is repeated cuttings through practices (commonly called high grading, diameter-limit cutting or select cutting), where the best trees are harvested and previously described non-marketable and defective trees are left. Cutting only the largest and best trees removes those trees that are best suited for the site and leaves trees for growing stock that are less adapted to the site. Yet, repeated high grading with no stand improvement has progressively removed the best timber and left the stand in a degraded condition.

Most of these harvests are conducted for short-term economic gain, without consideration for the growth and composition of the growing stock that is left and regeneration of the future forest. Historically, the only markets available were for the best trees, which promotes high-grading. This type of cutting does not make provisions for the regeneration of many desirable species, especially oaks and hickories. The mostly undesirable, shade-tolerant species (blackgum, red maple, sugarberry, boxelder, hornbeam, sourwood and beech) in the midstory and understory prior to the harvest remain, suppressing the growth and development of desirable, regenerating species. However, with the expansion of markets for low-quality products, landowners will have more options for addressing degraded stands.

Many of these harvests were done in the name of good forest management (Ezell 1992). Landowners thought that the large trees were the older trees, so they removed them to give room for young trees to develop. We now know that small trees that are left are not necessarily young trees (Clatterbuck 2004) and that cutting the biggest and best trees out of a stand usually results in degraded stands.

Repeated harvesting entries into a stand usually result in damage to some residual trees from logging wounds. In addition to poor harvesting practices, fire, insects and disease, wind, ice, grazing and grapevines have degraded many trees in hardwood stands. What we find in many degraded stands today is a mosaic of degraded remnants left over from previous harvests, some regrowth of desirable species and a large proportion of shade-tolerant species that are undesirable for timber production (Ezell 1992). Often, stands have a patchy distribution of trees, including crowded conditions in some areas (overstocked) and sizable openings or widely spaced trees (understocked) in others (Nyland 2006).

Site quality is another cause of degraded stands. Some sites are so poor, they are not capable of growing good hardwoods. These sites might include the thin soils and droughty conditions found on exposed ridges and steep, south slopes. Typical species composition is blackjack oak, post oak, chestnut oak, eastern redcedar, Virginia pine and vacciniums. However, many degraded stands occur on medium- to better-quality sites. Better-quality stands can be regenerated on these sites (McGee 1982). In most cases, rather than representing the true potential of stands on these sites, the trees present are often a result of a combination of harvesting practices and other factors such as burning or grazing, and not just because the site is poor (Smalley 1982, McGee 1982, Haymond and Zahner 1985). Because of the presence of degraded trees on these sites, many land-

Causes of Stand Degradation

1. High Grading or Diameter Limit Logging
   - Reduces stem quality
   - Reduces merchantable volume
   - May change species composition
   - Promotes canopy discontinuity
   - Changes diameter distribution
2. Grazing or Fire --- Increases rot and can reduce regeneration
3. Repeated Logging Entries --- Logging damage to residual trees and regeneration
4. Insects and disease, wind, ice storms and other factors

Bruce Kauffman

A degraded hardwood stand with oak decline.

owners and practitioners infer that these sites are poor. However, with careful planning and harvest of poorer trees, these better sites can produce better stands of hardwoods.

In summary, degraded stands usually have the following features (Nyland 2006):

- few trees of desirable species, good vigor or good form remain as growing stock, limiting the future potential for volume and value growth
- the stand often has a patchy distribution of residual trees, resulting in incomplete site utilization and little control over understory development
- limited usable volume remains, making further cutting commercially marginal or infeasible
- few large seed trees remain, complicating attempts to establish a new cohort
- understory plants may dominate the understory, particularly in the more open areas, further challenging chances to regenerate new seedlings across the stand

Assessing Degraded Stands (Adapted from: Ezell 1992)

1. Perform a forest inventory
2. Determine site quality
3. Determine stocking and distribution of desirable trees (AGS)
4. Consider species composition (desired vs. unwanted trees)
5. Estimate tree quality by considering tree form, potential tree grade and tree crowns of residuals
6. Evaluate regeneration potential through a regeneration survey, both desirable species and control of interfering vegetation
7. Estimate age of the stand
8. Determine objectives of management and markets

Why Does the Problem of Degraded Stands Persist?

While some causes of degraded trees are controllable, the majority of degraded stands are not managed. The simple answer is that the landowners have little economic incentive to improve the stand (McGee 1982). Markets for degraded hardwoods are not generally available, and where they do exist, the income is marginal at best. More options are available to rectify a degraded situation when markets exist for small and low-value material.

Improvement of some severely degraded stands may require a cash outlay and the cost of removing poor trees may exceed the value of the stumpage. Many owners are reluctant or unwilling to invest in these stands. Often they feel that other investments may yield more certain results. Moreover, timber may be viewed as a one-time windfall rather than a long-term investment. Some owners, aware of the length of time and associated risk of forest investments, choose not to spend funds on these stands. Often, because they cannot properly evaluate the site potential and lack knowledge of stand management and markets, owners cannot properly evaluate the possible return on their investment (McGee 1982).

With degraded stands, three options for management are generally available: (1) rehabilitate the stand, (2) regenerate the stand, or (3) postpone action or leave the stand alone.

Unfortunately, leaving the stand alone is the option used too often, even on sites capable of growing quality timber. Rehabilitation of a degraded stand requires the measure of acceptable growing stock. If there is not enough growing stock to produce a new stand, then regeneration of the stand is necessary. Regenerating the stand often has the potential to create a better quality stand than what is currently on the site.

Corrective Measures for Degraded Hardwood Stands

Stand degradation can occur quickly, but usually develops over a long period following successive harvests and wildfire. Acceptable growing stock (AGS) refers to trees of commercial and desirable species that are capable of increasing in value and volume, and are or can become viable crop trees. Stands are not considered seriously degraded if they contain at least 50 ft^2 of basal area of AGS per acre. Degraded stands usually lack trees in the sawtimber size class. Thinning is usually not economically feasible in degraded stands because of the lack of growing stock. Thus to address degradation, treatments should increase growing stock either by rehabilitation of the existing degraded stand or by regeneration. **The major key to deciding to rehabilitate or to regenerate is the measure of adequate growing stock**. The recognition and classification of AGS will often require professional assistance.

Determining a Course of Action

Degraded stands must be evaluated to determine the cause and the level of the problem, as well as their potential for value increases with treatment. McGee (1982) provides a useful checklist for evaluating and prescribing treatments for degraded and problem hardwood stands. Ezell (1992) and McGee (1982) base stand evaluation on six criteria: site quality, manageability of trees, culling of trees, desirability of the species, advance regeneration and stand age. Highly productive sites bring a higher return on investment, since the *site quality* is greater. The *manageability of trees* is determined by species, stem form and the ability to respond to silvicultural treatment based on crown position (dominant, codominant, intermediate, overtopped) and condition. Crown condition is evaluated on the fullness or size relative to expected size of a tree of that height and diameter. The estimated basal area (measure of stand density) of desirable trees feasible for future management is 30 to 50 square feet per acre or about 40 to 50 small sawlog-size trees per acre.

Trees to be culled may or may not be an asset to the stand. Although they may have little timber value, they may be desirable to wildlife and to potential regeneration through sprouting or seeding if they are of a preferred species. *Undesirable species* such as red maple, beech, hickories, dogwood and others are usually shade-tolerant, taking growing space from more valuable species, or inhibiting regeneration, so they should be controlled. The amount and distribution of *advanced regeneration* and the seeding and sprouting of desirable species must be assessed to determine regeneration potential. The ability of residual trees to respond to silvicultural treatments is related to *age*: young, vigorous trees with balanced crowns have a greater capacity to respond to release than older trees approaching maturity.

Wayne Clatterbuck

Degraded stand with a few acceptable growing stock (AGS) trees.

Wayne Clatterbuck

A diameter-limit harvest leaving white oak trees with little potential to increase in value. The second photo is of the same tree 15 years after the harvest. Note that the tree still retains surface defects (knots and branches) that degrades the stem. The tree grew 1.5 inches in diameter in fifteen years after release.

The Decision to Regenerate

If a sufficient number of AGS trees are not present in the degraded stand, then the stand should be regenerated, because a new young stand generally has the potential to create a better-quality stand. Methods of regeneration include clearcutting, patch clearcut, shelterwood and group selection. Most hardwood species can be regenerated by one, two or all three of these methods. The species likely to be present following the regeneration harvest will vary for each stand and will depend upon many factors including advance regeneration, seed and sprout sources.

Obviously, desirable species should be favored through pre- and post-harvest site preparation. Equally important is the determination of the unwanted species that might need to be controlled; simply harvesting degraded stands and allowing nature to take its course may not improve the stand composition. Midstory species such as maple, blackgum, dogwood and beech sprout prolifically, can be a problem and will need to be controlled (probably by herbicides).

Most species have specific pathways that promote successful regeneration. Yellow-poplar, sweetgum, black cherry and ash reproduce from seed; oaks and walnut from advance regeneration; and almost all small hardwood stumps will sprout to some degree. Recognizing the regeneration sources, regeneration methods, site productivity and the growth habit of each species and how they all interact in their associated competitive environments will assist in your assessment of site preparation needs for successful regeneration of the favored species.

While most hardwoods regenerate quickly and readily following some form of clear felling, one of our most favored groups, the oaks, presents special regeneration problems (Loftis and McGee 1993). For the oaks, advance regeneration (pre-existing seedlings from 1 to 4 feet tall) must be present or developed prior to the final harvest. Established advance regeneration gives oaks an initial advantage over faster-growing species. Without advance regeneration, oak will probably not be a component of the new stand. Serious mistakes are often made assuming that small (less than 1 foot) oak seedlings will compete with faster-growing yellow-poplar, birch, ash and locust when released. On higher-quality sites, oak advance regeneration of sufficient size (greater than 4 feet) and number (60 to 80 per acre) must be cultured at least three to five years or more to increase the probability that oaks will become an overstory species (Stringer 2005). On poorer sites, oaks are much more readily regenerated, often from small stumps.

Regeneration of most degraded stands requires removal of overstory and midstory trees, usually through clearcutting. Otherwise, these trees will influence the growth and development of the regeneration. Ideally, the clearcut is achieved by a commercial harvest and no cash outlay is required of the landowner. However, many degraded stands may not contain enough timber value for the harvest to be profitable. Regardless, clearcutting is an efficient regeneration method to quickly remedy degraded hardwood stands. Fortunately, most degraded stands regenerate readily following clearcutting.

The Decision to Rehabilitate

Stand rehabilitation involves improving the existing degraded stand by (1) harvesting less desirable trees and retaining desirable growing stock, and (2) securing and protecting desirable regeneration in the open spaces. Nyland (2006) lists four steps that occur during the recovery of degraded stands when adequate growing stock is present.

- protect desirable residual trees or groups of trees by removing the poor and undesirable trees
- growth is concentrated on residual trees of AGS
- regeneration fills the spaces between the widely-spaced trees
- enhance desirable seedling regeneration and development success by controlling, with herbicides, interfering understory and midstory vegetation

The removal of less desirable trees provides more growing space for the residual trees. McGee (1982) calls this "sparse tree retention" and it leads briefly to two-aged stand structure (Stringer 2002) with a sparse, older age class and a regenerating age class. From a stand productivity point of view, the growth of the sparse trees can produce a quick return in 10 to 20 years (Miller et al. 2004). However, when sparse trees are harvested, damage is likely to occur to the 10 to 20 year regeneration hardwoods.

An advantage of rehabilitated stands with two-age structure is that regeneration of the stand occurs without clearcutting. Additionally, some future short-term income is generated from retention trees that otherwise would not be available if these trees were harvested. Development of higher-grade butt logs is possible through additional growth when retention trees are selected with the potential to increase in grade. Also, by leaving some larger trees on the site, sexual reproduction can still take place, providing seed for regeneration as well as mast for wildlife.

On the other hand, rehabilitating stands does have several potential problems (McGee 1982). Trees selected for retention must have the ability to grow quickly into higher size and value categories. Epicormic branching may reduce the grade of these retained

Silvicultural Treatments for Rehabilitation of Degraded Stands

1. Two-age management or deferment cutting or sparse tree retention
2. Site preparation techniques (either pre- or post-harvest) of clearcuts and deferment cuts to favor regeneration of desired species
3. Enrichment plantings (if prescribed) and control of undesirable species in the midstory and understory
4. Crop tree release of acceptable growing stock (AGS)
5. Adjusting harvest opening size to target advantageous conditions based on regeneration present, site-quality conditions and AGS
6. Consider mixed pine-hardwood stands on lower-quality sites

Wayne Clatterbuck

Forked and poor quality trees remaining after repeated high-grading.

trees. In addition, trees must be logged and culls controlled without physically damaging the retention trees. Many smaller trees must be cut, lopped and injected, which is usually done as an expense. Once these smaller trees are controlled, then the regeneration will have an opportunity to grow unhindered. As retention trees reach harvestable size, there must be a means to harvest these trees with minimal damage to the developing regeneration.

Rehabilitating degraded stands is not a panacea. It is a stop-gap treatment that provides some benefit while shaping the stand to be more productive in the future. Many degraded stands do not have enough desirable trees to make the effort worthwhile. The decision to rehabilitate rather than regenerate should be based on an objective evaluation of available growing stock. If the rehabilitated stand can provide some income and logs in the future, the stand can be rehabilitated; otherwise, the stand should be regenerated. Regardless, rehabilitated stands will probably need to be regenerated in 10 to 30 years.

Choosing Other Options

Sites on upper slopes, ridges and eroded soils have inherently poor productivity and tend to slowly grow short-bodied hardwood trees. Many of these trees have been subjected to fire and occasional cutting, which has further degraded stand quality. These sites may be better managed for other uses such as wildlife habitat. Another possibility is mixed hardwood-pine stands where pine is planted at a wide spacing (perhaps 100 or more pines per acre) and natural hardwoods are allowed to grow between the pines (Mullins et al. 1998). Pines are well-adapted to and grow at a faster rate than hardwoods on these poorer and drier sites. The attractiveness of this two-stage method is that the pine can provide an earlier income, while hardwoods grow for a longer time.

Many degraded hardwood stands on low productivity sites can also be converted to pine. However, control of hardwood competition can be costly. Markets for degraded hardwoods can substantially reduce site preparation needs.

Action is postponed or many degraded hardwood stands are left alone with some hope that they may improve. Degraded stands are not likely to improve much without treatment. A few trees per acre may increase in value, but the culls, damaged, poorly formed and undesirable trees will also continue to grow. A degraded stand today will, without some type of treatment, remain a degraded stand. Owners should carefully assess their property and determine the priority of degraded stands within their management goals.

Enrichment planting is a low-cost compromise between doing nothing and spending the time and money to completely harvest and regenerate the stand (Haymond and Zahner 1985). Where a certain species is sparse or absent, enrichment planting would allow the introduction of one or more desirable species without completely regenerating the stand. Competing vegetation in the vicinity of the planted seedling must be controlled to give the planted seedling a chance to prosper. Another method is to plant seedlings after complete vegetation removal (clearcutting) to enhance a species that may not be part of the natural regeneration pool. Enrichment planting has been discussed by practitioners and researchers, but few trials have been conducted, especially in planting hardwood seedlings in a residual hardwood stand. Although recommendations can not be made based on research data, introducing pines in hardwood stands to create a diversified, mixed stand has been successful on medium- to low-quality sites (Mullins et. al 1998).

Another alternative might be to adjust management so only portions of the stand are treated with a prescription rather than treating the entire stand. This alternative is appropriate in targeted areas where stocking (AGS) is favorable or on better-quality sites. In these circumstances, methods to enhance individual tree development may be more positive than stand level treatments. Managing the size of openings is a means of providing regeneration to targeted areas within stands (LeDoux 1999). Crop-tree release (Mercker 2004; Stringer et al. 1988) can be particularly useful when focusing on individual trees.

Summary

Degraded hardwood silviculture is complex, due to the range of species, sites and level of degradation. Degraded stands often result from mistreatment and neglect, but some poor stands result from natural causes. Most any set of treatments that can be prescribed that will improve the stand will

Factors That May Affect Degraded Stands

1. Stands with more than 50 square feet of basal area per acre of acceptable growing stock (AGS) are generally not considered degraded.

2. Normal thinning is generally not practical in degraded stands, but timber stand improvement (TSI) to remove unwanted trees may be. There is not enough AGS to justify a thinning. Regeneration harvesting and thinning are separate operations with different purposes. Thinning is an intermediate operation to promote residual trees. Regeneration harvesting is to initiate and develop regeneration.

3. Capital is usually limited for improving degraded stands. The costs and benefits of practices should be carefully considered. Dividing stands may be necessary because degraded stands often have areas that should be regenerated and areas where residual trees can be managed. It might be acceptable to culture portions of the stand rather than implementing treatments across the entire stand.

4. Generally treat high-quality sites first.

5. Stand regeneration is the better alternative than stand rehabilitation when AGS is not adequate.

6. Two-age methods are suggested for treatment of degraded stands in establishing viable and desirable regeneration as well as some potential increase in value of trees. Favored residual trees or groups of trees should be widely spaced with regeneration being promoted in the open spaces between trees.

7. Treatment of a tolerant, undesirable midstory and understory is usually necessary. Preharvest site preparation costs may be lower in hardwood stands than post-harvest activities.

8. On lower-quality sites, consider mixed pine-hardwood stands.

result in better conditions and increased productivity, but come at a cost that may be a serious deterrent. Judging whether enough acceptable growing stock is present is key in determining whether to rehabilitate or to regenerate degraded stands. There is no perfect, one-size-fits-all method for success. Individual stand conditions must be assessed and techniques applied that would bring the stand closer to conditions favorable for producing desirable trees, while keeping costs at a minimum. Most landowners are interested and prefer to do something environmentally positive to return degraded stands to more desirable conditions. Stand rehabilitation, where appropriate, and regeneration, where necessary, will set the stage for a gradual stand recovery.

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Regeneration Potential Recommendations for Degraded Stands

<table>
<tr><th>Species</th><th colspan="4">Acceptable</th><th colspan="2">Unacceptable</th></tr>
<tr><th>Stem Quality</th><th colspan="2">Good</th><th colspan="2">Poor</th><th colspan="2">Good/Poor</th></tr>
<tr><th>Vigor/Age</th><th>Vigorous/Young</th><th>Poor/Old</th><th>Vigorous/Young</th><th>Poor/Old</th><th>Vigorous/Young</th><th>Poor/Old</th></tr>
<tr><td>Regeneration Potential Adequate Present</td><td>Complete regeneration possible

Concentrate site preparation for regeneration on unwanted overstory and midstory trees <u>OR</u>

Culture sparse overstory trees</td><td>Complete regeneration required in near future

Concentrate site preparation on overstory and midstory trees</td><td colspan="2">Complete regeneration required

Concentrate site preparation for regeneration on unwanted overstory and midstory trees</td><td colspan="2">Complete regeneration required

Concentrate site preparation for regeneration on unwanted overstory and midstory trees</td></tr>
<tr><td>Regeneration Potential Currently Inadequate Present, but in need of culturing to become adequate</td><td colspan="2">Postpone harvest

Use midstory removal.

If harvest is required, leave groups of overstory trees

Concentrate site preparation for regeneration on competing understory vegetation</td><td>Postpone harvest

Use midstory removal

If harvest is required, leave groups of overstory trees

Concentrate site preparation on competing overstory and midstory trees</td><td>Postpone harvest

Use midstory removal

If harvest is required, concentrate site preparation on overstory and midstory trees</td><td colspan="2">Postpone harvest. Use midstory removal to culture regeneration

If harvest is required, concentrate site preparation for regeneration on overstory and midstory</td></tr>
<tr><td>Regeneration Potential Inadequate Not present</td><td>Postpone harvest

Culture spare overstory until adequate regeneration is established

If harvest is required, consider leaving groups of overstory trees</td><td>Complete regeneration required

Consider complete or partial artificial regeneration (species enrichment, mixed pine/ hardwood, or complete pine conversion)</td><td>Postpone harvest

Retain poor - formed overstory as a seed source for regeneration

If harvest is required, consider leaving groups of overstory trees</td><td>Complete regeneration required

Consider complete or partial artificial regeneration (species enrichment, mixed pine/ hardwood, or complete pine conversion)</td><td colspan="2">Complete regeneration required

Consider complete or partial artificial regeneration (species enrichment, mixed pine/ hardwood, or complete pine conversion)</td></tr>
</table>

Source: Adapted from Dr. Jeff Stringer, Dept. of Forestry, University of Kentucky

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HARDWOOD SILVICULTURE

Improving Species Composition in Mismanaged Bottomland Hardwood Stands in Western Alabama

(Connor F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.)

IMPROVING SPECIES COMPOSITION IN MISMANAGED BOTTOMLAND HARDWOOD STANDS IN WESTERN ALABAMA

Troy S. Taylor, Edward F. Loewenstein, and Arthur H. Chappelka[1]

Abstract—Forests of the Coastal Plain of Alabama are among the most diverse, productive, and complex in the United States. Long-term mismanagement, however, coupled with a lack of refined scientific knowledge on bottomland oak silvical characteristics and on their regeneration dynamics, has resulted in a reduction in both the quantity and quality of the oak component in many of these stands. A study was implemented in western Alabama to compare survival, growth, and animal browse of planted Nuttall oak seedlings using plastic tube shelters, wire browse protection, fertilization, mulch mats, and control. Treatment effects on seedling height and caliper growth indicate that fertilization application and type of seedling protection significantly affect both groundline diameter and height. The use of seedling protection positively affected tree growth form and protected seedlings from herbivory compared to those unprotected.

INTRODUCTION

There are thousands of mismanaged acres of bottomland forests that exist in Alabama today from past highgrading and other destructive practices. As a result, the proportion and quality of oaks retained in these forest stands has been diminished. The consequence has been the establishment of a higher fraction of stems that are composed of non-oak and other undesirable tree species. Stands that typically have included moderate proportions of high-value tree species, such as cherrybark and Nuttall oak, have been reduced to mixed-species stands of lower economic value.

A decrease in the number of mature oaks growing on productive bottomland hardwood sites can create special problems in successfully regenerating them after a harvest. Even when good seed years occur, the stocking densities and spatial arrangement of oak reproduction is sporadic at best and sometimes non-existent. Much of this is due to a lack of silvical knowledge concerning the natural reproduction dynamics of oaks within these productive sites. Limited knowledge of the formulae to successfully recruit and establish oak seedlings is largely stochastic in nature; that is, we know what silvicultural methods should encourage oak seedlings to become established, but success cannot be predicted with any certainty. As a result, numerous plant species have been able to capitalize on the high light environments created during harvest operations.

Many plant species that have the ability to flourish in these highly productive bottomland hardwood forests are shade tolerant (e.g. *Carpinus caroliniana, Halesia diptera*, etc.). This is one of the primary reasons that oak regeneration is futile in these environments. Stand prescriptions that encourage oak regeneration are often similar to those that favor the development of potentially faster growing competitor species (Kormanik and others 1995). The ramifications are that oak reproduction is often subject to well-developed understories dominated by shade tolerant species. The lower stratum of these forests often includes *Vitis, Smilax, Arundinaria*, and numerous other tolerant non-commercial tree species. These undesirable species have the ability, unlike the oaks, to become established and persist in an understory almost completely lacking in direct sunlight for many years. As a result, these species create a dense mat of vegetation that covers the forest floor so completely that penetration by direct sunlight is almost fully impeded.

These predicaments are extremely problematic for bottomland oak seedlings, because they are notoriously slow in attaining the vertical height required to rise above this layer of vegetation. They are so slow, in fact, that even when ample light is available they still are shorter in height relative to adjacent vegetation. A large proportion of oak reproduction present in this type of understory usually experiences mortality caused, at least in part, by their inability to become fully established. Extreme low-light environments at the ground level in these forests creates a situation where many desirable oak species cannot compete successfully for the necessary light, nutrients, and other resources that limit plant growth.

The initial inability of oak seedlings to grow rapidly in height makes them especially vulnerable to animal browse. Although a number of seedlings experience mortality due to stresses associated with competing vegetation, there still are many that become established in these conditions. Those seedlings unable to rise above 1.25 m (Castleberry and others 1999) however, will in many instances experience heavy browse pressure from the high population densities of both white-tailed deer (*Odocoileus virginianus*) and feral pigs (*Sus scrofa*). The potential impact of animal browse on desirable hardwood regeneration is poorly understood. Herbivory of naturally-regenerated commercial species has adversely impacted other habitat types by changes in species composition (Anderson and Loucks 1979, Hough 1965, Marquis 1981, Ross and others 1970, Tilghman 1989, Walters 1993). The presence of these animals makes it especially difficult to regenerate valuable timber, because they feed heavily on seedlings and sprouts

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of preferred species. These problems are further exacerbated by the fact that these animals tend to stay within small pockets in the forest until the area is overbrowsed (Moore and Johnson 1967). Although light browsing usually will have no detrimental effects on the future stands in these areas, heavy browse damage can potentially lead to stem deformities, changes in species composition, reduced stocking, or extended rotations.

High population densities of herbivores and heavily shaded understory environments in mature forests have led to oak regeneration failures (Gillespie and others 1996) and stimulated an increase in the number of stems of undesirable species. In southern forests, undesirable shade-tolerant species have been increasing in dominance over time at the expense of the oak component. The fate of these forests that were once heavily stocked with oak trees is in question; quality oak seedlings are now scarce, and sapling-size specimens are virtually non-existent. Techniques to recruit oak reproduction using natural regeneration methods are still being developed and, as yet, are not reliable.

If some assurance of oak species' stature in recently cutover floodplain forests is desired, the supplemental establishment of oaks through planted seedlings could partially alleviate some of the problems associated with natural regeneration methods (species composition, density, spatial distribution, etc.) (Pope 1993). In order for artificial oak regeneration to be successful, however, two factors need to be considered: (1) faster growing competitor species (vines, herbaceous weeds and undesirable tree species), and (2) high population densities of both white-tailed deer and feral pigs.

Rapid early height growth is the key to overcoming both herbivory and the dense mat of vegetation that is present in the lower strata of these forests. In an effort to promote this growth, some measure of seedling protection may be necessary to ensure that plantings are successful. Efforts to protect seedlings from animal browse damage led to the invention of plastic tree shelters in England in 1979. These plastic tubes were approximately 4 feet tall and allowed enough light to the seedling so they were able to survive and become established, and also protected seedlings from animal browse until they emerged from the end of the tube. Not only did the tree shelters protect seedlings from browse damage, but improved seedling survival and rapid early height growth were also observed (Manchester and others 1988). Since that time, many different styles of tree protection devices have been tested throughout the world. In the United States, research programs in Michigan have shown that tube shelters effectively increased oak seedling survival and early height growth (Lantagne 1995, Lantagne and Miller 1997, Lantagne and others 1990). Comparable tests in North Carolina, Pennsylvania, and Connecticut also showed similar trends (Manchester and others 1988, Walters 1993, Ward and others 2000). In the Southeastern United States, several studies have investigated the effectiveness of tree shelters in urban environments (West and others 1999, West and others 2002) and in abandoned agricultural fields as a method of reforestation (Schweitzer and others 1999) with excellent success. While Dubois and others (2000) investigated the growth and establishment of cherrybark oak in a harvested area in eastern Alabama, there have been no reportings of tree shelters being used to aid in the establishment of bottomland oak species on recently cutover bottomland hardwood floodplain forests.

If protection from animal browse is the main factor limiting oak regeneration success, then any method of seedling protection (i.e., tube shelters or wire cages, for example) should afford similar results. However, if plastic tube shelters can stimulate greater height growth than by browse protection alone, then their use in southern bottomland forests should be encouraged. Our objectives were to examine the synergy of browse protection type and enhanced height growth on oak reproduction at the site of a recent clearcut in west Alabama. Specifically, we investigated the difference in the growth, survival, and animal browse intensity on planted Nuttall oak (*Quercus nuttallii* L.) that have been subjected to various combinations of plastic tree shelters, wire cages, and fertilization.

METHODS AND PROCEDURES

Nuttall oak seedlings were purchased in January 2000 and stored in a cooler at 40 °C until they were transported to the planting site. Prior to outplanting, the root systems of each seedling were dipped in a 10 g solution of Viterra™ to aid in keeping the roots moist.

This study was conducted in a second-bottom mixed hardwood community adjacent to the Black Warrior River in Greene County, AL, approximately 10 miles due north of Demopolis. The landowners' intent originally was to plant the area with pine. As a result, the area was clearcut and the site prepared by shearing and windrowing following logging operations. Pre-harvest vegetation on the study area ranged from the swamp chestnut oak/cherrybark oak type on drier sites to the willow/water-laurel oak type on wetter sites (Shropshire 1980). The swamp chestnut/cherrybark stands contained a large proportion of water oak (*Quercus nigra* L.) and sweetgum (*Liquidambar styraciflua* L.) but also included green ash (*Fraxinus pennsylvanica* Marsh.), white oak (*Q. alba* L.) and hickory species (*Carya* spp.). Also present in smaller numbers were American elm (*Ulmus americana* L.), winged elm (*U. alata* Michx.), and southern red oak (*Q. falcata* Michx. var. *falcata*) (Shropshire 1980).

Two planting areas were located in close proximity to each other, situated with an east-west orientation, and separated by a windrow approximately 3 m in width. A portable laser-distancing device and flagging were used to delimit each planting area and to establish planting rows. The planting area on the north side of the windrow measured approximately 82 m by 40 m and accommodated six planting rows. The planting area south of the windrow measured approximately 90 m by 41 m and received seven planting rows. Each planting spot within each row was then differentiated using color-coded pin flags to discern which treatment was to be applied at each particular location. In the spring of 2000, a total of 324 Nuttall oaks were planted in holes dug using a portable gas-powered auger with a 15 cm bit. A total of 144 seedlings were planted on the north side of the windrow, while 180 were planted on the south side.

Seedlings were watered one time with approximately two cups of water 1 week after planting to aid in their establishment due to a coincident drought. After planting, baseline measures of seedling height and groundline diameter were recorded. Groundline diameter was measured at approximately 2.5 cm above true groundline to avoid swelling that is common at the base of all trees. Seedling height and groundline diameter data were again measured at the end of each growing season in October 2000, 2001, and 2002. Due to the high population density of both white-tailed deer and feral pigs, a measure of browse intensity was documented as well. Browse incidence was quantified based on the presence or absence of the terminal bud and the amount of forking along the seedling bole as a result of herbivory. Treatment differences were tested at the $\alpha = 0.05$ level.

Herbicides were applied around seedlings of each protection type several times during the first two growing seasons to control competing vegetation. The first application was in May 2000 using a 4 percent (by volume) RoundUp Pro™ solution. To more effectively control some of the more tolerant weed species, subsequent herbicide applications were amended with 0.5 percent (by volume) of an additional surfactant (Timberland 90™). Applications were made in late June and August of 2000, and May and July of 2001. Most competing vegetation was controlled by the use of the chemicals, but some stems were manually severed.

EXPERIMENTAL DESIGN

Three hundred twenty-four Nuttall oaks were planted in a completely randomized design at the study area in February 2000 at 3 m by 6 m spacing. One-third of the seedlings were placed in 1.2 m tall opaque plastic tube shelters, one-third in 1.2-m-tall wire cages, and the remaining one-third of the seedlings were unprotected. One-half of all seedlings within each treatment received 2 10-gram fertilizer tablets (20-10-5, NPK) at the time of planting, for a total of six treatment combinations with 54 seedlings each. Black plastic mulch mats (approximately 1 m by 1 m) were employed at each planting hole across the study to further reduce the effects of competing vegetation.

RESULTS

Of the 324 Nuttall oak seedlings planted for this experiment in spring 2000, 309 (95.4 percent) were still alive after two growing seasons. While there were no significant differences in survival among treatments, 18.75 percent (3) of the seedlings that died were from the control group while 43.75 percent (7) and 37.5 percent (6) were from the wire cage and tube shelter protection type, respectively. Sixty-two percent (10) of the seedlings that experienced mortality had received a one-time fertilizer application at the time of planting, 38 percent (6) had not.

General Linear Model analyses ($\alpha = 0.05$) were used to examine the relationships between treatment/protection type and seedling height and groundline diameter growth after two growing seasons. Height growth differed significantly ($P < 0.0001$) among treatments (fig. 1). Treatment type was significant ($P < 0.0001$) as was fertilizer use ($P = 0.0019$). Groundline diameter growth differed significantly ($P < 0.0001$) between the different treatment combinations (fig. 2). Treatment type was significant ($P < 0.0001$) as was fertilizer use ($P = 0.0002$).

Duncan's Multiple Range Tests indicate the use of plastic tube shelters stimulated significantly greater height growth among seedlings than either the use of wire cages or control (table 1). Height growth by seedlings in wire cage protection was also significantly greater than for those in the control group, and fertilized seedlings exhibited greater height growth after two growing seasons than those unfertilized. Groundline diameter was also affected by seedling

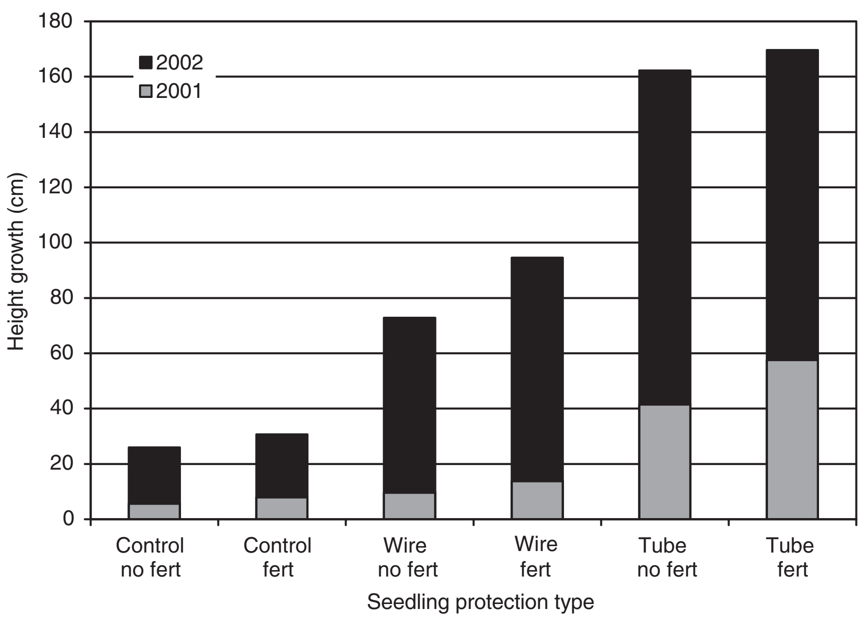

Figure 1—Height growth (cm) of planted Nuttall oak seedlings by seedling protection type and fertilizer use after two growing seasons.

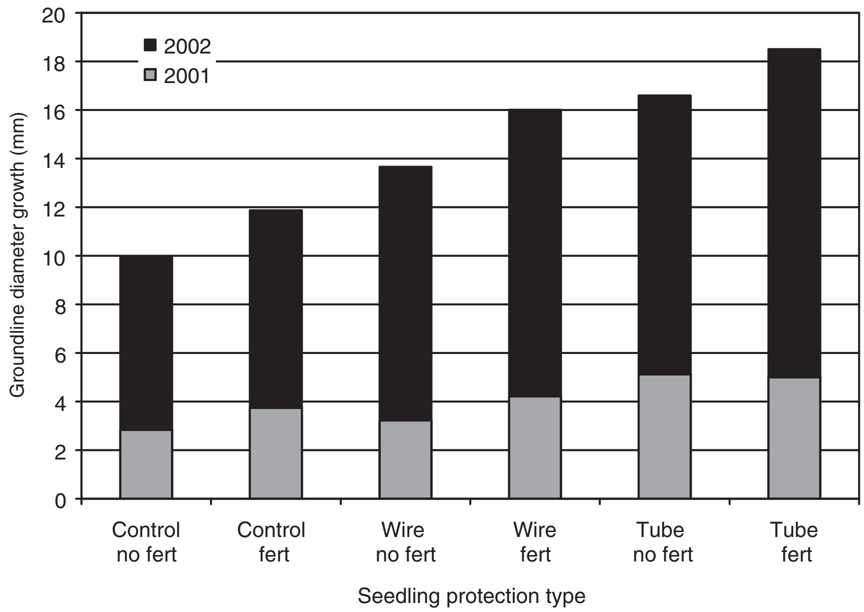

Figure 2—Groundline diameter growth (mm) of planted Nuttall oak seedlings by seedling protection type and fertilizer use after two growing seasons.

Table 1—Mean height and diameter growth of planted Nuttall oak seedlings by protection type and fertilizer use after two growing seasons

	N	Mean height[a] growth	Mean GLD growth
		cm	*mm*
Protection type			
S	102	167.18a	17.10a
W	101	84.18b	14.99b
C	105	28.46c	10.94c
Fertilizer usage			
Yes	152	99.12a	15.31a
No	156	87.43b	13.08b

S = plastic tube shelter; W = wire cage; C = control.
[a] Means followed by the same letter within the same column are not significantly different ($\alpha = 0.05$) using Duncan's New Multiple Range Test.

protection type. Seedlings in plastic tube shelters were significantly larger in caliper than those in the wire cages, and seedlings in wire cages were larger than the control. Similarly, fertilized seedlings exhibited greater groundline diameter growth than unfertilized.

Analysis of variance (ANOVA) results suggest there were significant differences in herbivory among the protection types over the duration of this study. Post-hoc tests reveal that the degree of browse incidence on the control seedlings was significantly greater than either the wire cages or plastic tube shelters. Ninety-five percent of the unprotected (control) seedlings were damaged by animal browse and no longer retain their terminal buds. Twenty-eight percent of those were browsed heavy enough to cause extensive forking along the bole while 67 percent sustained only slight browse damage. In contrast, less than 5 percent of seedlings in tube shelters or wire cages sustained browse damage to the terminal leader. There were no significant differences in browse incidence between the wire cage and plastic tube treatments.

DISCUSSION

Results from the first growing season indicated that fertilizer use significantly affected seedling height growth but not groundline diameter growth. Data from the second growing season indicated that fertilizer enhanced diameter growth but not height growth. Total seedling height and diameter growth was significantly elevated by the use of fertilizer over the 2-year period. Over the course of the study the groundline diameter of seedlings increased approximately 15 percent while height growth increased 25 percent by the use of fertilizer, compared to those unfertilized. Based on these results it appears that the use of fertilizer does provide an initial boost in seedling height growth which may help them overcome the destructive influences of both competing vegetation and herbivory. Whether or not these effects are lost over time is of little importance if the initial height gains in enable seedlings to rise above browse level (1.25 m).

The use of seedling protection devices significantly increased both groundline diameter and height growth after two growing seasons. Seedlings in wire cage protection were approximately 300 percent taller than those in the control group, whereas seedling which utilized plastic tree shelters were nearly 650 percent taller than those in the control group. These figures are slightly higher than those previously reported in the literature. Lantange and Miller (1997) reported gains in height of 375 percent, and Manchester and others (1988) report gains of 132 percent after two growing seasons for trees in shelters compared to those in the control group. Differences in growth may be attributable to the fact that those studies were done in the Northern United States where growth rates are typically slower. However, previous studies in the South also suggest height growth differentials may indeed be in the 300-400 percent range (Dubois and others 2000, Schweitzer and others 2000) even without intensive competition control. Differences in height growth between this study and others may be due to the fact that there was nearly 100 percent vegetation control surrounding all planted seedlings at this study site. In addition, there was virtually no competition for light, nutrients, or other factors that limit plant growth. This likely enhanced the growth rates and may be atypical of results found in less intensive planting regimes. The nearly complete vegetation control may also have impacted survival rates across all treatments. Some studies involving tree shelters reported high mortality rates for control seedlings (Manchester and others 1988), and this was not true for this study, where we had 95 percent survival across all treatment groups.

The intense browse pressure evidenced in seedlings in the control group may also have been an artifact of our vegetation control. There are abundant white-tailed deer in the area; however, because competing vegetation had been treated with herbicide and was either dead or dying, alternate browse was unavailable. Planted oaks were the main vegetation within the planting areas in early spring. Wire cages and plastic tube shelters protected two-thirds of the seedlings from browse with the remaining one-third of seedlings in the control group free to be browsed. This resulted in a high proportion of the control seedlings actually losing height, some by nearly 23 cm, from repeated browse since the time of planting. This not only affected tree height, but subsequent tree form was drastically altered. Control seedlings tended to be short and shrubby compared to the taller and typically single-stemmed form of protected seedlings.

The control treatment was the least costly of the protection types, but poor growth rates and tree form are an outcome of herbivory that can often lead to poor success rates in re-establishing a forest stand. Costs of both the wire cages and the plastic tube shelters are comparable but have different qualities associated with them. For example, the wire cages do protect seedlings from browse damage to the terminal leader, but do not protect seedlings from side browse as branchlets extend through the wire. As a result, cage-protected seedlings are not as straight and generally have poorer form compared to those in plastic tube shelters. Unless side branches are removed, the cage protection devices will be very difficult to remove when the seedlings rise above browse level. Plastic tube shelters are the most costly of the treatments studied, but their use ensures that requisite rapid early height growth, coupled with good tree form, can be attained for desirable species. Although not investigated, plastic tube shelters might have a lower cost per successful seedling compared to other methods.

SUMMARY

The 1.2-m-tall opaque plastic shelters stimulated both greater seedling height and groundline diameter growth over two growing seasons compared to those enclosed in wire cages or those in the control treatments. Partially as a result of the growth rate differential, tree form also was superior with increasing levels of protection with the best form attained through the use of plastic tube shelters and the worst form for seedlings in the control treatment. The effects of fertilizer on planted Nuttall oak seedlings were demonstrated through enhanced seedling height and groundline diameter growth compared to those unfertilized. Incidence of animal browse was significantly reduced by the presence of seedling protection devices. The use of protection devices and fertilizer, either separately or in concert, can enhance early seedling growth and aid in the establishment of artificially regenerated bottomland hardwood species.

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Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Choosing a Silvicultural System

(Extension Notest, Ontario)

EXTENSION NOTES

Ontario

CHOOSING A SILVICULTURE SYSTEM

If you're planning to harvest trees from your woodlot, a forest management plan can help you achieve the highest economic returns possible and ensure the long-term health of your forest. One of the most important steps in developing a plan is choosing a silviculture system. Silviculture systems are different approaches to harvesting, regenerating and growing forests. The three main silvicultural systems used in Ontario include: the selection system, the shelterwood system, and the clearcut system.

This Extension Note describes the silvicultural systems and some of the factors you should consider as you select a system that's right for you and your property.

THE SELECTION SYSTEM

HOW IT WORKS

Individual trees or groups of mature, unhealthy or other selected trees are harvested periodically. Most of the trees are left to regenerate the stand naturally. Before any harvesting is done, an inventory of the forest is completed. The inventory identifies the tree species, the different sizes of trees, the quality and health of the trees and the availability of habitat in the forest. Based on this information, a tree marking prescription is written and all trees to be cut are marked with yellow paint. Crop trees are usually marked with blue paint. Crop trees are the trees you want to grow for their future commercial value, for their value to wildlife or as sources of seed for regenerating desired tree species. Every eight to 15 years, the stand is thinned to give crop trees room to grow, and some unhealthy and mature crop trees are harvested. Care is taken during the thinning and harvesting operations to

Silviculture is the science of growing trees avoid damaging the site and the crop trees. Damage to young and old trees can lower the future value of the wood.

Road access and a good network of skid trails are important. Good access will improve the efficiency of each thinning and also minimize the damage to crop trees.

The selection system can be adapted to encourage the growth of different species. Cutting individual, mature trees in the canopy encourages the growth of shade-tolerant species, such as maple, beech and hemlock, which are growing in the understorey. Cutting groups of trees, in an adaptation called the "group selection system," encourages the growth of intolerant species, like poplar, and mid-tolerant species, like oak, basswood, cherry and white pine. The group selection system creates sunny gaps in the canopy where these species can grow.

THE RESULTS

This system maintains a diverse, all-aged forest with a wide range of species of different sizes and ages. These natural-looking forests provide continuous supplies of wood, fuelwood and other forest products, as well as habitat for wildlife and attractive areas for recreation.

WHERE IT WORKS BEST

The selection system is well-suited to the mixed hardwood forests of southern Ontario, where the small periodic cuts mimic the forest's natural cycle of renewal. Mixed hardwood forests rely on small-scale natural disturbances, such as lightning, fire, wind, ice storms and disease, to kill individual trees or groups of trees and create the space that young trees need to grow.

BENEFITS

- preserves the genetic diversity of the forest
- full canopy protects site from erosion
- maintains natural-looking, diverse forest
- provides good wildlife habitat and areas for recreation
- generates long-term income and a steady supply of wood products

DISADVANTAGES

- requires investments in evaluating the forest, selecting and marking crop trees, thinning and harvesting
- assistance from forestry experts is recommended
- large areas are required to generate sufficient volumes of wood and income
- crop trees and regeneration can be damaged during harvest operations

The selection management system maintains a diverse, all-aged forest with a wide range of species of different sizes and ages.

The shelterwood system maintains a forest canopy to protect, shade and shelter a new crop of trees.

SHELTERWOOD SYSTEM

HOW IT WORKS

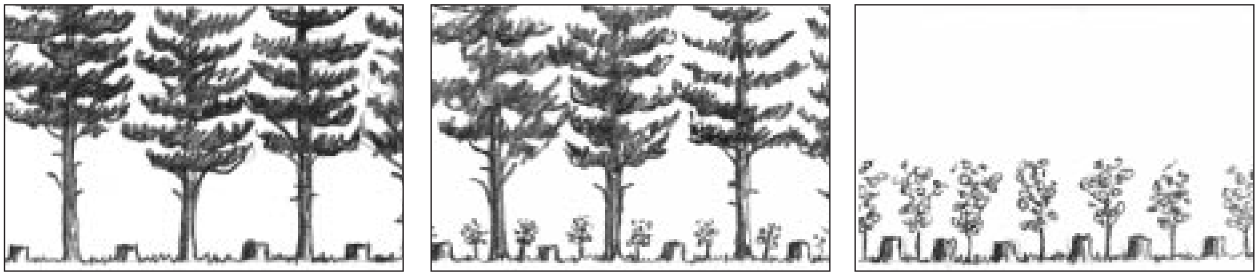
Mature trees are harvested in a series of two or more partial cuts. The cuts stimulate the germination and rapid growth of a new forest in the shelter and the shade of mature trees. The mature trees usually provide seed for regenerating the site, but sometimes regeneration is achieved by seeding, planting or stimulating coppice growth. You will need good roads and skid trails to access the site to complete each harvest. Care is taken at each harvest not to damage the site or the regeneration.

This system can involve three different kinds of harvests:

1. **Preparatory cut**
   The preparatory cut is a thinning operation that gives selected trees room to grow large crowns. Trees with large crowns provide more seeds than trees with small crowns. A preparatory cut is only done if there is a shortage of trees with large crowns on the site. The first harvest is usually done when the trees are 60 to 80 years old.

2. **Seed cut**
   The seed cut removes about half the mature trees in the stand. It opens up the stand, allowing sunlight to reach the forest floor, where it stimulates the germination and growth of seedlings. The second harvest is usually done when the trees are 80 to 100 years old.

3. **Removal cut**
   The removal cut harvests all the mature trees. It can be done as a single harvest or as a series of partial harvests. The removal cut is conducted after a dense



The shelterwood system can involve three different kinds of harvests: the preparatory cut (left), the seed cut (centre) and the removal cut (right).

carpet of saplings (trees taller than 1.5 metres) is established in the shelter of the mature trees. By giving the saplings full sunlight, the removal cut encourages the rapid growth of a new forest. The final harvest is usually done when the trees are 100 to 120 years old.

THE RESULTS
The shelterwood system produces an even-aged, fast-growing forest. It favors mid-tolerant species, such as oak, white ash and white pine, which can germinate in shade but later require some sunshine to survive. This system can be adapted to quickly regenerate maple sugar bushes.

WHERE IT WORKS BEST
This system is well-suited to mixed hardwood and conifer forests in southern Ontario that lack sufficient natural regeneration to grow desired species. The shelterwood system mimics major disturbances, like wind, fire and insects, that create large gaps in the forest canopy where mid-tolerant species can grow.

BENEFITS
- preserves the genetic diversity of the forest
- partial canopy protects site from erosion while new growth is getting established
- maintains some wildlife habitat
- can be used to regenerate oaks which provide food for wildlife

DISADVANTAGES
- requires investments in evaluating the forest, select-ing and marking crop trees, thinning and harvesting
- assistance from forestry experts is recommended
- can cause loss of habitat for animals that require a mature closed canopy, such as the red-shouldered hawk

CLEARCUT SYSTEM

HOW IT WORKS
All the trees are harvested in one cutting operation. In a modification of the clearcut system, called the “seed-tree method,” individual trees or groups of trees are left standing to provide seed for regeneration. The seed trees are large-crowned (capable of producing large quantities of seeds) and able to survive in windy, exposed conditions.

The clearcut area can be regenerated by:
- windborne seeds from nearby areas
- seeds from trees left on the site, singly, in strips or in groups
- coppice growth (the shoots that grow from the stumps of trees when they are cut or stressed)
- artificial seeding
- planting seedlings or trees

You may need to thin the regenerating forest and protect the young trees from competition with other vegetation and from small mammals.

THE RESULTS
Clearcutting produces an even-aged forest with trees that are about the same age. Although maple and other shade-tolerant species can become established in clearcut areas, clearcutting strongly favors the growth of shade-intolerant species, like jack pine, poplar, cedar and white birch. These species, which need full sunlight, grow fast and quickly dominate clearcut areas.

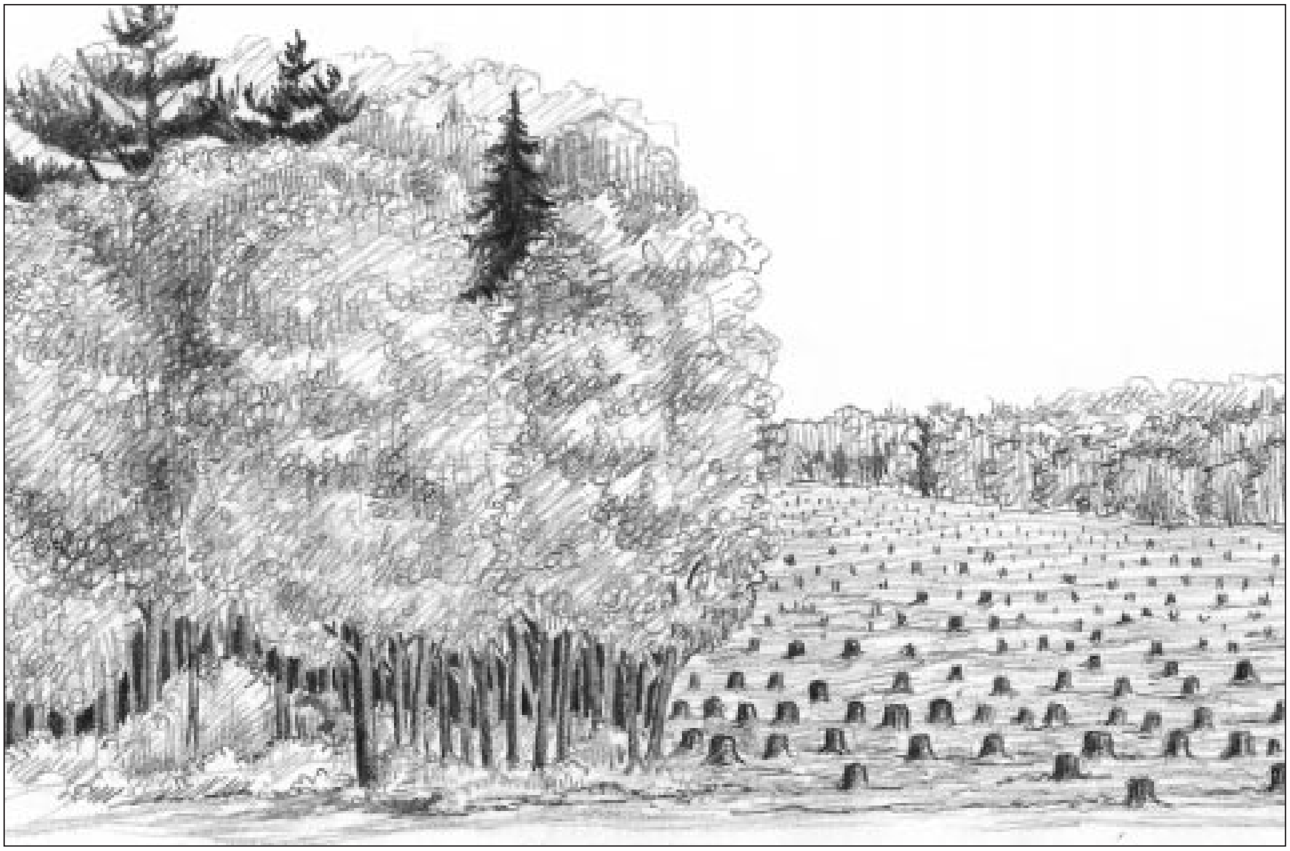
WHERE IT WORKS BEST
Clearcutting is a good choice for the Boreal forests of northern Ontario, where it mimics the natural disturbances that perpetuate this kind of forest ecosystem. In Boreal forests, large catastrophic occurrences, like forest fires and insect infestations, kill extensive areas of forest, which regenerate naturally to even-aged growth.

Clearcutting is not recommended for general use in the mixed hardwood forests of southern Ontario.

BENEFITS
- simplest harvest method with no need to protect remaining seed-trees from damage
- generates highest immediate financial returns
- favors intolerant species, which do not grow well in shade

DISADVANTAGES
- makes land more vulnerable to erosion from wind and rain
- erosion can carry silt into streams and rivers, reduc-ing water quality and damaging aquatic habitats
- regeneration in hot, exposed areas can be difficult and may require investments in preparing the site for seeding or planting, thinning, controlling competition and protecting young trees from small mammals
- can reduce the genetic diversity of the tree species in the new forest if the seed came from a few seed trees
- unpleasant to look at and of little value for recreation

Cut line



The clearcut system mimics natural disturbances, like forest fires, that kill extensive areas of forest which regenerate naturally.

FACTORS TO CONSIDER WHEN CHOOSING A SILVICULTURE SYSTEM

Choosing a silviculture system isn't easy. There are many factors to consider and many decisions to make. The most important ones are your personal goals, the condition of the stand today and your property's potential. The following considerations and questions will help you choose a system.

1. GOALS

Assessing your priorities will help you establish short- and long-term goals for your property. Begin by ranking the following possibilities in terms of importance to you:

- Immediate revenue from wood products or fuelwood
- Long-term revenue from wood products or fuelwood
- Wood products for personal use
- Fuelwood for personal use
- Wildlife habitat
- Natural-looking forest for recreation
- Revenue from maple syrup production
- Maple syrup for personal consumption

2. CLIMATE AND SITE CONDITIONS

Many tree species can grow in a range of conditions. However, their growth and survival rates vary greatly with climate, bedrock type and soil type. Assess your site to determine the tree species that are best suited to it.

- What forest region is your stand located in?
  - Great Lakes-St. Lawrence ....❒
  - Deciduous.......................................❒
  - Boreal ....❒
- What type of bedrock lies under the stand?
  - Canadian Shield ....❒
  - limestone ....❒
- How deep is the soil?
  - 0–50 centimetres ....❒
  - 50–120 centimetres ....❒
  - greater than 120 centimetres ....❒
- What kind of soil is it?
  - sandy ....❒
  - silty..❒
  - clay ....❒
- How much rain and snow falls on the site?
- How hot does the site get in summer?
- How long is the growing season?
- What native species grow best in your area?
- Is the site so steep that cutting the forest will make it vulnerable to erosion that could damage the site and the nearby streams and rivers?

Cut line

3. STAND AND SPECIES CHARACTERISTICS

Assessing the tree density, health and species composition of your forest will help you determine the volume and value of the trees in your forest and how much work you need to do to realize your goals.

- How big is the area that your stand covers?
- How many trees are in the stand?
- What species are present in the stand?
- How old and how big are the trees of each species?
- How many of the trees in your stand are mast species, which provide fruit and nuts for wildlife?
- How many cavity trees and snags are there in your stand to provide nesting, denning, escaping and feeding holes for birds and mammals?
- Is there a carpet of organic matter and decaying wood on the ground to enrich the forest soil and provide habitat?
- Are there any tall pines poking through the canopy that should be preserved for their value as nesting and roosting sites for birds?

4. DESIRED SPECIES

The three silviculture systems favor different species. Identifying the species you want to regenerate or grow will help you choose a system. If you want to regenerate shade-intolerant species like poplars or cedar, choose the clearcutting system which provides the sunlight these species need. If you want to regenerate mid-tolerant species like red oak or white pine, choose the shelterwood system. If you want to regenerate tolerant species, like maples, beech or hemlock, or to maintain a forest with many different species, choose the selection system.

You also need to consider the amount of labor and the costs involved in regeneration. Here's some questions to consider:

- What species do you need to regenerate to achieve your goals?
- What methods work best for regenerating your desired species?
- Are there sources of seed for natural regeneration in the present forest?
- Are there sources of seed for natural regeneration nearby?
- Can you regenerate desired species by stimulating coppice growth?
- Can you afford the time and costs of artificially regenerating the site by seeding or planting?
- Are you willing to weed or use mulches, fire or herbicides to hold back grasses and other plants that might compete with the regeneration?

MAKING A CHOICE

Are your goals compatible? Here are some points to review as you consider your options and possible compromises:

- If you want a natural-looking forest that provides wildlife habitat, as well as continuous supplies of timber, fuelwood, maple syrup or other forest products, the selection system may be right for you and your land. While the costs of regeneration are low, the costs of tree marking and thinning can be significant.
- If you want to regenerate mid-tolerant species like oaks or quickly establish a new sugar bush, the shelterwood system may be the best choice. By keeping a partial forest-canopy until regeneration is established, this system maintains wildlife habitat and does not increase the potential of erosion or fire. However, the costs of selecting and marking crop trees, tending and harvesting can be significant.
- If you want the fastest returns and/or to regenerate intolerant species like poplar, clearcutting may be the system you need. However, regenerating a clearcut takes a long time and can be difficult and costly. Clearcutting also removes the forest canopy which, in turn, reduces the diversity of habitat available to wildlife and makes the site more vulnerable to forest fires and erosion.

For more information on silviculture systems or arrange for assistance preparing a forest management plan for your property, contact your nearest office of the Ontario Ministry of Natural Resources or a local forestry consultant.

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Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Two-Age System and Deferment Harvests

(UT Extension SP 679)

UT Extension
SP679

Professional Hardwood Notes
Technical Information on Hardwood Silviculture for Foresters

Two-Age System and Deferment Harvests

Jeff Stringer, Extension Professor of Hardwood Silviculture, Department of Forestry, University of Kentucky

The two-age system is designed to maintain two distinct age classes in a forest. This system is generally initiated using a deferment harvest, sometimes referred to as a shelterwood or clearcut with reserves (Figure 1). The deferment harvest retains a limited basal area of canopy trees while allowing the majority of the area to regenerate. The harvest initially creates a stand that contains scattered or small groups of older trees, typically one rotation length in age, surrounded by a regenerating age class. The canopy trees that are left are termed reserve trees. At the end of a second rotation length the stand contains a limited number of large reserve trees, two rotation lengths in age, and a larger number of trees that are one rotation length in age.

Figure 1. Typical two-aged stand after a deferment harvest and site preparation treatment.

The two-age system is a viable method for managing many hardwood stands where longer-lived species are present. The system provides for vigorous regeneration and the development of average size and valued sawtimber trees and a significant component of older and larger high-value veneer and grade sawtimber trees. The system also provides for structural components that are lacking in even-aged stands. These structural components can benefit wildlife populations and provide old-growth characteristics. Like any silvicultural option, the two-age system has benefits and constraints and is not appropriate for every management objective or stand condition. The system does provide landowners and managers with options not available with other systems; however, proper implementation is required.

Benefits and Constraints of the Two-Age System

The two-age system initiated by a deferment harvest provides a number of benefits, including:

- Development of large-diameter sawtimber or veneer trees
- Production of a wide range of forest products from pulp to veneer in the same stand at the same time
- Ability to regenerate shade-intolerant and intermediate-shade-tolerant species

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- Improved aesthetics compared to clearcutting
- Increased structural diversity and retention of habitat components compared to clearcutting
- Increased initial revenue compared to other types of non-clearcut regeneration techniques
- Development of old-growth structural characteristics
- Maintenance of sexual reproduction in reserve trees throughout the entire rotation and the ability to "life boat" species that would otherwise be eliminated if the area was clearcut

While the two-age system has several benefits, it also has several constraints and effects that must be considered prior to its prescription, including:

- Lack of appropriate long-lived species to maintain the system
- Forest fragmentation and habitat effects similar to clearcutting
- Reduction in initial revenues compared to clearcutting and possibly diameter-limit harvests
- Limited development of shade-tolerant species
- Damage to new age-class trees if a portion of reserve trees are removed prior to the end of the second rotation length

The benefits and constraints of the system must be carefully considered before prescribing its use. One of the more important issues that determine if the two-age system is an appropriate silvicultural option is the presence of relatively long-lived species. If these species are not present, then the two-age system is probably not appropriate and traditional even-age or group selection methods should be considered if shade-intolerant and/or intermediate-shade-tolerant species are managed. However, if the system meets management objectives and can be used with the species present, then a deferment harvest and the use of the two-age system represents a reasonable regeneration alternative.

The two-age system requires the long-term retention of reserve trees, and their characteristics and selection are critical for successful implementation of the system. Reserve-tree characteristics can vary considerably and are based on management objectives. Regardless, the reserve trees must be able to maintain themselves when challenged with an open environment. The selection of the reserve trees, their individual characteristics, position in the landscape, number and distribution must be carefully determined and managed. Research and operational experience has provided information on a number of these criteria for several of the more important hardwood species and forest types.

Deferment Harvests

Two-aged stands are typically developed using a deferment harvest. However, deferment harvests are also used as a means of establishing even-aged stands, so it is important to understand how deferment harvests differ based on their intended purpose. When deferment harvests are used for developing even-aged stands, the initial reserve tree densities are relatively high, around 30 square feet of basal area per acre, compared to reserve tree densities recommended for the two-age system. Trees are removed 10 to 15 years after the initial harvest, leaving only the regenerating age class. This type of deferment harvest differs from a traditional shelterwood in that the density of reserve trees is less than that of a shelterwood overstory and the reserve tree density is not intended to affect (or shelter) the regenerating age class. Most often this type of deferment harvest is used to alleviate the bleak appearance of a clearcut (Figure 2). When a deferment harvest is used for aesthetic purposes, the characteristics of the reserve trees are less important and rigorous than when the deferment harvest is being used in the two-age system. When implementing a deferment harvest as part of the even-age system, the reserve trees should contain enough surviving merchantable volume (and value) that a commercial harvest can be used to remove them 10 to 15 years after the initial harvest. Issues such as longevity of the species selected are not important considerations of reserve trees in deferment harvests when used in the even-age system.

When a deferment harvest is used in the two-age system, the reserve tree density is much lower than when used with the even-age system. Typically, reserve tree density is not above 15 square feet of basal area per acre and the selection criteria for these trees are more rigorous than when a deferment harvest is used to establish an even-aged stand.

Shelterwood Harvests and the Two-Age System

The two-age system also can be initiated using a shelterwood. In this instance, the shelterwood overstory density is adjusted to encourage the proper regeneration of intermediate-shade-tolerant species (typically 45 to 60 square feet per acre). After regeneration establishment, normally 10 to 20 years, the shelterwood overstory should be reduced to 10

Figure 2. Simulated comparison of a clearcut and a deferment harvest showing the aesthetic differences between the methods.

to 15 square feet per acre. The remaining trees are termed reserve trees and this method of regeneration is referred to as an irregular shelterwood. Whether to use an irregular shelterwood or a deferment harvest to develop a two-aged stand is based on the regeneration requirements at the time of the initial harvest. The irregular shelterwood is used to encourage intermediate-shade-tolerant species and a deferment harvest is used to establish shade-intolerant and intermediate species. One problem with the irregular shelterwood is that is requires that enough volume and value be retained in the stand to allow for a commercial harvest 10 to 20 years after the initial cut, while still retaining 10 to 15 square feet of basal area per acre. Regardless, the end result is the same – a two-aged stand is developed with a limited number of reserve trees being maintained for two rotation lengths with the remainder of the stand occupied by a younger regenerating age class.

Basics of the Two-Age System

The challenge of implementing the two-age system is to ensure that both age classes maintain long-term growth and development. This requires that the older reserve trees be carefully selected to ensure survival and maintain growth and vigor over a second rotation and that their density (number or basal area) is limited so that they will not significantly hinder regeneration of the younger age class over the long-term.

In its simplest form, the two-age system is initiated by a deferment harvest typically retaining between 10 to 15 square feet of basal area per acre. This level of retention is especially important, as all of the reserve trees are left for the entire second rotation length. Initial research involved the use of much higher basal areas, in some cases as high as 30 to 35 square feet per acre. However, as research progressed it became apparent that these basal areas dramatically affected the long-term height growth of the regenerating age class. Research also found that the regenerating stems directly under the reserve tree crowns were stunted with a large number exhibiting significant sweep and stem deformation. By limiting the reserve tree densities, both of these problems can be minimized.

Generally, the 10 to 15 square feet of basal area per acre of reserve trees is obtained through the retention of scattered individual sawtimber-sized (> 10 inches dbh) stems. The large area between reserve trees leaves abundant room for regeneration to flourish in full sunlight over an extended period, in many cases over an entire rotation length. This allows the initial 10 to 15 square feet of basal area of reserve trees to be retained for a second rotation length, with the majority of the trees in the regenerating age class experiencing minimal impacts from the reserve trees. Reserve trees can also be grouped rather than retained as scattered individuals. The grouping of reserve trees has advantages in certain situations, including protection from wind-throw, and the minimization of deformation of regenerating stems compared to leaving scattered individual trees. However, in all cases the intent is to provide two distinct age classes, with the older class providing as little interference with the young age class as possible. This is especially true if volume growth and timber quality are objectives.

At the end of the second rotation, all of the large reserve trees are harvested, as well as the majority of the trees that are one rotation length in age. Only 10 to 15 square feet of this one rotation age class is left as reserve trees for the next rotation. Cultivation of these future reserve trees should be considered during intermediate treatments.

Reserve Tree Criteria

Reserve tree criteria are based on management objectives. For example, the system can be used to initiate the development of old-growth forests, maintain mast production for wildlife, as well as develop large, high-value sawtimber and veneer trees. Each of these objectives will produce a different set of reserve tree characteristics and criteria. In some instances, a specific characteristic can meet the needs of more than one objective.

The majority of the interest and research in the two-age system and deferment harvests is focused on timber objectives. To this end, the primary characteristics of individual reserve trees include:

- long-lived commercial species
- appropriate crown characteristics including live crown ratios (typically > 40 for hardwoods), well-balanced crown proportions and overall crown vigor
- stem form and maintenance of potential veneer or high-quality sawtimber
- ability to withstand harvest
- located to avoid wind-throw and other post-harvest perturbations

These characteristics help assure that the reserve trees emerge unwounded from the deferment harvest, respond positively in growth and vigor after the harvest, maintain themselves and their value to the end of the next rotation, and can withstand environmental stresses associated with the open-grown status of the reserve trees. If objectives other than timber are being considered, then reserve tree characteristics are often altered. For example, leaving trees that are heavy mast producers may be important for wildlife objectives. Regardless, the reserve trees need to be carefully selected to ensure that they survive and provide the required benefits.

DBH and Crown Characteristics of Reserve Trees

To ensure harvest survival and long-term growth response, reserve trees are generally selected from dominant and co-dominant crown classes. Figure 3 shows examples of good and poor two-age reserve tree candidates. Note the live crown ratio (lcr) of more than 40 percent and the well-balanced crown shape of the good-candidate trees (column A). Research has found that some species (ex. white oak) exhibit dieback and mortality when the lcr is below 30 percent. Poor candidates (Figure 3B) generally have thin or deformed crowns, dead major canopy branches, flat-topped crowns or lcr's below threshold levels. Most reserve trees should come from dominant and co-dominant trees, because sub-dominant trees often have significant vigor problems as indicated by their crown characteristics. There are instances where intermediate crown class trees have sufficient characteristics to warrant consideration as reserve trees. However, these trees need to be carefully evaluated to ensure that they possess the correct characteristics and they are able to survive the harvest.

While there is a need to select reserve trees from the main canopy, this should be done with an eye to minimizing timber value of the reserve trees. Holding reserve trees of significant monetary value when not necessary decreases timber revenues and reduces money available for management. Table 1 compares the stumpage value of reserve trees of average dominant/co-dominant size to those selected with the smallest diameters and value that still meet reserve tree criteria for vigor and future value. The data from these seven upland oak hardwood tracts (encompassing 25 different stands) indicate that significant increases in timber revenues can be generated if dbh is considered in selecting reserve trees. However, considerations that minimize value and thus diameter of reserve trees should not outweigh considerations of vigor, value and the ability to survive harvests.

Figure 4 shows the relationship between the average dbh of potential reserve trees by species compared to the average dbh of dominant and co-dominant trees in seven upland hardwood tracts on the Cumberland Plateau in eastern Kentucky. The bold diagonal line shows a 1:1 relationship between the average dbh of reserve trees and average dbh of dominant and co-dominant trees. This means that reserve trees, if they were of the same size as dominant and co-dominant trees, would lie along this 1:1 line. The average minimum diameter at breast height (dbh) targets are shown by dashed lines, representing the average minimum dbh of reserve trees of each species group compared to the average dbh of all of the dominant and co-dominant trees in the stand.

Figure 3. Comparison of good (column A) and poor (column B) reserve tree candidates associated with a deferment harvest. Note overall crown size, balance and live crown ratios of the two sets of reserve tree candidates.

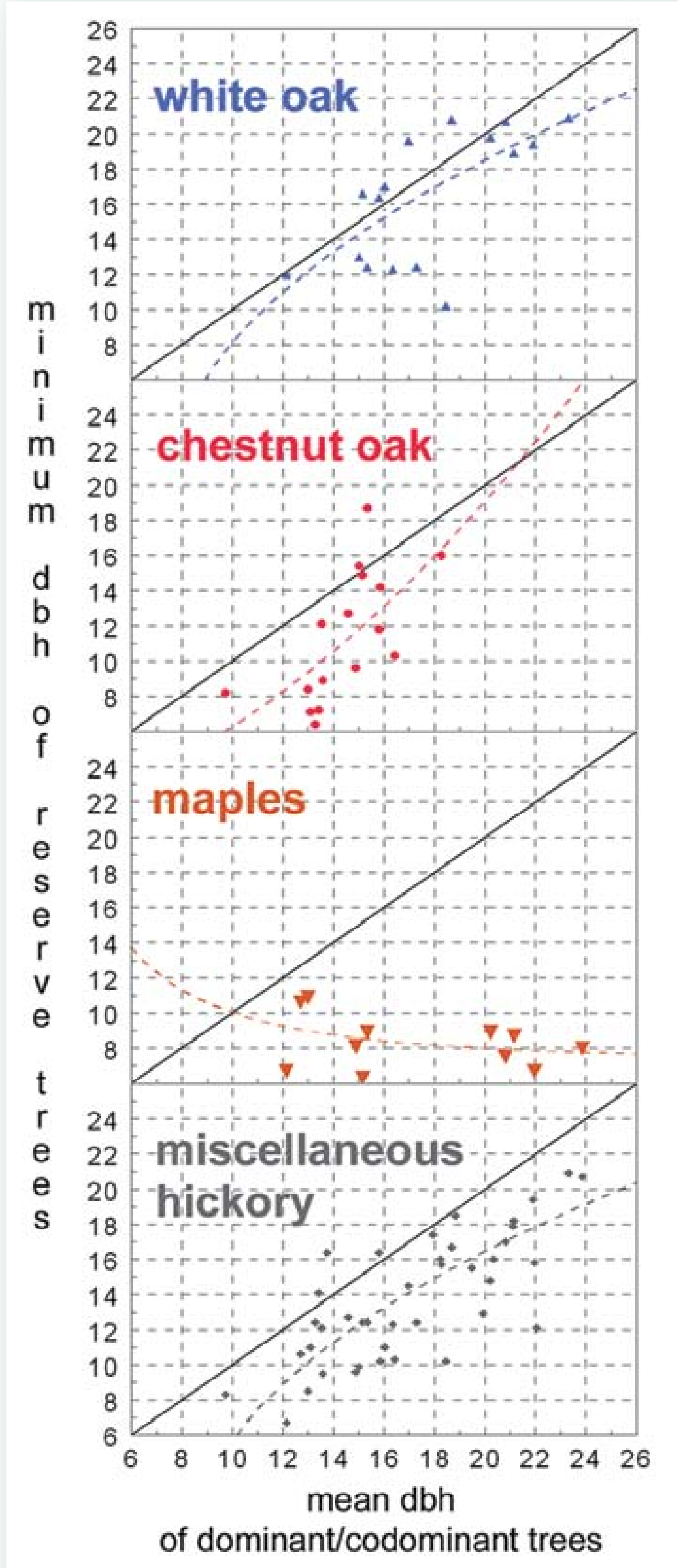

Figure 4. Minimum average dbh for reserve trees for species groups based on the average dbh of dominant and co-dominant trees in each stand for seven tracts on the Cumberland Plateau in eastern Kentucky. The diagonal line shows a 1:1 relationship.

Table 1. Stumpage value per acre of reserve trees (20 ft²/acre basal area) of average dominant and co-dominant dbh compared to reserve trees of minimum dbh that meet criteria for timber objectives for seven tracts in eastern Kentucky.

	Average DBH		Minimum DBH	
Tract	$/acre	Percent of sale	$/acre	Percent of sale
1	301.50	23.0	238.59	18.4
2	334.09	32.1	186.85	16.9
3	289.03	22.6	245.00	20.2
4	322.82	22.5	223.97	22.5
5	328.41	17.9	273.72	14.6
6	281.36	23.3	248.41	20.7
7	327.63	32.5	189.79	13.9
Mean	312.12	24.8	229.48	17.1

In the case of white oak, appropriate reserve trees were very close in dbh to the average dominant and co-dominant trees, generally not deviating more than 3 inches in dbh from the dominant and co-dominant average. It should be noted that many stands in these seven tracts contained large numbers of intermediate and overtopped white oak trees. However, they did not possess the crown characteristics required for retention as reserve trees and the average minimum diameter for reserve white oak trees was relatively close to the average dbh of dominant and co-dominant trees. The potential reserve maples are significantly less in dbh (resulting from their shade tolerance) than the average size of dominant and co-dominant trees. However, it is improbable that many of these potential reserve trees could survive logging and would not typically be selected as reserve trees.

Unfortunately, when the two-age system was first used in the United States, reserve tree selections were made so that their dbh's were minimized, having as little impact as possible on timber receipts from the deferment harvest. However, problems quickly arose with the reserve trees' ability to satisfy long-term timber objectives.

Figure 5 shows the difference in dbh between reserve trees that were marked according to proper reserve tree criteria provided (open circles) and reserve trees that were marked with the primary objective of not significantly altering timber revenues at the time of harvest (+). Note that the dbh for the latter group of trees falls well below the average dbh of appropriate reserve trees when the average dbh of dominant and co-dominants reaches 14-16 inches. Essentially, to avoid timber volume and value being left in reserve trees in these tracts, appropriate reserve tree criteria were ignored, leading to the selection of small-diameter, sub-canopy trees. Unfortunately, these small-diameter trees did not possess the necessary attributes for two-age reserve trees. These data indicate that when the average size of the main canopy trees reaches grade-sawtimber size, some merchantability can be expected to be unavoidably retained in the reserve trees. Results from research and operational trials indicate that it is important to maintain proper reserve tree criteria and only minimize the diameter of reserve trees once other criteria have been considered.

Once the average dbh of reserve trees and their basal area has been determined, approximate reserve tree spacing can be established (Table 2). The determination of an approximate spacing is helpful in marking individually scattered reserve trees, providing field personnel with a reasonable target to assist in maintaining the proper level of retention.

Stem Form and Quality of Reserve Trees

Stem form and future tree quality and value are important criteria for reserve tree selections where

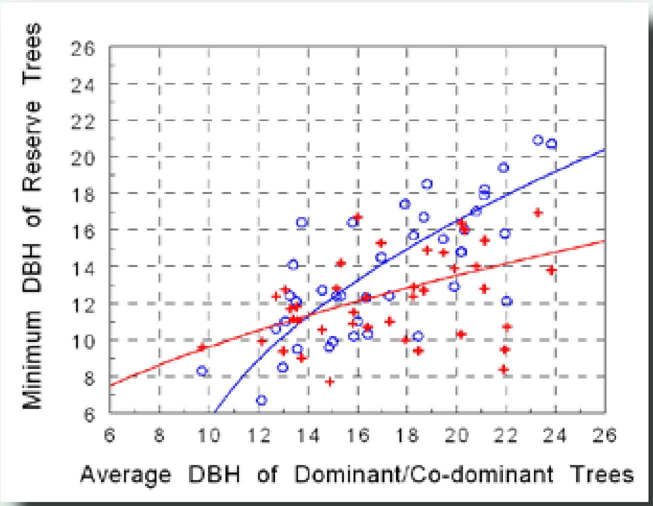

Figure 5. Comparison of average dbh of appropriate upland hardwood reserve trees (open circles and blue line) and the average dbh of inappropriate reserve trees (plus signs and red line) that were retained to avoid reduction in timber revenues with little concern to long-term reserve tree growth.

Table 2. Spacing (feet) between scattered reserve trees.

Reserve Tree DBH	Ft² Basal Area per Acre of Reserve Trees		
	10	15	20
	------------ feet ------------		
6	29	24	21
8	39	32	28
10	49	40	34
12	58	48	41
14	68	56	48
16	78	64	55
18	88	72	62
20	97	80	69
22	107	88	76
24	117	96	83
26	127	103	90
28	136	111	97
30	146	119	103

timber is an objective. Stems should be straight, free of rot and have limited defect indicators on the butt log. Typically, reserve trees should be capable of producing veneer-quality logs or high-quality sawlogs when they are ultimately harvested (potential U.S. Forest Service (USFS) tree grade =1). One of the problems associated with exposing reserve trees is a potential loss in their long-term timber quality due to the development and maintenance of mainstem branches that can degrade tree quality and value. These branches develop from epicormic buds that form epicormic branches, and if retained long enough, become large branches that can significantly degrade timber value.

Research has shown that the basal area retention recommended for deferment harvest (10 to 15 square feet of basal area per acre) provides for regeneration that quickly grows up around butt logs. The developing regeneration quickly reduces light levels near the boles of reserve trees, leading to shedding of many epicormic branches that initiate due to the harvest. It is important to remember that the epicormic branches are formed from suppressed buds that are present on the trees prior to harvest. They are defect indicators or are associated with defect indicators prior to the harvest and only become added problems when they sprout and the resulting epicormic branches remain long enough to become large branches. This results in prolonged knot formation. Upper logs are at greater risk for degrade compared to the butt logs in a deferment harvest. Regardless, it is important to understand which defect indicators harbor suppressed buds that can turn into epicormic branches and can potentially result in long-term degrade.

Table 3 provides information on defect indicators that provide a risk for epicormic branching in white and chestnut oak. Only a few of the defect indicators on the bark of these species contain suppressed buds resulting in epicormic branches. Figure 6 shows epicormic branches originating from a suppressed bud cluster on the butt log of a white oak reserve tree one year after a deferment harvest. Those marking reserve trees should understand the risks associated with epicormic branching and be able to recognize defect indicators that harbor suppressed buds in the species being marked.

Other Risk Indicators and Factors

Reserve trees should also be able to withstand stress-inducing factors such as challenges from insects, pathogens and disease complexes. While it is not possible to plan for attacks from all insects and diseases, it is prudent to plan for challenges from known problems. For example, potential defoliations by gypsy moth and endemic insects should be considered where appropriate. In some instances, crown characteristics have been shown to be associated with a trees' ability to withstand the initial front of gypsy

Figure 6. Multiple epicormic branches developed from a suppressed bud cluster on the butt log of a white oak reserve tree one year after deferment harvest.

Table 3. Butt log defect indicators, suppressed bud numbers and epicormic branching of white oak (*Quercus alba*) and chestnut oak (*Q. prinus*) reserve trees.[1]

	White Oak		Chestnut Oak	
Defect Indicator	**# Suppressed Buds**[2]	**# Epicormic Branches**[3]	**# Suppressed Buds**[2]	**# Epicormic Branches**[3]
live branch	10.02	2.50	0.00	0.00
multiple epicormic branches	9.14	1.14	0.00	0.00
single epicormic branch	7.67	1.33	0.17	0.17
suppressed bud cluster	4.73	0.95	0.28	0.09
single suppressed bud	0.04	0.01	0.00	0.00
dead branch (knot)	3.94	0.74	0.10	0.03
heavy distortion	0.12	0.03	0.00	0.00
medium distortion	0.00	0.00	0.00	0.00
light distortion	0.00	0.00	0.00	0.00
barrel swell	0.00	0.00	0.00	0.00
surface rise	0.00	0.00	0.00	0.00
bump	0.00	0.00	0.20	0.20
seam	0.00	0.00	0.00	0.00
bird peck	0.00	0.00	0.00	0.00
wound – old	0.00	0.00	0.00	0.00
wound – new	0.00	0.00	0.00	0.00

[1]Data collected from 2,340 defect indicators on 280 reserve tree butt logs on 8 tracts on the Cumberland Plateau in eastern Kentucky.
[2] # of live suppressed buds at each defect indicator
[3] # of epicormic branches produced at each defect indicator 3 years after harvest

moth invasion. These characteristics can be added to the list of reserve tree criteria. Another example is the issue of oak decline. Characteristics associated with oak decline should be included in the selection of oak reserve trees. Other factors involving wildlife considerations may need to be included in reserve tree criteria. For example, the need for bat habitat may require the retention of scaly-barked trees like shagbark hickory as reserve trees. All of these factors could alter the species of reserve tree candidates, crown condition and other reserve tree criteria.

Longevity of Reserve Trees

Longevity is an issue that must be thoroughly addressed in the selection of reserve trees. Table 4 provides a list of species, their mean operational ages and their suitability for use as reserve trees. While this list was developed from a survey of silvicultural experts in the eastern U.S., it does provide a general guideline for the appropriateness of species for consideration as reserve trees. Species that can not remain alive or maintain vigor through a second rotation length should not be considered as reserve trees. In some instances, this may preclude the use of the two-age system in stands dominated by short-lived species. It should be noted that these species might be appropriate for a deferment harvest associated with even-age management or as a part of an irregular shelterwood where they will be removed 10 to 20 years after the initial harvest.

Topographic Location of Reserve Trees

The topographic position of reserve trees can be important relative to their ability to withstand knockdown associated with harvest and/or windthrow, the most common post-harvest damage to reserve trees. Research in steep upland terrain has indicated that reserve trees, regardless of species, occurring on shallow soils or where soils are at or

Table 4. Estimated life expectancies (years) of common species in the eastern U.S.[1]

Species	Mean	Range	Species	Mean	Range
American beech	168	100-250	black walnut	131	75-200
white ash	129	80-150	sassafras	69	30-175
black cherry	115	70-175	black locust	75	15-150
bitternut hickory	133	100-150	Nuttail oak	125	80-163
mockernut hickory	127	75-175	southern white oak	127	80-150
shagbark hickory	137	80-200	pin oak	116	80-170
pignut hickory	117	60-200	water oak	130	80-200
sugar maple	162	75-225	swamp white oak	157	100-200
red maple	106	50-175	overcup oak	135	80-165
northern red oak	151	90-200	cottonwood	79	50-100
scarlet oak	105	65-150	black willow	65	40-100
black oak	129	75-200	pecan	117	60-200
chestnut oak	141	75-200	green ash	98	60-150
white oak	194	90-250	silver maple	78	50-100
cherrybark oak	139	90-200	water tupelo	123	90-175
post oak	137	70-190	baldcypress	264	150-500
bur oak	181	125-250	Virginia pine	76	40-125
sweetgum	112	80-125	shortleaf pine	110	75-150
blackgum	116	80-150	pitch pine	110	75-200
yellow-poplar	136	80-300	eastern white pine	140	75-200

[1]Ages developed from a survey of silvicultural experts in the eastern U.S. by Dr. George Hopper at the University of Tennessee, Department of Forestry, Wildlife and Fisheries

near saturation during periods of the winter are more susceptible to wind-throw.

Table 5 provides wind-throw data of more than 250 reserve trees from eight 20-acre deferment harvests. These harvests encompassed a range of topographic positions common to upland hardwood stands in the south and east. Wind-throw averaged less than 5 percent in hollows and lower slope positions and increased to 7 to 10 percent on ridges and upper slopes. The greatest wind-throw, 40 percent, was found on noses of ridges having relatively thin soils. While not indicated in the table, a high percentage of reserve trees growing directly on the banks of the exposed stream and drainage channels on these sites were also subjected to high wind-throw.

Figure 7 shows a map indicating topographic positions where post-harvest wind-throw can be significant. It should be noted that harvest knock-down associated with manual felling in steep terrain is also more prevalent on relatively shallow soils. On topographic positions that are not suitable for the retention of exposed individual reserve trees, remove all of the trees or retain reserve trees in groups on these areas.

Table 5. Post-harvest wind-throw of upland hardwood reserve trees in eastern Kentucky based on topographic position.

Topographic position	Wind-throw percent
Cove/hollow	4.34
Lower slope	5.00
Upper slope	10.31
Ridge	7.69
Nose	40.01

Harvest Damage

Operational and research experience with deferment harvests indicates that reserve trees should be clearly marked so that they can be easily seen from all sides. Marking reserve trees rather than marking cut trees saves significant time and helps ensure a reduction in reserve tree harvest damage. On relatively gentle terrain, skidding should be controlled

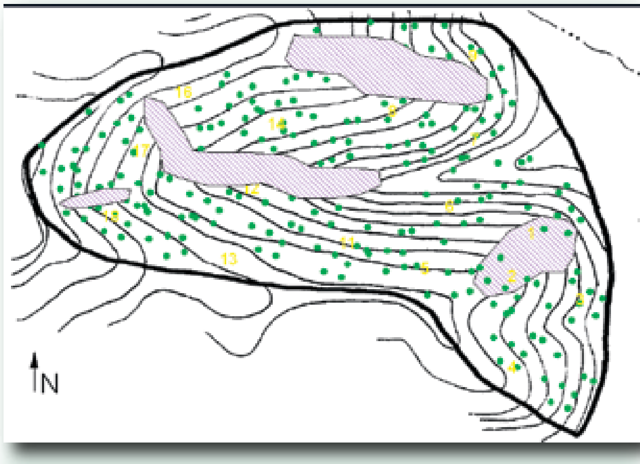

Figure 7. ***Topographic map of 30-acre deferment harvest in an upland hardwood tract in eastern Kentucky. Hatched areas indicate topographic positions associated with high wind-throw of reserve trees.***

to reduce basal wounding. In steep terrain, where manual felling is used, the majority of harvest damage will come from felling.

A recent study of harvest damage to reserve trees in two-age deferment harvesting on steeply sloping terrain in eastern Kentucky found that 78 percent of the damage was top damage, knock-down and bent-over stems from felling operations and only 22 percent of the damage was from basal wounding due to skidding. This study also found that reserve tree damage from logging firms previously engaged in clearcutting varied widely from 34 to less than 10 percent. Proper marking of reserve trees and placing a bounty on reserve tree damage in sales contracts substantially reduced damage to less than 10 percent.

The marking of reserve trees must also ensure that their location does not make their protection from harvest damage impossible. This concern is more important for harvests in steep terrain. For example, if reserve trees are marked directly down slope from large, leaning, cut trees, it may be difficult or dangerous for manual fellers to avoid reserve trees. Also, the smaller the reserve tree dbh is compared to cut tree dbh, the greater the propensity of damage to the reserves. All of these factors must be taken into account in the selection of individual reserve trees.

The season of harvest also will affect the wounding of reserve trees. Research on skidding damage of shelterwood overstory trees indicates that harvesting in the fall and winter yields significantly less wounding to residual stems compared to spring and growing-season harvests. This indicates that timing two-age deferment harvests from November through February will significantly reduce basal wounding.

Site Preparation of the Regenerating Age Class

The deferment cut will create an environment where initial stand regeneration is similar to that attained after a clearcut. Therefore, treatments to enhance natural regeneration should be prescribed. This could entail the use of a site preparation treatment to enhance natural regeneration or pre-harvest cultivation of oak advance regeneration using a midstory removal. Regardless, regeneration potentials should be considered prior to scheduling a deferment harvest. The timing of the harvest and associated site preparation treatments should be carefully considered to aid in maximizing the development of the regenerating age class.

Typically, post-harvest site preparation treatments entail the cutting of all residual commercial species other than the reserve trees and the deadening of noncommercial species. One exception to this prescription is that small-diameter residual stems shading or growing directly adjacent to reserve tree boles should be retained to shield butt logs. Also use of site preparation treatments in areas directly adjacent to reserve trees will yield little long-term value, because trees regenerating directly adjacent to reserve trees typically incur growth reductions and pronounced sweep due to overtopping effects of the reserve trees.

It is important when using herbicides in site-preparation treatments to take into consideration the species of the reserve trees. While rare, cases of significant herbicide damage have occurred to reserve trees when an extremely large number of stems of the same species or genera were being treated directly adjacent to reserve trees. Herbicide movement to reserve trees was suspected from root grafting between reserve trees and treated intermediate and overtopped crown class trees of the same species.

Expected Growth and Response of Reserve Trees

The exposed reserve trees, if selected correctly, will respond quickly to full release. Leaf area of reserve trees will increase, with a resulting increase in dbh and volume growth. While some degradation of upper logs will occur, the resulting increase in butt log diameter and value will more than offset the loss in sawlog height. Eight year post-harvest dbh measures from white oak and chestnut oak reserve trees found a doubling of annual growth for both species.

Average mean annual increment for white oak reserve trees was 0.277 inches compared to 0.118 inches for control trees. Chestnut oak responded the same as white oak, averaging 0.243 inches per year compared to 0.099 inches for control trees.

Reserve tree crowns will respond to the release as indicated by the above mentioned increases in dbh. Some species, such as northern red oak, cherrybark oak and yellow-poplar can be expected to significantly increase their horizontal crown area. Other species such as white oak will thicken and drop their crowns. Crown response indicates diameter growth increases, regardless of whether the crown increases in diameter or depth.

Use of Two-Age System for Maintaining Species at Risk

The two-age system can be used to maintain species in a stand that might be lost if even-aged or individual tree selection methods are used. This is especially true if canopy species are not properly regenerating. A widespread example is oak species on intermediate and high-quality sites. If advance regeneration is not present at the time of a regeneration harvest, then these species can be lost from the stand. This often occurs when clearcutting is used without the presence of oak advance regeneration. The two-age deferment harvest can be used to retain these species as reserve trees (where appropriate), allowing them to continue sexual reproduction and acorn production throughout the next rotation. Research has shown that properly selected reserve trees can create new advance regeneration that can be cultured prior to the second harvest, thus providing the potential for long-term maintenance of these species.

Marking Guidelines

The following guidelines are to be used in stand assessment for the two-age system and for the marking of reserve trees in deferment harvests associated with the two-age system.

1. Determine whether the two-age system is appropriate for the stand. The stand must contain species and tree ages that are capable of maintaining vigor if left for another rotation length. Stands that contain predominantly short-lived species are generally not suitable for deferment harvests or the use of the two-age system. The exception may occur when removal of a portion or all of the reserve trees associated with a deferment harvest is planned. In these instances, reserve trees that will be removed relatively soon after the harvest may be shorter-lived. However, reserve trees that will be retained until the end of the second rotation length must be long-lived (Table 4).

2. Delineate topographic positions that are not suited for the retention of reserve trees. These generally include areas with shallow soils or with other soil conditions that would lead to windthrow or knock-down during harvest. In these areas, mark all the trees for removal or leave reserve trees in groups (Figure 7 and Table 5).

3. Determine the average dbh of dominant and co-dominant trees in the stand and establish appropriate target diameters for reserve trees (Figure 4).

4. Determine spatial distribution of reserve trees. If left scattered throughout the stand, determine an approximate spacing of reserve trees given retention basal area (10 to 15 square feet of basal area per acre for long-term reserve trees). If reserve trees are to be grouped, determine the size of the groups (Table 2).

5. Based on objectives, determine other criteria for reserve trees of appropriate diameter including species, crown shape, lcr, stem form, defect indicators and other characteristics associated with management objectives. This coupled with the dbh guideline developed in step 3 provides individual tree marking guidelines for the stand.

6. Using the information from steps 1 through 5, mark reserve trees so they can easily be seen from all sides.

7. Do not mark reserve trees where they are likely to be unavoidably damaged during the harvest.

8. Specify harvest timing to avoid bark damage either due to felling or basal wounding attributable to skidding.

9. Provide incentives for reserve tree protection in harvest contracts. Harvests, regardless of terrain or harvest system, should damage less than 10 percent of the reserve trees. It is useful to specify a monetary penalty for reserve tree damage above this level.

10. Develop a site preparation prescription for the regenerating age class where appropriate. This could entail the use of post- or pre-harvest site preparation or the use of the oak shelterwood treatment where improvement of oak advance regeneration is required prior to a regeneration harvest.

Summary

The two-age system is a viable system for managing many hardwood stands where longer-lived species are present. The deferment harvest used to initiate the system can provide for vigorous and dense regeneration of the stand, while the carefully selected reserve trees provide a potential for large-diameter, high-quality timber production. The system can also be used as an aesthetic alternative to clearcutting and can provide long-term stand structural components that are often not present with even-age methods. These structural components can benefit wildlife populations and provide old-growth characteristics in the stands. Regardless, proper selection of the two-age reserve trees and appropriate site preparation treatments associated with the deferment harvest are critical to maximizing benefits from this system.

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Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Oak Shelterwood: A Technique to Improve Oak Regeneration

(University of Tennessee Extension SP 676)

UT Extension
SP676

Professional Hardwood Notes
Technical Information on Hardwood Silviculture for Foresters

Oak Shelterwood: A Technique to Improve Oak Regeneration

Jeff Stringer, Extension Professor of Hardwood Silviculture, Department of Forestry, University of Kentucky

The oak shelterwood method has been developed to enhance the regeneration potential of oaks growing on intermediate and high-quality sites. The method involves a well-timed mid-story removal to improve the number and vigor of oak advance regeneration and a subsequent overstory removal to facilitate regeneration of the stand (Figure 1).

Oak Regeneration Dynamics

Successful regeneration of oak on intermediate and high-quality sites (upland oak site index > 65 to 70 feet) is limited due to the lack of the vigorous advance regeneration and/or saplings/pole-sized trees that are capable of sprouting. Vigorous advance regeneration and/or stump sprouters are required at the time of regeneration on intermediate and high-quality sites, due to the abundance of competing species. Oak advance regeneration that is small in stature and low in vigor can quickly become overtopped by co-occurring species after a regeneration event. On poorer-quality sites, oaks are subjected to less competition, and often contain an adequate pool of advance regeneration or trees that are capable of sprouting.

In many instances, oak stands on intermediate and high-quality sites contain well-developed, mid- and under-stories of shade-tolerant species typically composed of red maple, sugar maple and American beech. This stand structure leads to light levels at

Untreated with well-developed mid-story.

First growing season after mid-story removal.

Figure 1. Oak shelterwood method and the implementation of the mid-story removal treatment in a typical upland oak stand.

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the forest floor that are not sufficient to provide for the long-term growth and development of oak advance regeneration. When a cohort of new seedlings is established under an intact canopy with a well-developed mid-story, the cohort languishes. The seedlings peak in height growth between 6 inches and 2 feet and mortality quickly reduces numbers. Ultimately, their ability to respond to increased light levels from a canopy disturbance is limited or non-existent.

The more shade-intolerant the species of oak, the more pronounced the effect. Figure 2 shows the height growth and survival of a cohort of northern red oak, one of the most shade-intolerant oaks, which has established and grown under an intact canopy on a high-quality site. After 10 years, only 10 percent of the original cohort is left, with an average height of less than 1 foot. Figure 3 shows similar height growth development for white oak, one of the most shade-tolerant oaks, on an intermediate-quality site. Both of these indicate that under undisturbed canopies with well-developed mid- and under-stories, the cohort establishes, grows negligibly in height and over time dies off. This process repeats itself throughout the life of the forest unless a disturbance occurs at the right time to break the cycle.

Basics of the Oak Shelterwood Method

The oak shelterwood method has been developed to culture vigorous oak advance regeneration. It accomplishes this through a well-timed mid-story removal, improving light levels for adequate oak advance regeneration development, followed by a canopy release after the advance regeneration has reached a height where it can compete successfully with co-occurring species. The basic science behind the oak shelterwood method is well-documented. While species- and site-specific information for this method is under development, enough is known that recommendations can be made regarding its use in many oak-dominated stands.

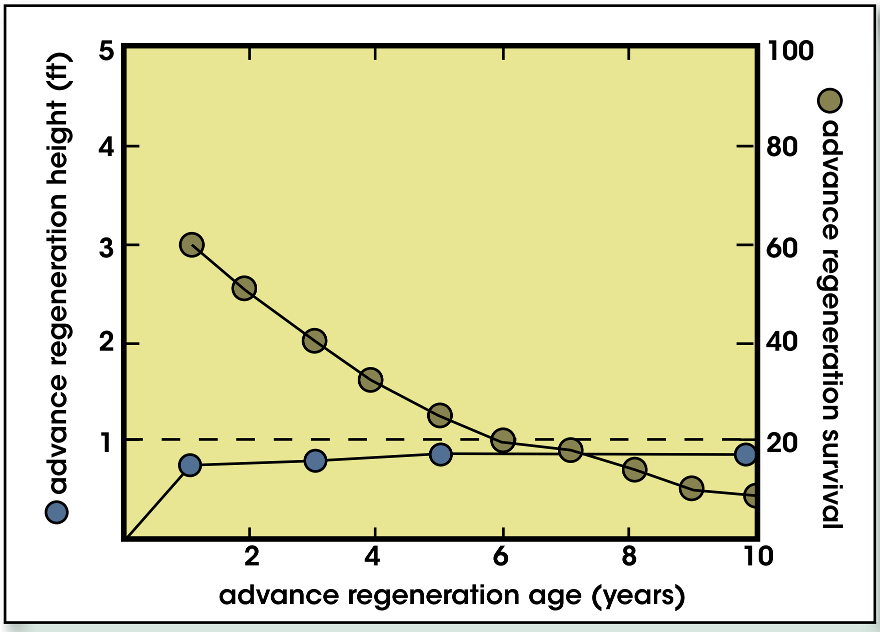

Figure 2. Northern red oak advance regeneration cohort height growth and survival under a typical mid-story on a mesic site.

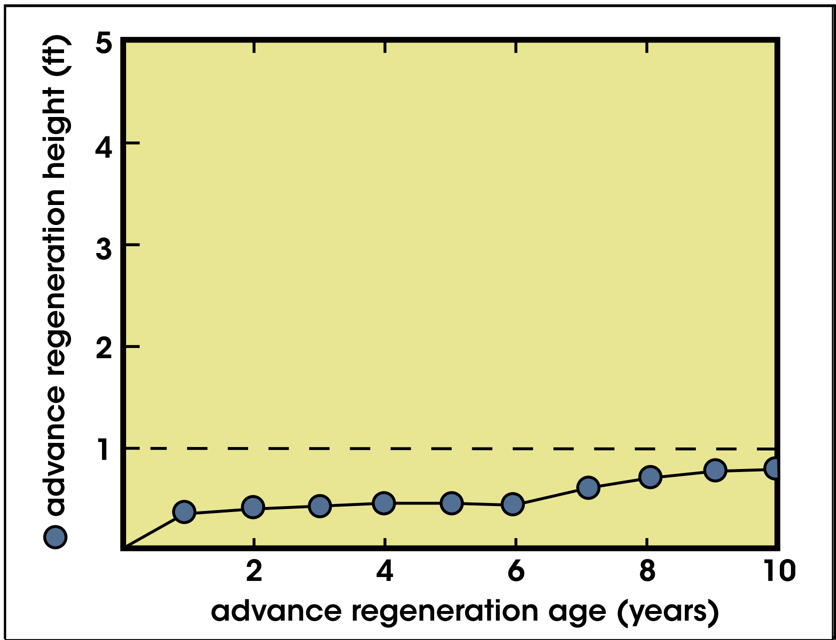

Figure 3. Height of white oak advance regeneration growing under a typical red maple mid-story.

The methods concept is simple. After the initial establishment of a cohort of oak seedlings, the mid- and under-stories are removed using herbicides. Typically, approximately 20 percent of the total stand basal area is removed, starting from the smallest trees that can be operationally treated (typically ½ to 1 inch dbh) increasing in diameter but stopping short of removing trees that would open holes in the main canopy. The removal of leaf area close to the ground without opening up the canopy increases diffuse light levels to a point where the newly established seedlings are not severely suppressed and can maintain continued height growth. Survival of the cohort will also improve.

It is important to note that opening the canopy can easily allow for sufficient amounts of direct sunlight to reach the forest floor, spawning the regeneration of many co-occurring species. Many of these species can quickly overtop small oak advance regeneration and lead to their demise. Therefore, it is imperative that the mid-story removal is aimed at increasing diffuse light levels and minimizing main canopy openings.

The ultimate aim of the mid-story treatment is to provide for an adequate number of high-vigor oak advance regeneration that can successfully compete when the overstory is finally removed. If the numbers and size of advance regeneration are sufficient, site preparation treatments at the time of overstory removal will not be required.

Figure 4. Suppressed oak advance regeneration.

Vigor of Advance Oak Regeneration

Vigor, as used in the context of the oak shelterwood method, describes the ability of the advance regeneration to respond quickly in height growth at the time of its full release, typically associated with some type of regeneration harvest. While all aspects of vigor are not thoroughly understood, vigorous advance regeneration is typically indicated by height and stem diameter and form. In turn, these provide clues to the strength of the root system that is a function of its size and available carbohydrate supply. Ultimately, it is this factor that has much to do with the success of advance regeneration upon full release.

While it is true that the sprouting nature of oak can lead to root systems that are older and can be much larger than indicated by the top, there is a general relationship between height, root mass and root carbohydrate stores for a young developing cohort of oak seedlings. As a cohort languishes under a dense mid-story, root carbohydrate reserves are reduced and stems lose apical dominance. Figure 4 shows an advanced regeneration white oak that has been suppressed under a red maple mid-story for 14 years. It is less than 2 feet in height and has lost apical dominance.

The key to the mid-story removal is to implement it directly after seedlings are established and to provide seedlings with enough light to generate root systems stocked with carbohydrates, allowing them to maintain apical dominance. The vigorous root system is especially necessary to ensure good sprouting if the stem is severed during a regeneration event. Even if the stem remains intact after a regeneration event, the crown must quickly develop a main leader and the root system must be well-developed to allow the advance regeneration stem to rapidly increase in height. At a minimum, oak advance regeneration stems should be 3 to 4 feet tall. It is also helpful if the oak advance regeneration possesses apical dominance. However, this latter attribute can be overcome if the root system is vigorous enough.

Which Stands Can Benefit

The system has been developed for stands that currently have oak-dominated overstories on intermediate to high-quality sites (site index > 65 to 70 feet for upland oak). Generally, these are bottomland sites with well-drained, silty loam soils. Upland high-quality sites are found in coves and north or northeast slopes with significant A horizons. Intermediate-quality sites are common on upper east- and lower south- and southeast-facing slopes. When site indices drop below 65 feet on upland sites, oaks are generally capable of regenerating themselves. This is because these stands carry less leaf area and the under-stories are generally higher in diffuse lighting, allowing for the development of vigorous advance regeneration. Also, poorer-quality sites have less vigorous competition from co-occurring species.

On sites above 65 to 70 feet site index, mid-stories are much more developed, limiting advance regeneration growth. Also, the challenge from co-occurring species can be significant upon full-canopy release. Bottomland sites are highly variable and may or may not contain well-developed mid-stories. When mid-stories are present, these stands can benefit from the oak shelterwood treatment.

Typically, this system has been used in stands where the overstory has the potential to provide adequate acorn crops of appropriate oak species and develop advance regeneration. However, when oak advance regeneration is lacking, this system has the potential to be used with underplantings of oak seedlings. Oak seedlings can be planted directly after the mid-story treatment and have been shown to respond well to mid-story removal. The overstory should be removed after the seedlings have acclimated to the environment and obtained heights of at least 6 feet.

There may be stands where the oak advance regeneration occurs in groups or clumps. In these cases, implementation of the mid-story removal treatment should only occur in and around the areas where the oak regeneration exists. It should be noted that there may be reasons to treat all unwanted mid-story species throughout the stand, even in areas where no advance regeneration is present. This could be done to remove or reduce unwanted species and might be advantageous for long-term management and reducing the need for a site preparation treatment in association with a regeneration event.

Timing of the Treatments

This system was designed to be implemented when oak advance regeneration is present. Implementing the mid-story removal prior to the establishment of an oak cohort is risky. If abundant numbers of seedlings are not established within a year or two after the mid-story removal, the advance regeneration of shade-tolerant species (typically present in most oak-dominated stands) will respond to the treatment, and oaks that establish themselves after the treatment will be in jeopardy. Recent studies also indicate that implementing the mid-story removal when the seedlings have been suppressed for several years may severely limit their ability to respond quickly to the treatment. These studies indicate that the seedlings lose vigor quickly. When provided improved diffuse lighting from the mid-story removal, it takes several years for the seedling to respond with detectable height and diameter growth. Generally, the longer the period of suppression of individual cohorts of seedlings, the smaller their numbers, the less vigor they have and the longer they take to respond, if at all.

Implementation of the Oak Shelterwood Method

Step 1. Candidate Stands

Implementation of this method should start with the identification of stands that could benefit from the method. Selection criteria include:

- intermediate to high-quality sites (> 65 to 70 feet site index for upland oak, or the equivalent),
- co-dominant and dominant oaks present (unless underplanting is possible)
- management objectives require maintenance of an oak component
- requiring regeneration now or in the near future

Step 2. Determining Oak Regeneration Potential of Candidate Stands

Once candidate stands have been defined, they should be scouted for their oak regeneration potential. Regeneration targets for maintenance of an oak-dominated canopy typically require a minimum of 50 to 100 dominant or co-dominant oaks at the time of canopy closure after a regeneration event (typically 10 to 15 years after regeneration). This requires that stands contain, prior to a regeneration event, advance regeneration at least 3 to 4 feet tall or sapling/pole oak stems that have the ability to stump sprout. The latter should be trees less than 10 inches in diameter and 65 years old for white oaks and 35 years old for red oaks.

Due to differences in competition pressure and condition of the advance regeneration, it is difficult to determine the exact number of advance regeneration stems per acre that are required to successfully regenerate an oak-dominated stand. However, if advance regeneration is non-existent or less than 2 feet tall (regardless of the numbers), then the stand is lacking in oak regeneration potential and the oak shelterwood method could be employed to improve this condition. If there are less than 100 advance oak regeneration greater than 3 to 4 feet in height and/or stump sprouters per acre (normally 100 to150 per acre), then some successful oak regeneration can be expected. Use of the oak shelterwood method in these stands would improve the oak percentage in the regenerating canopy. If stands contain the proper advance regeneration pool and/or adequate stump sprouters, then a regeneration harvest can be scheduled immediately and the oak shelterwood method is not required.

As indicated previously, this system could also be used with artificial regeneration. This would involve the underplanting of seedlings prior to a regeneration event and the oak shelterwood method used to improve their vigor prior to a regeneration harvest. Research has indicated that bare-root seedlings cultured in this fashion do have the ability to positively respond to the system.

Step 3. Timing the Mid-Story Removal

Proper timing of the mid-story removal is important for the overall success of this method. If an abundant acorn crop in the last several years has generated a large number of seedlings that still have apical dominance, then the mid-story removal treatment should be implemented as soon as possible (see below). If the seedlings are few in number, are extremely small (≤ 2 foot in height) with the majority of them having

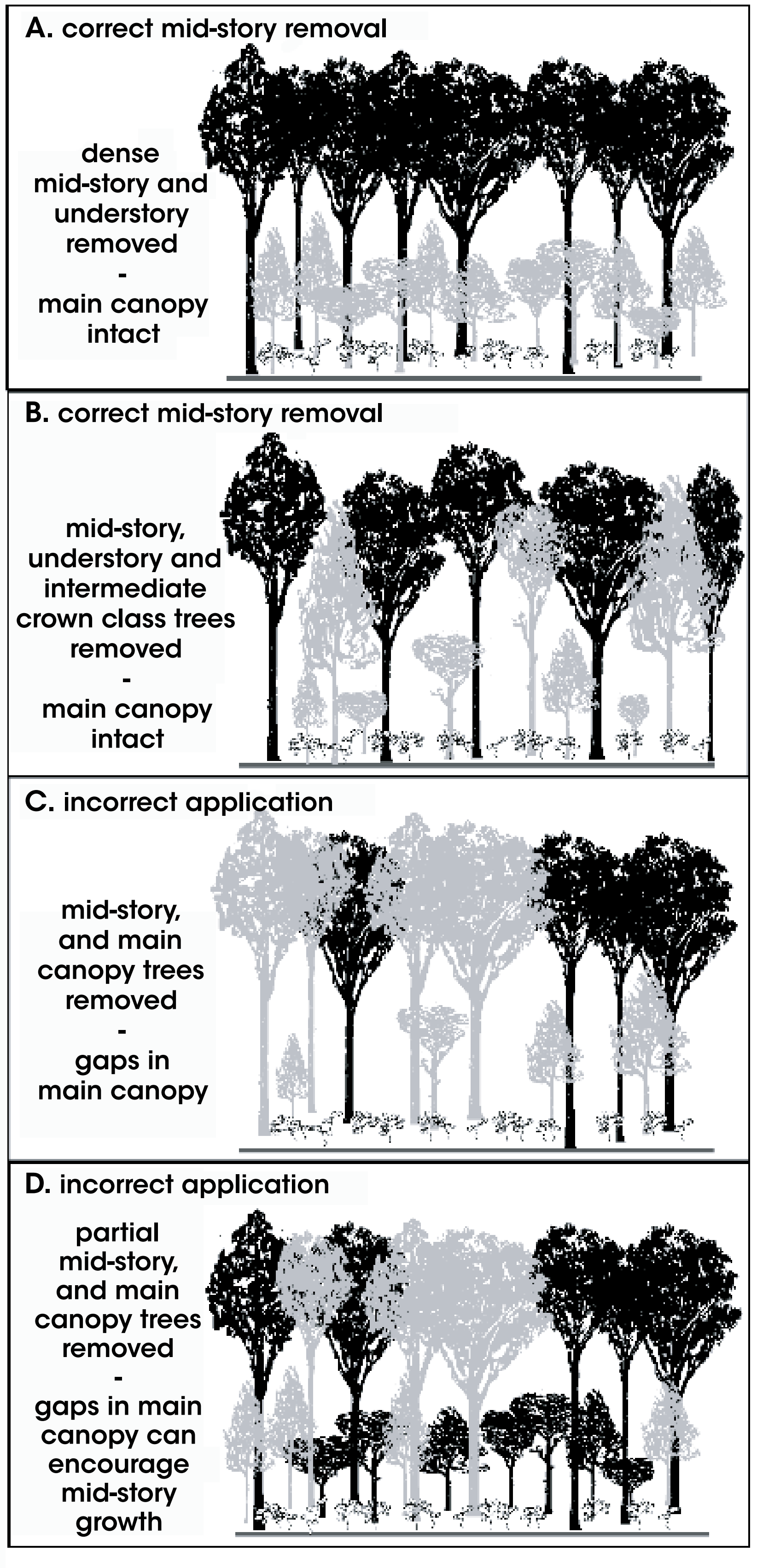

Figure 5. Correct and incorrect application of mid-story removal.

lost apical dominance, then the mid-story removal should be delayed until an abundant acorn crop produces a new cohort. The small, poorly formed advance regeneration present may not be capable of a reasonable response to the mid-story treatment, and waiting for a new cohort to develop may be required. Once a cohort of seedlings has established, implement the mid-story removal.

As a general recommendation, if there is no advance regeneration present, do not attempt the mid-story removal. There are two reasons for this. First, there is no evidence that implementing the treatment will improve oak seedling establishment. Second, the improved light conditions from the mid-story removal will stimulate the advance regeneration of competing species if present. Even if a good acorn crop occurs several years after a pre-emptive mid-story removal, the newly established cohort may be significantly behind in height growth, ultimately leading to its demise.

It is important to note that under conditions where there is no competing advance regeneration and there is reason to expect a reasonable mast crop in the next year or two, the pre-emptive mid-story removal might prove beneficial. However, caution should be exercised in implementing the mid-story removal prior to establishment of oak advance regeneration. The only other situation that would reasonably allow for a mid-story removal without the presence of advance regeneration is if oak is artificially established in the stand. This is typically accomplished using 1-0 or 2-0 bare-root seedlings.

Step 4. Implementing the Mid-Story Removal

The objective of the treatment is to remove the mid-story and understory to provide a significant increase in diffuse lighting without opening up the main canopy. Typically, a target removal of approximately 20 percent of the stand basal area should be planned. While determining the basal area removal is good for planning purposes, typically the treatment is implemented by removing sub-canopy trees, starting with the smallest trees that can be treated. Begin with the smallest, and move up in size but stop short of removing co-dominant or dominant trees (Figure 5).

In some stands, the under- and mid-story may all be overtopped crown class trees and they can be completely removed (Figure 5a). In some cases, the under- and mid-story trees may include overtopped and intermediate crown class trees. Removal of intermediate crown class trees can occur as long as co-dominant or dominant crown-sized gaps are not created (Figure 5b). Figures 5c and 5d show cases where main canopy openings were created, allowing direct radiation to enter the forest. Figure 5d shows a mid-story that was left intact coupled with openings in the main canopy. Under these conditions, the remaining mid-story trees will flourish and increase their leaf area and crown size, further decreasing light levels on the ground.

In almost all cases, the under- and mid-story trees should be treated with herbicides. Simply cutting shade-tolerant under- and mid-story trees will lead to sprouting and cause a greater shade problem for advance oak regeneration than if they had been left standing as single stems. Using herbicides ensures the elimination or significant reduction of competing species and also has the added bonus of removing or reducing the seed source of competing species from the stand. Because oak advance regeneration can not be harmed, individual tree treatments must be used. Methods usually include tree injection, hack and squirt, or basal bark application. Selection of herbicides is generally not critical. However, there have been instances where a significant number of trees per acre have been treated with herbicides with soil activity and some effects on the advance regeneration pool have been observed. Conduct the mid-story removal during the season that is most appropriate for the herbicide treatment prescribed.

Step 5. Monitoring the Advance Regeneration

In the years after the mid-story removal, inspect the stand to ensure that the oak advance regeneration is progressing in growth and to determine if any competition problems have arisen. If there is a seed source of shade-tolerant species in the area, then new advance regeneration of these competing species may establish. These can be taken care of as appropriate through a follow-up herbicide treatment.

Unfortunately, oak seedlings may take some time to respond to the treatment. Response may occur the first year or two after the treatment, especially if the seedlings are of a fast-growing species, are young and exhibiting good apical dominance, and are growing on a good-quality site. Examples of these species and sites would be northern red oak on mesic upland sites or cherrybark oak on bottomland alluvial sites. It may take several years for a slower-growing species such as white oak on an intermediate-quality site to respond.

Step 6. Full Release

The timing of the final release treatment, usually a regeneration harvest, should coincide with the oak advance regeneration attaining a height of 3 to 4 feet or more, the taller the better. The more intense the competition is estimated to be upon release, the larger the advance regeneration should be. Once the advance regeneration has reached the appropriate size, the overstory can be removed by the most appropriate regeneration harvest. Complete clearcuts, patch clearcuts or group openings are generally recommended. Regardless of regeneration harvest, make sure that enough overstory is removed to ensure vigorous regeneration response. If necessary, a site preparation treatment for natural regeneration can be employed to aid in regeneration success. However, successful implementation of the oak shelterwood treatment would negate the need for this treatment.

Other Considerations

There is evidence that oak advance regeneration that has been suppressed for a number of years can respond positively to coppicing. This allows for the root system to produce a top with apical dominance and possibly in better balance with the root system. However, thorough testing of this technique has not been conducted.

The role of prescribed fire in the oak shelterwood method is also a question. Prescribed fire can be used to top-prune poorly formed advance regeneration. However, the intensity of prescribed fire that could be used would only top kill under- and mid-story shade-tolerant trees, resulting in significant sprouting and ultimate interference with oak advance regeneration development. It is possible to combine a prescribed fire with herbicides (either pre- or post-fire treatment). However, the results of this method of competition control have not been thoroughly tested. There have been instances where prescribed fire has been used to successfully remove competing species that were shade-intolerant (ex. yellow-poplar) or where the shade-tolerant competition was newly established from seed. Regardless, prescribed fire might have potential to use in this method, but the risks, benefits and the specific stand and competition conditions must be closely evaluated.

Summary

The oak shelterwood method is a useful tool to help improve the ability of oak to regenerate. Proper timing and implementation are critical for the effective use of this method. Application steps include:

- Determination of appropriate stands based on site quality, oak dominance and oak regeneration potential
- Proper timing of the mid-story removal treatment to ensure that oak advance regeneration is present prior to implementation
- Proper removal of under- and mid-story trees so as not to open the main canopy and to kill treated trees
- Implementation of the final regeneration harvest after the advance regeneration has reached adequate size.

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Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Southern Hardwood Management

(USDA Forest Service Southern Region Management Bulletin, R8-MB 67, March 1994)

Southern Hardwood Management

Cooperative Extension
Services

Southern Region

United States
Department of Agriculture

Forest Service
Southern Region

Management Bulletin
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Preface

Hardwood forests represent an extremely diverse and valuable assemblage of species. To some, hardwood management is a confusing and difficult concept to grasp. Unfortunately, past harvests in many hardwood stands removed only the best quality stems of a few select species, leaving poor quality often less desirable species in the wake. Because of past practices in many hardwood stands, some may not believe that hardwood forests can be properly managed for pulp, lumber, water quality, aesthetics, wildlife habitat, and a host of other amenities. We hope this publication will serve to expand the private forest landowners' horizon to the possibilities of hardwood management. We have assembled chapters on the various hardwood forest types found across the South. Other chapters address management practices designed to regenerate and maintain stand and site quality, plus many other benefits.

As more demands are placed on hardwood resources, chapters 18 and 19, which deal with water management regulations and wildlife considerations, will be of special interest to many landowners. Incentive programs such as the Conservation Reserve Program, and Forest Stewardship, have great promise in advancing the active management of hardwood resources.

Acknowledgments

This publication is the result of a collaborative effort by extension forestry specialists and the USDA-Forest Service, Southern Region. Authors of each chapter were chosen for their subject matter expertise. The editors wish to thank those involved in this project for their contributions. Special notes of thanks go to Daniel Sims, USDA Forest Service, retired, and James E. Neal, Southern Regional Extension Forester, retired, for their steadfast help in shepherding this project along and obtaining funds for publication, and to Patsy Boone for her effort in preparing the final copy of this manuscript.

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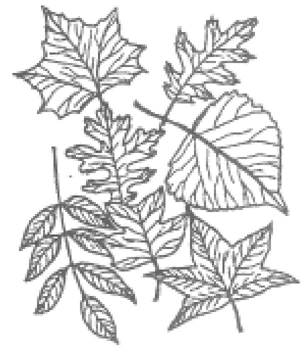

1. Southern Hardwood Management: Make Every Acre Work

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Within the management of forest resources, few endeavors carry such potential as the silviculture and use of hardwood trees. Those broadleaved trees (and cypress) of the southeastern forests can produce tremendous numbers of distinct, valuable and unique values. Managing hardwood forests is challenging and rewarding. From the bottomland forest of the river edge swamp to the ridge lines of the mountains (and all the land between), hardwood tree species provide a host of products.

As with any natural resources, there are always opportunities to better manage for value production. Whether you want increased recreational opportunities, screening, firewood, birdwatching, hunting, pulpwood, water, aesthetics, mushrooms, or lumber, careful management of your hardwood resources can help you generate these values. Professional foresters along with your clear management objectives can create almost any combination of values you want.

There are several interesting features of hardwood tree management. The first -is the diversity of species usually present in any forest. Hardwoods, like pines, can be effectively farmed as plantations to produce any forest product desired. Many times, plantations of hardwood trees may not economically produce the products you want. Multiple-species forests with many trees of different ages are usually what most people think of when hardwood forests are mentioned.

The great diversity of species within a hardwood forest system can all be part of some management objective. From the wildlife benefits from food and cover to the specialty wood market, a number of trees play limited and unique roles in the life of the woods. The small, medium, and large-sized trees all play a role in the beauty and utilization of the hardwood forests. These different kinds of trees can also support portions of your present and future management plans.

As you walk in your woods you may start to notice that what at first looked like tremendous diversity from the road is actually clumps, groups, and limited mixtures of trees. Site differences such as slope, moisture, aspect toward the sun, and soil depth all can change the complexion of the hardwood forest. On some sites you may only find one or two of the most welladapted and successful trees present. Other sites may have multiple layers of many species.

The clumps and groupings you find in hardwood forests is primarily the result of trees reproducing in the local areas. You could consider these stands of trees "family" groups. Some reproduction strategies result in widespread trees of the same species over a hillside or clumps of trees in small pockets.

An important feature of hardwood forests is that they reproduce from both seeds and from stump and root sprouts. Many times, this means that once a tree becomes established, sprouts can keep that species of tree present for many years. Many hardwood management practices use sprouting to reproduce a hardwood forest of a desired species at a low cost.

Another aspect of hardwood forest diversity that can be valuable for producing a number of different products is the number of trees per acre. Depending upon your management objective, perhaps 75 crop trees are all you will harvest. Clearing the rest of the trees is not cost effective and can lead to damage of the crop trees. Noncrop trees are valuable for their nurse crop role and other values.

Many management systems employ natural successional patterns to reach landowner objectives. Succession of one species or set of species by other species is part of our natural heritage. These natural patterns of forest change can be used to produce your objective -- whether it's an increase in wildlife, timber, or other goals. At the same time, these changing patterns can help protect your forest from pests and loss of productivity.

A complex natural system is difficult to perfectly organize for production of a single product. Small changes in tree regeneration or in pest cycles can initiate major shifts in the mixture of ages, species, and health of your trees as well as other changes in the composition and value of your forest, over time. Working with what is available, enriching production potential, and patient, 'knowledgeable and objective-driven management can help you reach your goals for a specific hardwood site. Contact a professional forester to help you develop a management plan for your forest. (See chapter 21.)

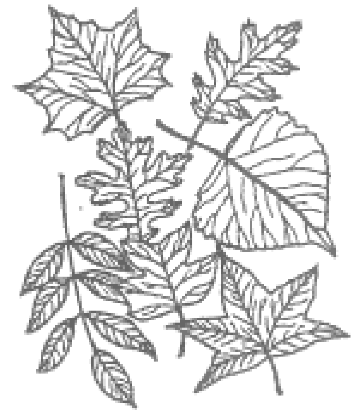
Hardwood management is easy -- but it's a long cycle. While you cannot master hardwood forest management in a lifetime, you can easily produce some valuable products while e4oying the wildlife, scenic vistas, and other natural resources. Land ownership has great privileges. It also carries with it some major responsibilities. Living things constantly change with continual shifting of product mixes. Being a good steward of the land means keeping the system healthy and productive.

Hardwood management is fun. If you have a small woodlot or a large acreage, working with a complex and ancient forest system is enjoyable. The things and stories you can find in the woods surpass the best books or television mini-series. Family traditions, summer work, chores, or small business all can be tied to your hardwood resource. Reasonable and timely inputs to your hardwood forests can more than repay the investment.

Hardwood management is profitable. Profit can be calculated many ways for many different products. In a world where natural resources are becoming rarer, populations are increasing and a world market is developing for many products, values from the basic soil and forest production unit will increase. Future market potentials may he with fee hunting and urban firewood, pulpwood and water quality protection or Shitake mushrooms and acorns, but the productivity and health of the hardwood forest will remain of value.

Hardwood forests occupy a large acreage across the South. The potential values of most have not been realized. Through proper and conscientious management you can turn that "wasteland, weedy brush, worthless slope, tree junk and swamp" into productive acres without massive time and money investments. Make every acre work for you while you enjoy the values that hardwoods can bring.

2. Hardwood Site and Stand Inventory



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SITE EVALUATION

A particular forest site is defined as an area relatively uniform in its capacity to grow trees, characterized by interacting combinations of plant and animal life, climate, landform, and soil conditions.

The success or failure of a forest management plan depends on correct evaluation of forest sites, and sound judgement in fitting species to site to meet landowner objectives. This is especially true for the more site-sensitive hardwoods.

Quality of the site will dictate to a large extent: species composition; ease or difficulty of getting desired regeneration; cultural practices; and ultimately, growth and yield of the stand.

Generally, hardwoods grow best in deep (60 inches or more), moist, medium-textured (loamy) soils. They have a well-developed layer of topsoil more than 6 inches deep. These soils are adequately drained (no mottling), with moisture-retaining subsoils (no mottling). These soils occur most often along stream and river bottoms within the Piedmont and Coastal Plain, upland coves, and lower slopes and benches, especially on north and east exposures in the uplands.

Site quality is often more variable in the mountains. Here, topography features such as elevation, aspect and slope steepness, slope position, length and shape, strongly influence site quality.

Characteristics of Good Hardwood Sites:

* Well-drained stream and river bottoms (with alluvial soil);
* Mountain coves and gulfs; Benches (natural terrace formations on side slopes);
* Mid and lower slopes facing north or east;
* Lower slopes facing northwest or southeast;
* Gradual/concave slopes.

Characteristics of Good Soils

* More than 3 feet deep, with a well-developed layer of top soil;
* Medium-textured loams (little or no heavy clays or deep sands);
* Moist, well-drained topsoil with moisture-holding subsoil;
* Less than 65 percent rock content.

Characteristics of Poor Hardwood

* Sites Upland ridges (especially narrow ridges);
* Upper and mid-slope facing south, southwest, west;
* Steep/convex slopes;
* Poorly drained or excessively drained sites.

Characteristics of Poor Soils

* Shallow (less than 24 inches to bedrock);
* More than 65 percent rock or gravel;
* Poorly drained, or excessively drained soils (often organic soils or deep sands);
* Excessively high clay or sand levels in upper soil layers;
* Hardpan or impermeable layer near surface.

Methods to Determine Site Quality

1. Direct Determination of Site Index

Site index (SI) is expressed as the height in feet of a dominant, free-to-grow tree of a particular species in a 50-year growth period. Example: A 50-year-old yellow-poplar that has been in a free--to-grow dominant or co-dominant crown position within the stand throughout its life is 100 feet tall. The site index for yellow-poplar on this site = 100 SI (50).

Site index is the most common method used to determine site quality. It is accurate and simple to use when: (a) suitable trees are available for the required height and the age measurement and, W when accurate site index curves are available.

Suitable site index trees must be:
--Free to grow, dominant or co-dominant crown position;
--Free of past suppression or top breakage.

Such trees are most commonly found in well-stocked, even-aged stands, undisturbed by past cutting and preferably 40 to 60 years old.

Unfortunately, direct site-index determination is not reliable in many degraded hardwood stands that no longer represent true potential for the site. Reliable site-index trees are often hard to find in stands logged poorly by high-grading, or damaged by fire, grazing, ice or snow. Poorly stocked, uneven-aged stands or stands where desired species are not present are also poor candidates for direct site-index measurement. Some species are better suited to direct site-index determination. Intolerant species with single, well defined leaders and ring porous hardwoods with distinct annual rings such as oak, ash, and yellow-poplar are well suited.

The following site-index ranges for upland oaks (base age 50 years) indicate site quality.

WEST OF THE MISSISSIPPI RIVER

Site	Red Oak	White Oak
Good	SI more than 70	SI more than 65
Medium	SI 55 to 70	SI 50 to 65
Poor	SI less than 55	SI less than 50

EAST OF THE MISSISSIPPI RIVER

Site	Red and white oaks
Good	SI more than 80
Medium	SI 65 to 80
Poor	SI less than 65

Bottomland site ranges in the South will be about 10 points higher than for upland sites east of the Mississippi.

2. Volume

Site productivity can be ranked according to growth in cubic feet per acre per year.

85+	cubic feet/acre/year	Good
50-85	" " " "	Medium
20-50	" " " "	Poor

This alone is impractical for most hardwood stands because of lack of growth-and-yield information.

3. Soil Series

Soil series (soil mapping unit) descriptions have been prepared by the Soil Conservation Service (SCS). They list preferred species and site-index estimates. However, much of the forest land has not been soil mapped and soil series alone does not account for all factors.

4. Indicator Plants and Experience Factors

Certain plants, especially lesser understory plants, are so sensitive to site quality that their presence or absence, or relative abundance may serve to classify site quality. Understory vegetation can be affected by species and stocking conditions of the overstory and by forest history. Being able to "read the site" includes taking note of indicator shrub and herb vegetation and effects of past land-use.

Examples Of Indicator Plants

Good Sites	Poor Sites
Wild hydrangea	Vaccinium. species (blueberry)
False Solomons-seal	
Trillium	Scrub oak (Post, Blackjack)
Wild geranium	
Broadleaf sedge	Pitcher plant
Pawpaw	
Wild ginger	
Beech	

5. Indirect Methods

Possibly the most accurate methods of assessing hardwood site quality involves e factors other than the growth and condition of current vegetation. Researchers are deve practical methods for estimating site quality based on factors such as landform, climate, soil condition, past use and other environmental effects. These methods accurately assess site quality without relying on the type and condition of the vegetation that happens to occupy the site at any given time.

Tables 2-1 to 2-3 show how environmental factors are used to determine site suitability for various species and species mixtures.

Table 2-1. Site guide for Coastal Plain.

LANDSCAPE CHARACTERS			MANAGEMENT TYPE	
Landform	Moisture Regime	Soil Texture	Preferred	Suitable
Flood plains, stream, terraces, and alluvial fans.	Wet	Fine	Hardwoods: ash, gum, w/w oaks, & cypress	
	Moist	Fine to medium	Oaks, cherrybark, Nuttall, Shumard, etc. Cottonwood, ash, sycamore, sweetgum	Hardwood/pine mixtures (loblolly)
Upland	Wet	All	Hardwoods: w/w oaks, gum	Pine: loblolly, slash
	Moist	Medium	Pine, loblolly	Pine/hardwood mixtures
		Fine	Pine: loblolly, slash	Pine: shortleaf
(Mostly Ridges)	Dry	All inc. coarse, gravelly & cobbly	Pine: longleaf, shortleaf, sand	Pine: loblolly
		Severely eroded	Pine: loblolly	

Table 2-2. Site guide for mountains.

LANDSCAPE CHARACTERS			MANAGEMENT TYPE	
Landform	Moisture Regime	Texture	Preferred	Suitable
Coves, alluvial fans, stream terraces, flood plains	Moist	Medium	Hardwoods: yellow-poplar, oaks, walnut, sycamore	
	Wet	Fine	Hardwoods: ash, sweetgum, birch, w/w oaks	

Landform	Soil Depth[1]	Moisture Regime	Texture	Preferred	Suitable
Ridges Less than 20 percent slope	Deep More than 30 inches to bedrock or hardpan	Moist[5]	Fine-Medium	Hardwoods: oaks, yellow-poplar, ash	Pine[2]: Loblolly, shortleaf, white[7], P/H mixtures
		Dry[6]	Coarse	Pine: shortleaf, white	
	Shallow Less than 30 inches to bedrock or hardpan	Moist[5]	Fine to Medium	Pine: white[3], shortleaf	Pine, Virginia
		Dry[5,6]	Medium Coarse	Pine, Virginia	Pine[7], white
		Droughty[5,6]	Coarse to Skeletal	Pine, Virginia	

Land-form	Aspect	Soil Depth[1]	Slope %	Slope Position[4]	Texture	Preferred	Suitable
Side Slopes	Northerly	Deep	All	All	All	Hardwoods: oaks, yellow-poplar, ash, basswood, walnut	
		Shallow	All	U	All	Pine: shortleaf, loblolly	Pine[7], white
				L	All	Hardwoods: oaks, yellow-poplar	Pine: shortleaf, white, P/H mixtures
	Southerly	Deep	All	U	All	Pine: shortleaf, white	Pine, Virginia
				L	All	Hardwoods: oaks, yellow-poplar, ash	Pine[7], white, P/H Mixtures
		Shallow	Less than 50	All	All	Pine, Virginia	Pine: shortleaf, loblolly[2]
			More than 50	All		Limited management possibilities	Pine, Virginia

See footnotes on next page.

FOOTNOTES FOR TABLE 2.2 SITE GUEDES TO MOUNTAINS

1 / Deep = 30 inches ; shallow = less than 30 inches.
2/ Winter weather risk.
3/ Especially where bark beetles are a problem.
4/ U = upper 1/2; L = lower ½
5/ Broad ridges.
6/ Narrow ridges.
7/ Above 2,000 feet.

Table 2-3. Site guide for *Piedmont and Cumberland Plateau.*

LANDSCAPE CHARACTERS			MANAGEMENT TYPE
	Moisture Regime	Texture	Preferred
Flood plains, stream terraces, coves, gulfs	Wet	Fine	Sweetgum, w/w oaks/ash[1]
	Moist	Medium	Oaks, yellow-poplar, hickories, sycamore, sweetgum

Landform	Past Erosion	Moisture Regime	Texture	Preferred	Suitable
Ridge Tops	Slight	Wet[3]	Fine Medium	Hardwoods: sweetgum, maple	Pine, P/H, loblolly
		Moist[3]	Medium	Pine, loblolly	Pine, shortleaf
		Dry[4]	Coarse	Pine, loblolly	Pine, Virginia
	Severe	Moist[3]	Medium	Pine, loblolly	Pine, Virginia
		Dry & Droughty[3,4]	Coarse to skeletal	Pine, Virginia	Pine, loblolly

Landform	Aspect	Slope Position	Past Erosion	Texture	Preferred	Suitable
Side slopes (Manageable areas exceeding 15-20% slope)	Northerly	Upper	Slight	All	Loblolly pine, shortleaf	
			Severe	All	Pine, loblolly	Pine, Virginia
		Lower	Slight	Fine to medium	Hardwoods, oaks, yellow-poplar, ash, hickories	Pine/hardwood mixtures (loblolly)
			Severe	Coarse	Hardwoods, oaks, yellow-poplar, sweetgum	Pine, pine/hardwood loblolly
	Southerly	Upper	Slight	All	Pine, loblolly	Pine: Virginia, shortleaf
			Severe	All	Pine: Virginia, loblolly	
		Lower	Slight	Fine to medium	Pine: loblolly, shortleaf	
			Severe	Coarse	Pine, loblolly	Pine, Virginia

1 /w/w oaks = water willow oak
2/ (White pine could also be suitable for ridges and side slopes above 2,000 feet elevation.
3/ Broad ridges
4/Narrow ridges

The following definitions apply to the terms used in tables 2-1 to 2-3.

Wet - Periods of excessive moisture because of flooding, perched water tables (soil hardpans), and poor drainage. Presence of mottled soils.

Moist - Well-drained soils, but with enough moisture to maximize tree growth throughout the year. Usually associated with loamy soils with some moisture-retaining clays in the subsoil.

Dry - Sites with insufficient moisture for maximum tree growth at least part of the year because of excessive drainage or topographic position.

Droughty - Excessively drained, usually very shallow, except for deep sands. Insufficient moisture for quality hardwood tree growth.

Texture - The relative proportions of the various soil separates in a soil material.

Fine - usually associated with clay-textured soils.

Medium - Usually associated with loamy-textured soils.

Coarse - Usually associated with sandy-textured soils.

Skeletal - A soil with more than 35 percent by volume of gravelly material. Such material is less than 3 inches in diameter or is cobbly -- 3 to 10 inches in diameter.

Scientists have developed other evaluation methods for southern species and published them as technical reports. See the references at the end of this chapter.

SITE-REQUIREMENT CHARACTERISTICS

Yellow-poplar

Best growth and form occurs in the rich loamy coves of the mountains or on deep, well-drained stream bottom terrances in the Piedmont and mountains. Yellow-poplar grows better than other hardwoods on a relatively wide variety of sites. It usually is not well-adapted to sites with a SI50 less than 70 to 75. This species cannot tolerate excessively wet sites. Neither will it perform well on dry, shallow soils (less than 30 inches deep).

Oak

Oaks demand the best sites for high-quality timber. Northern red oak in the uplands and cherrybark in the bottomlands are examples of high-value oaks that are site demanding. They require deep soils, preferably loamy, well-drained, but with a moisture-retaining capacity in subsoils. Northern red oak grows well on benches and lower slopes with north and east exposure. Cherrybark oak is usually found on second bottoms, which are terraces slightly more elevated than the current flood plain. It often grows with Shumard and swamp chestnut oak. White and black oak are less demanding and often grow together on medium quality sites.

Scarlet oak and chestnut oak are better adapted to poorer, ridge sites on high plateaus and lower mountains. Post oak and blackjack oak may dominate the poorest sites. These sites are often targeted for pine conversion. Water oak and willow oak often dominate forest bottoms (active flood plain) with overcup oak and water hickory associations on poorer, water-logged sites.

Sweetgum

Sweetgum grows over a wider range and tolerates wider soil-moisture conditions than do most other high-value hardwoods. R grows well on well-drained sites that receive ample precipitation. Such sites include well-drained stream and river bottoms. Sweetgum grows well in association with both upland and bottom species. It does well in small stream bottoms and deep loamy soils of upland slopes and ridges.

Hickories

A major component in many hardwood stands, hickories usually grow in association with oaks. They are seldom a preferred timber species because of slow growth and poor quality, especially on upland sites. Hickories may be more valuable as a stand component for wildlife mast production.

Other Hardwoods

Other species found in association with those mentioned above include: black walnut, ash, maple, sycamore, basswood, elm, blackgum and others.

STOCKING GUIDES

Stocking is often a problem in hardwood stands. More often than not, these are remnant stands, following years of high-grade or diameter limit cutting, wildfires and grazing. The stocking in these stands is often inadequate and does not reflect the true potential of the site for either quantity or quality. Often the best management alternative is to harvest what remains of the stand and regenerate it. However, if the stand contains adequate growing stock, trees of favorable species, age, and quality potential, then other management alternatives are available.

First, let's define acceptable trees. These "crop trees" are favored in management throughout the life of the stand, with the very best trees carried to final harvest. Acceptable growing-stock trees are characterized as follows:

Sawtimber, 11 inches or more in diameter at breast height (d.b.h.). Salable trees may not be large enough to be "mature," but would be of desirable species, good form and quality. They're satisfactory as crop trees in a final stand, or as a potential product for an intermediate cut within 20 years.

Poletimber, 6 to 11 inches d.b.h., provide salable trees for small products if markets e3dst. Of such species, form and quality that they are suitable for crop trees if this size class is managed as the main stand. They could also be retained for future intermediate cuts within the next 20 to 40 years.

Small trees, 2 to 5 inches d.b.h. These trees are of acceptable species, form, and quality, and could be selected as future crop trees if this size -class were selected as the main stand. They may be suitable to leave for 20 to 60 years for future intermediate cuts.

Stands adequately stocked to carry the present stand to rotation age will contain about the following number of crop trees:

Size*	Number of trees
6	200-340
8	140-240
10	90-150
12	70-115
14	50-90
16	40-100
18	35-60
20	30-50

* Diameter, in inches, measured 4 1/2 feet above the ground.

This is merely a guide and does not mean that all the trees must be outstanding in quality and form. Many of these potential crop trees will be cut during intermediate thinnings. Others will undoubtedly succumb to insects, disease or other causes. The guiding principle should be to favor and carry to final harvest the best 40 to 50 trees per acre. All intermediate cutting and cultural work should be done to promote the growth and value of these better trees.

REGENERATION EVALUATION

When too few acceptable growing-stock trees are available or when the stand reaches maturity, evaluate the stand for natural regeneration potential before the harvest.

On most hardwood sites, natural regeneration will be sufficient to replenish the stand. Go through a stand before the harvest cut to see if you can expect to have enough seedlings, seedling sprouts, root sprouts, or stump sprouts of the desired species to develop into an adequately stocked stand following overstory removal. Tolerance of species to shade, and whether the species is heavy or light-seeded, will govern the steps needed to start a new stand.

Intolerant, light-seeded species such as yellow-poplar, ash, and cottonwood will regenerate from seed if the seedbed conditions are favorable and sunlight is available. Seed from species such as yellow-poplar and ash remain viable on the forest floor for several years. They are usually plentiful if these species were present before harvest. Also, birds, animals, and wind transport seeds from nearby stands. Logging activity is usually sufficient to scarify the forest floor and provide the mineral seedbed needed for germination. Removal of the overstory and brush will enable sunlight to reach the forest floor, helping the light-seeded species to germinate and grow fast enough to compete with other plants. Usually, seed trees are unneeded on hardwood sites.

When regenerating heavy-seeded species of intermediate shade tolerance, such as the oaks, well-established seedlings should be in the understory at the time of harvest. These seedlings develop after germination under the shade of the forest canopy. Many seedlings die quickly, others die back and resprout, but some endure under closed canopies for several years, and become advanced regeneration. Their top growth may be very slow, but the root system continues to develop.

Advanced regeneration is particularly important for oaks because new seedlings are produced sporadically, and grow too slowly to compete successfully with other species. Oak saplings, at least 4 to 5 feet high, with well-developed root systems, are most desirable as advanced regeneration. These young trees will respond quickly and vigorously to sunlight after the harvest cut, and should grow fast enough to compete with other species. Logging usually does not harm advanced regeneration because sprouts will grow vigorously from the root collars of saplings and seedlings that are broken or cut during harvest. Sometimes measures must be taken before final harvest to develop advanced regeneration if it is not already present and oak is desired in the new stand.

Young hardwood stands almost always contain some stump sprouts, and occasionally entire stands can develop from stump sprouts. Because of their vigorous early growth, stump sprouts often dominate other forms of reproduction. The quality and longevity of trees resulting from stump sprouts are sometimes questioned, but stems that start from small stumps below or near the ground line are usually good risks. Some hardwoods also produce root sprouts. Species such as black locust, sweetgum and sassafras produce them prolifically and may regenerate almost entirely from root sprouts.

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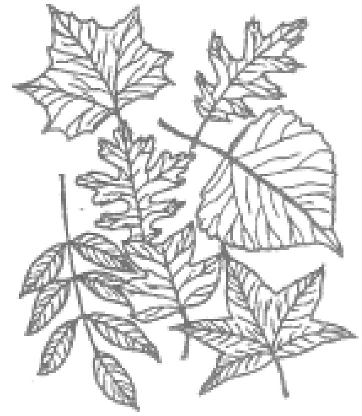
3. Mixed Appalachian (Cove) Forest Type



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The Mixed Appalachian (Cove) Forest Type is a very complex and diverse forest located in the east-central parts of the United States. This type is found in three physiographic provinces: (1) Appalachian Plateau (2) Blue Ridge and (3) Ridge and Valley.

The three provinces consist of the geographic regions ranging from southwestern Ohio through central Pennsylvania, south along the coasts of Delaware and northern Virginia. The region continues through the western ridge and valleys of Virginia, North and South Carolina to the northwestern sections of Georgia and Alabama. The western boundary extends north through the eastern ridges and valleys of Tennessee and Kentucky.

SPECIES

The Mixed Appalachian (Cove) Forest Type is also described by foresters as the mixed inesophysic forest. It contains the most diversified and richest mixtures of tree species found. These species develop best in well-drained, moist, upland sites. The dominant species, when managed, can provide high economic returns. They include sugar maple, American beech, yellow-poplar, white basswood, yellow buckeye, northern red oak and white oak. Those species that exist in smaller numbers are sweet and yellow birch, black cherry, white ash, red maple, blackgum, black walnut, cucumbertree, bittermit hickory and shagbark hickory. Conifers make up a very small percentage of the total growing stock in this type.

PHYSIOGRAPHY and SOILS

The elevation differences that exist in the Mixed Appalachian (Cove) Forest Type range as much as 1,000 feet on the western and eastern slopes of the region. Deeply-eroded valleys exist in the mountainous regions of West Virginia in the northern section of the area. The southern region has well-defined, narrow ridges that continue into Alabama and Georgia. Broad valleys in this section lie "several thousand feet lower than the mountain ridges that surround them.

The best known mountains in the section consist of the Blue Ridge range, characterized by elevations of up to 3,000 feet. They culminate in the North Carolina Smokies at 6,000 feet. The mountains in this area are typically very broad as well as high.

SOILS

Two major soils exist in the Mixed Appalachian (Cove) Forest Type. The northwestern sections of the area consist primarily of sandstone and shale. The soils are strongly acid in nature with limestone reducing pH when present. The soils are moderately to excessively drained.

The southeastern soils are comprised of sedimentary rock including granite, but reflect the same soil characteristics as the northern section.

STATISTICS

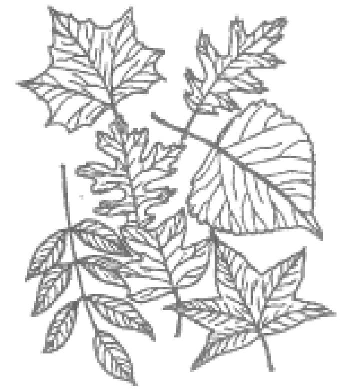
Nearly 62 percent of the Mixed Appalachian (Cove) Forest Type is classified as commercial forestland. About 80 percent of it is in private ownership. The public section owns 12 percent while 8 percent is owned by the forest industry.

At the turn of the century the forests of the Mixed Appalachian (Cove) Forest Type were cut over extensively for the high quality and value of the species of black walnut, black cherry, yellow-poplar, basswood and white oak. Later in the century the black, scarlet and red oaks, beech and maple were cut.

Land clearing and eventual abandonment of the steeper slopes converted the original, high quality stands to low quality, low grade stands of mixed hardwoods and conifer.

Reduced wildfires in the area have not reduced the need for continued education to eliminate fire in quality hardwood production. Continued forest management of these stands will eventually reduce the number of stems that have been reduced in value, resulting from wildfires.

4. Oak-Mixed Hardwoods Forest Type



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WHERE SOUTHERN HARDWOODS GROW BEST

The oak-mixed hardwood forests (oak-hickory complex) of the South occupy the largest area of any hardwood group in the region. The oak-mixed hardwoods are found throughout the Southern Appalachians and eastward to the Piedmont plateau and Coastal Plain where they join with the oak-pine forest type. To the west the oak-mixed hardwoods extend through the Cumberland highlands, the Ozarks, and merge with the Central Hardwood region. While many species of both hardwoods and conifers are found throughout this 60 million acres of forests, the oaks predominate, occurring both in pure stands and as mixtures with a wide variety of hardwoods and conifers. See figure 4-1 and table 4-1.

. Growth and productivity of these forests range from very poor to excellent, depending upon such factors as soil depth and fertility, elevation, availability of soil moisture, slope and aspect of sites, temperature extremes, and to a great degree on past land-use practices. In general, best growth is found on moist, well-drained north and east facing slopes, in coves, and along major and minor water courses and drainages. Reproduction of the oak-mixed hardwood forests is primarily by natural means-- seed, root sprouts, and stump sprouts. The oaks and many species associated with them tolerate shade. They can live in the understory for long periods as sprouts and seedlings, growing vigorously once the overstory is removed. Other species, yellow-poplar for instance, do not have this capacity to survive under heavy shade and must have full sunlight as young seedlings.

Several distinct forest cover types are recognized within the oak-mixed hardwood region. These serve as examples of forest cover and only provide reference points for natural systems, which have become confused. The complexity of soils, topography, weather, drainage patterns, and especially the influence of past land practices interact to present a confusing mixture of species associations over large portions of the area. The discussions below relate to general characteristics of forest types. Exact characterization of specific localities and individual stands, and hence silvicultural prescriptions for their management, can only be made after detailed on-the-ground analysis.

Figure 4-1. Ranges of seven oak-mixed hardwood forest types in the South.

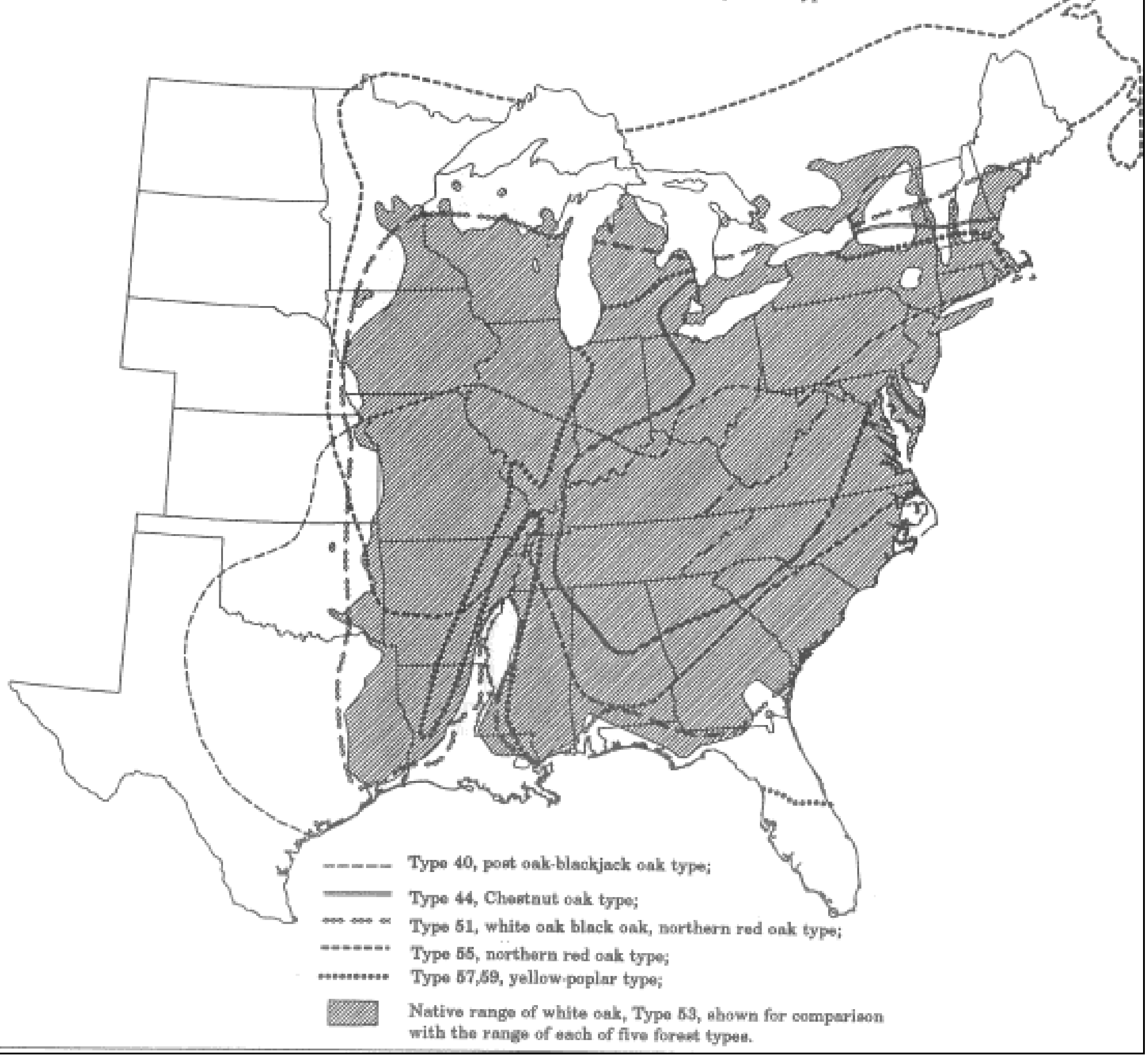


Table 4-1. Characteristics of natural southern forest sites covered with oak-mixed hardwood forest types.

TYPE	PRIMARY SPECIES	GEOGRAPHIC DISTRIBUTION	ALTITUDE RANGE	ECOLOGICAL RELATIONS
Post-blackjack oak	Post oak blackjack hickory other oaks pines redcedar elm blackgum sourwood	Texas east to Atlantic Coast of Fla. To NC. Southern Appalachians	400 to2,500 ft.	Droughty sites. Shallow clays and deep sands. Climax on dry sites. Subclimax on moist sites.
Chestnut oak	Chestnut and other oaks hickory sourwood birch gums poplar walnut maple cherry pines	Throughout Appalachians into the Piedmont.	Primarily on the ridge tops and dry slopes. 1,500 to 4,600 ft.	Sprout origin. Intermediate shade tolerance. Tenacious on dry sites. Poor competition on better sites.
White oak, black oak, northern red oak	White oak, black oak, northern red oak other oaks hickory yellow-poplar maples blackgum ash elm sweetgum pines	Throughout Appalachians and Piedmont into the Coastal Plain	500 to 4,000 ft.	Prevalent on many soils. Subclimax to climax dependent on soil type.

Table 4-1, continued

Type	Primary Species	Geographic Distribution	Altitude Range	Ecological Relations
yellow-poplar, white oak, northern red oak	Lower elevations: ash walnut black locust Higher elevations: black cherry ash beech maples pines	Appalachian Mountains, Piedmont plateau, and west into the central forest region.	500 to 4,500 ft.	Typically found on deep, moist, loose-textured soils. Favors mountain covers and moist north and east facing slopes. Yellow-poplar'' shade intolerance and susceptibility to fire often eliminate species from type.
yellow-poplar	Maple beech ash northern red oak white oak blackgum hickories pines sweetgum blackgum	Louisiana east to the Atlantic coast and north to central Michigan and New England.	Up to 3, 500 ft.	Prevalent on moderately deep to deep, moist, medium, and fine textured, well-drained soils. Subclimax species but will replace itself if severely disturbed. Intolerant to shade. Seed remains dormant on forest floor for years.
white oak	Northern red oak black oak chestnut oak scarlet oak post oak hickory blackgum yellow-poplar ash maples pines	Texas east to Atlantic Coast excluding most of Florida and north to Great Lakes and New England.	400 to 2,000 ft.	Most common on moderately dry to moderately wet sites. Climax on drier sites. Subclimax on moist sites.

Table 4-1, continued

Type	Primary Species	Geographical Distribution	Altitude Range	Ecological Relations
Northern red oak	Moist sites: yellow-poplar black cherry maple ash white oak beech buckeye Dry sites: upland oaks hickory blackgum maple	Spotty throughout Appalachians.	Up to 5,500 ft.	North and east slopes with adequate moisture. Occasionally on south and wet dry slopes. Subclimax on better sites.

The seven cover types discussed below are the principal ones within the southern oak-mixed hardwood region by the classifications recognized by the Society of American Foresters. They are:

Post oak-blackjack oak type Chestnut oak type
White oak, black oak, northern red oak type
White oak type Northern red oak type
Yellow-poplar, white oak, northern red oak type
Yellow-poplar type

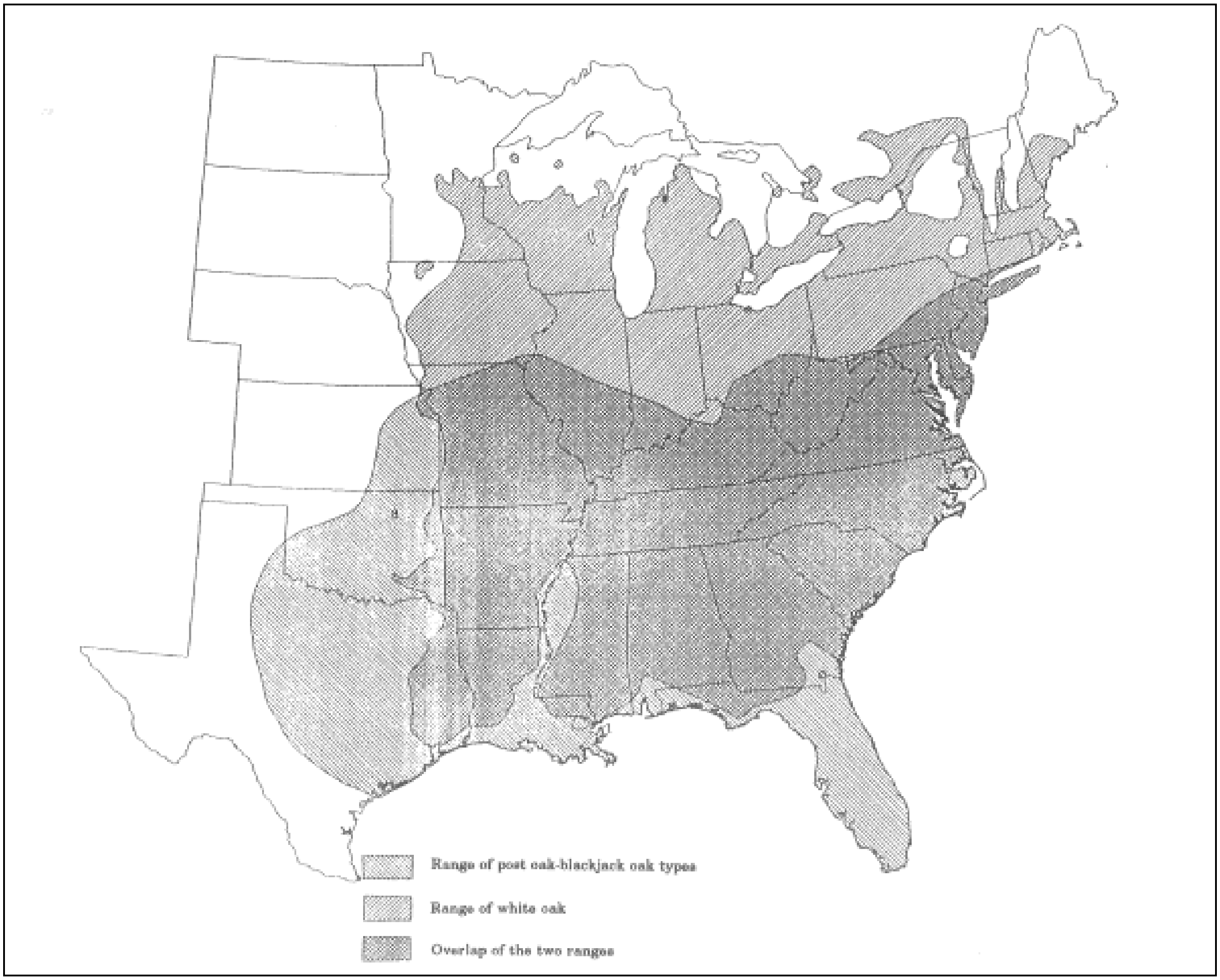
POST OAK, BLACKJACK OAK TYPE

In the southeast this type is found from Texas east to the Atlantic Coastal Plain and north to the sand hills of North Carolina; in the Ozark-Ouchita highlands; and on dry ridges and shallow soils of the southern Appalachians. See figure 4-2. The type is found on droughty sites and is very low in productivity. Surface soils may be shallow with a high clay content underlain by clay or clay-loam subsoils. Alternatively, surface soils are often deep sands over gravelly, sandy clay subsoils.

Post and blackjack oaks predominate on these poor sites, reproducing primarily by sprouting. Associated species include pignut and mockernut hickories, black, scarlet, southern red, bluejack, white and turkey oaks, shortleaf and Virginia pines, winged elm, blackgum and sourwood. On sites with increasingly better moisture regimes, the proportion of black and red oak and the hickories increases. Available soil moisture is limiting on these sites and little opportunity exists to improve growth on stands within this type. Moister sites can be converted successfully to pine. However, over time converted sites will revert to their former composition.

Understory vegetation commonly found includes sumac, blueberry, huckleberry, hawthorn, wild grapes, greenbrier, and wild plum. Herbaceous vegetation associated with this type includes bluestem, sedges, panicgrass, wiregrass, pussytoes and broomsedge.

Figure 4-2. Range of Type 40, post oak-blackjack oak type.



CHESTNUT OAK TYPE

Occurs on the drier sites and ridge tops throughout the Appalachians and extends to some degree into the Piedmont. See figure 4-3. Chestnut oak is found in pure stands or with associated species that vary by elevation, topographic position and, conditions of the soil. Chestnut oak reproduces by sprouting. Associated species include several other oaks, the hickories, sourwood, maple, birch, sweetgum, blackgum, black cherry, yellow-poplar, and several conifers.

Chestnut oak is usually limited to poorer, dryer sites because of its inability to compete with other species on the better soils. In those instances where the species does become established on better-quality sites, it responds with better growth and yields.

Understory vegetation common to this type includes mountain laurel, blueberries and huckleberries, dwarf chinkapin oak, rosebay rhododendron, wild grapes, flame azalea, greenbriers, brambles, bittersweet, hobblebush, mapleleaf viburnum, minniebush, mountain sweetbell and witch-hazel. At higher elevations, mountain and striped maples may also be found in the understory.

WHITE OAK, BLACK OAK, NORTHERN RED OAK TYPE

This type occurs over a wide area of the East. In the South, variations of the type extend from the southern Appalachians into the Coastal Plain. The range of this type coincides with that of the white oak type (figure 4-4). While the white, black, and northern red oaks predominate, other oaks that may be significant component of stands are pin, scarlet, southern red, chinkapin and post oak. Associated species include hickory, blackgum, maple, yellow-poplar, ash, elm, basswood, sweetgum and other hardwoods in addition to several conifers.

This type is found over a wide range of soils. On the most productive soils, stands of mixed hardwoods, which include a high percentage of the better oaks, produce medium- to high-quality timber when managed properly, especially on moist north- and east-facing slopes and in coves.

Many trees, shrubs, and herbaceous species are found in the understory of this type. Trees and shrubs include dogwood, sassafras, sourwood, serviceberry, redbud, hornbeam, hophornbeam, witchhazel, vacciniums, viburnums, spicebush, laurel and rhododendron. Common vines are greenbrier, wild grape, Virginia creeper and poison ivy. Common herbaceous species are mayapple, Solomons-seal, false Solomons-seal, trilliums, snakeroot, bellworts, asters, goldenrod and several others.

WHITE OAK TYPE

The white oak type has an extensive range throughout the East. In the South its range extends from Texas through the Appalachians and the Atlantic Coastal Plain. See figure 4-4. White oak is the major species component in this type, with associated species comprising no more than 20 percent of stocking. Associated species are other oaks, blackgum, hickory, yellow-poplar, white ash, maple and eastern white pine.

This type is most commonly found on moderately dry to moderately moist sites. On the drier sites, several dry-site species such as chestnut oak may be found in association with the white oak. On medium and better sites, management techniques suitable to white oak regeneration and growth are recommended.

Associated understory vegetation commonly found with the white oak type are those woody and herbaceous species listed under the white oak, black oak, northern red oak type above.

Figure 4-3. Range of Type 44, chestnut oak type.

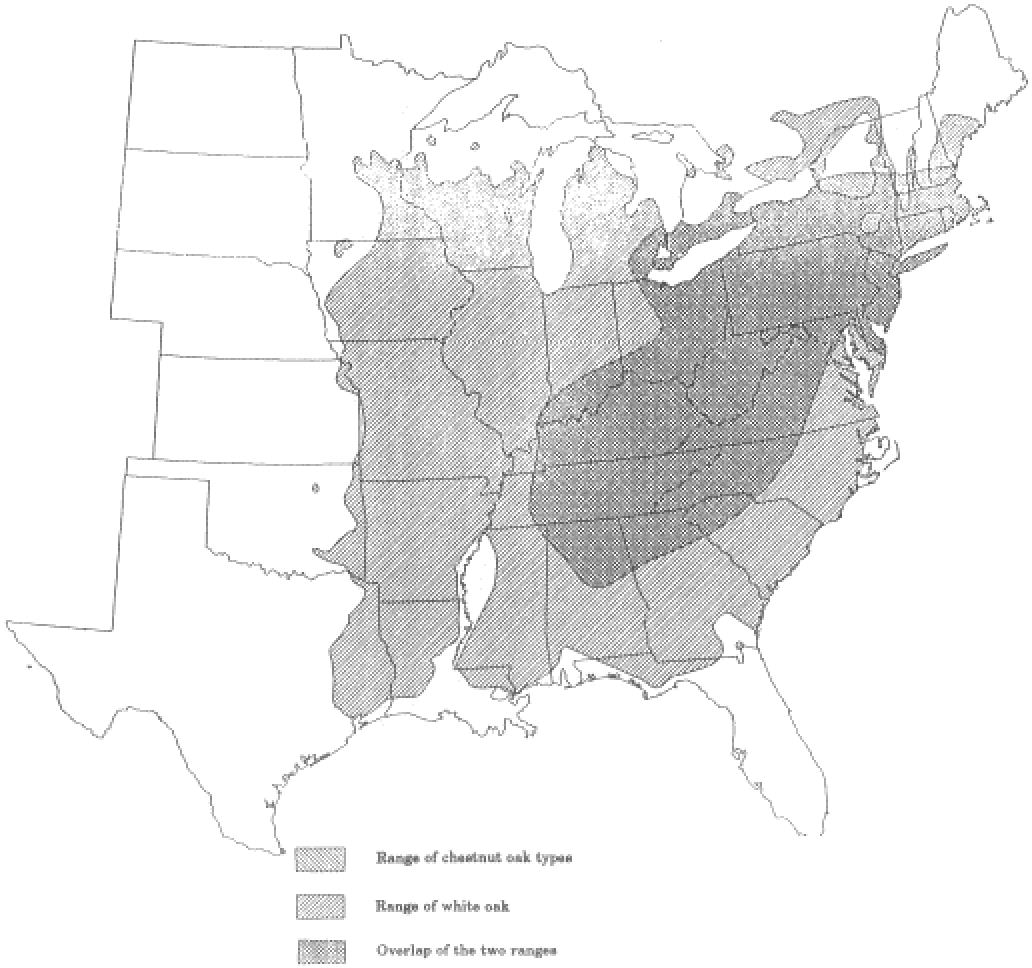


Figure 4-4. Range of Type 52, white oak, black oak, northern red oak types.

NORTHERN RED OAK TYPE

This forest type is found in the South only in the southern Appalachians where stands of this type are spotty. See figure 4-5. Stands are found mostly on north- and east-facing slopes on excellent, well-drained loams and similar high quality soils. Associated species include many of the better hardwoods such as yellow-poplar, black walnut, black cherry, white oak, white ash, buckeye and sugar maple.

Woody understory species commonly associated with this type are dogwood, hophornbeam, hornbeam, serviceberry, sassafras, redbud, witch-hazel, rhododendron, mountain laurel and pawpaw. Common herbaceous species are wood nettle, touch-me-not, stonecrop, Solomons-seal, false Solomons-seal, and mayapple. On drier sites, teaberry, tick-trefoil, goldenrod and trailing arbutus may also be found.

YELLOW-POPLAR, WHITE OAK, NORTHERN RED OAK TYPE

The three species included in the type name make up the majority of stocking. Associated species are white ash, black walnut, black locust, sweet birch, butternut, eastern hemlock, black cherry, white pine, white ash, cucumbertree and the maples. As seen in figure 4-6, the range of this type coincides with that of the yellow-poplar type. In the South this type is found through the Cumberland and Allegheny Mountains and Plateaus; the Blue Ridge, and the Valley and Ridge province and extends into the Piedmont. This type is characteristic of those stands designated "cove hardwoods", but is also found on high-quality north- and east-facing slopes and on well-drained flats. Proper management of stands in this forest type will yield some of the finest Appalachian hardwoods available.

Understory species associated with this type include maples, oaks, hickories and cherries, but yellow-poplar is rarely present because of its intolerance to shade. Other understory species are grape, spicebush, hydrangea, viburnum, and dogwoods. Herbaceous species such as trilliums, toothworts, springbeauties, anemones and several species of ferns are also common.

YELLOW-POPLAR TYPE

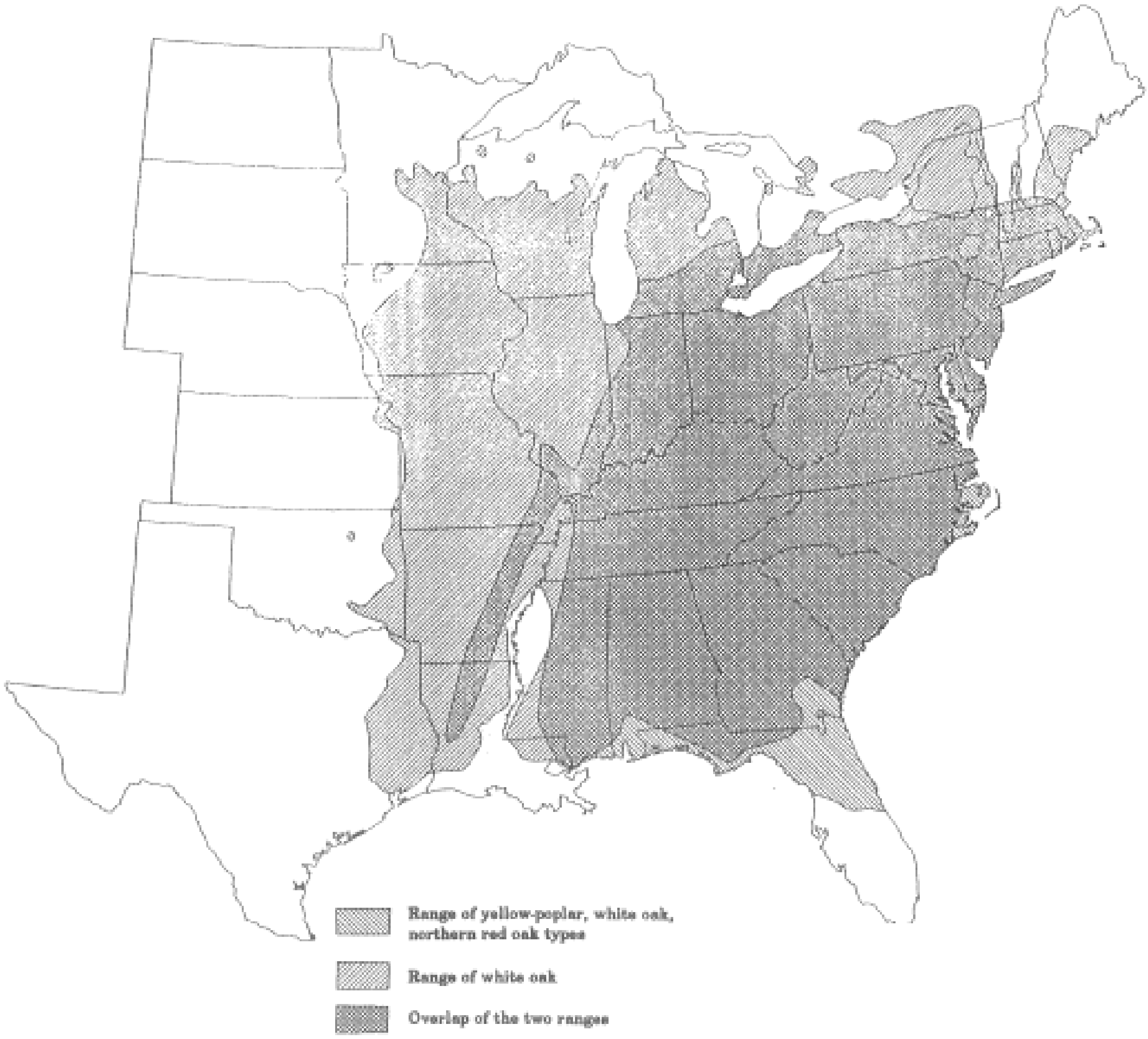
In the South, this type is found throughout the Appalachians at low to mid-elevations southward to Georgia and Alabama. See figure 4-6. While many stands of this forest type are pure yellow-poplar, the species also grows in association with white ash, red and white oak, blackgum, hickory, black cherry, cucumbertree, sweetgum, maple, loblolly and white pine and others.

Yellow-poplar is site-demanding, growing well on only the better moist but well-drained sites where it outgrows most other species. The species seeds prolifically, the seed remaining dormant in the humus for several years. Upon removal of the overstory the seed germinates rapidly and seedlings grow well in full sunlight.

Understory species, both woody and herbaceous, commonly associated with this type are those listed above as being associated with the yellow-poplar, white oak, northern red oak forest type.

Figure 4-5. Range of Type 55, northern red oak type.

Figure 4-6. Range of Type 57, yellow-poplar, which coincides with range of Type 59, yellow-poplar, white oak, northern red oak types.



5. Oak-Pine Forest Type

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RANGE

Pine-hardwood forests occur almost everywhere pines grow. The range is shown in figure 5-1. They come about in two ways. One is for pines to invade hardwood stands by seeding into large openings. The other is for hardwoods to invade pine stands, due principally to the exclusion of fire. The latter is the most common case, and from an economic standpoint most pine-hardwood sites are probably better adapted to production of pine.

On most sites, pine-hardwood stands are a transition from pines to hardwoods. Pines are adapted to seed-in on bare soil in open areas. Pine seedlings will not survive for long when shaded by or competing with larger trees. Most of the desirable southern hardwood species also require direct sunlight for best growth. Many, however, have the ability to survive for decades in the understory or midstory, in effect waiting until an opening overhead is created.

The virgin pine forests of the South existed because frequent ground fires kept hardwoods from becoming established on those upland sites. Pines, after the first few years, can survive light fire. The pines replaced themselves, by seeding into large openings in the forest canopy created by storms, crown fires, pine beetle attacks, or other infrequent severe natural disturbances. Now that wildfires no longer burn unchecked, hardwoods are able to seed-in beneath the pine. Without management, most pine stands will eventually become pine-hardwood and then hardwood forests. The exception is where soil conditions (usually droughty soils) or frequent fires favor pines by inhibiting establishment of hardwoods.

SPECIES

The pine-hardwood cover type includes a wide variety of species over its geographic range. The following is a list of the major ones.

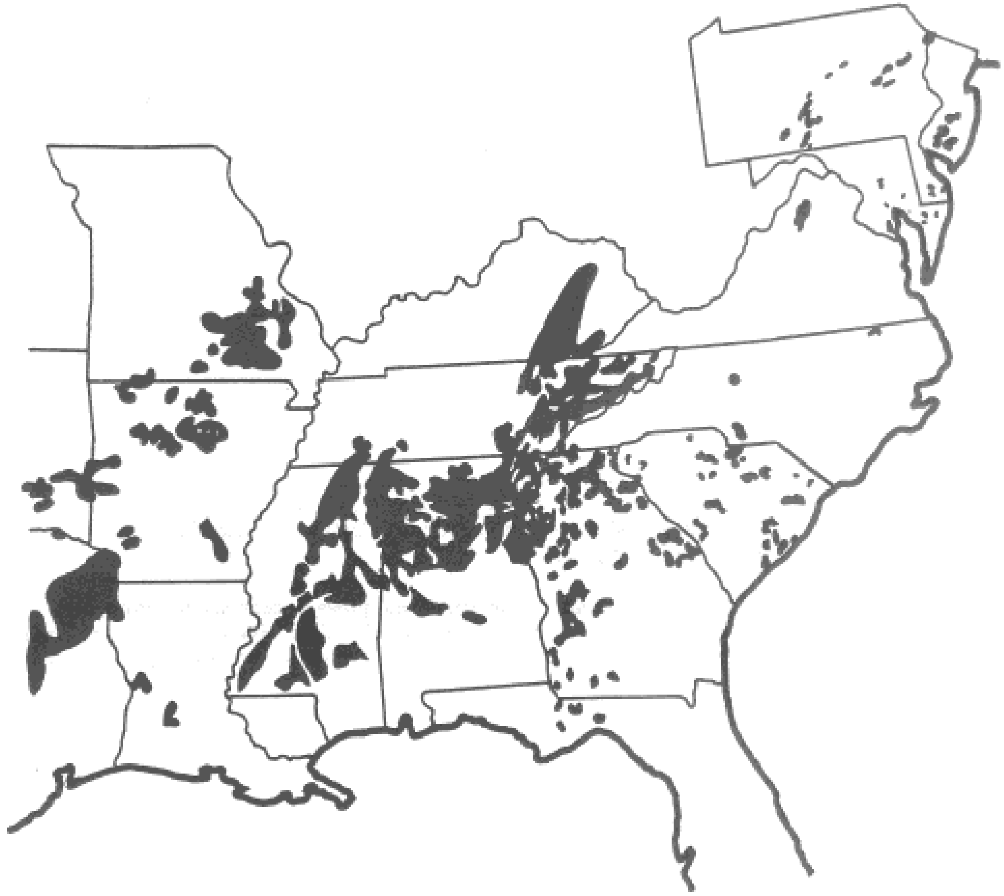

Figure 5-1.Primary occurance of the pine-oak timber type. (by L. C Harshaw after Eyre 1980)

Pines

loblolly pine	Virginia pine	slash pine
shortleaf pine	longleaf pine	

Hardwoods

white oak	southern red oak	pignut hickory
post oak	chestnut oak	yellow-poplar
black oak	turkey oak	sweetgum
scarlet oak	blackjack oak	black gum
northern red oak	mockernut hickory	red maple

PHYSIOGRAPHY AND SOILS

The loblolly pine-hardwood type is the most common and widespread of the pine-hardwood forests. It is scattered across the Coastal Plain and Piedmont from Texas to Delaware. It occurs in swamps along the coast up to dry sites of 2,000 feet elevation in the Piedmont. On the Coastal Plain, the soils are derived mostly from unconsolidated sand, silt, and clay marine sediments or sometimes peat. In the Piedmont the soils are derived from igneous, sedimentary, or metamorphic rock.

VIRGINIA PINE-OAK TYPE

The range of the Virginia pine-oak type is from southern Pennsylvania to northern Georgia and Alabama. It occurs at elevations below 3,000 feet in the plateaus and foothills of the southern Appalachian Mountains and the Piedmont. The best sites for this type are old fields with clay and loam soils, where hardwoods invade openings in old Virginia pine stands. At the other extreme are rocky, dry mountain ridges where the pine's ability to withstand drought enables it to compete with hardwoods.

SHORTLEAF PINE-OAK TYPE

This type occurs at scattered locations throughout shortleaf pine's extensive range. It is common at elevations below 2,000 feet in the Piedmont, Cumberland Plateau, and southern Appalachians. It is also found in northern Mississippi, northern Arkansas, southern Missouri, southeastern Oklahoma, and northeastern Texas. Shortleaf pine-oak forests are typically found on dry, coarse-textured, rocky, or shallow soils. These soils are mostly derived from sandstone, but sometimes from shale or granite. Usually the shortleaf pine-oak type is only a transition between and pine and a hardwood forest. An exception is on the margins of the Cumberland Plateau, where the soil conditions seem to make the shortleaf pine-oak forests a stable, permanent association.

LONGLEAF PINE-SCRUB OAK TYPE

The longleaf pine-scrub oak type can occur on the lower Coastal Plain from North Carolina to Florida and west to Texas. It is most common in the sandhills region of North and South Carolina, Georgia, and northwest Florida. It typically occurs on deep, droughty, acid sands. This type is maintained by periodic fires, to which longleaf pine is well-adapted. Without fire, the scrub oak would eventually dominate the site and prevent pine regeneration.

SLASH PINE-HARDWOOD TYPE

The slash pine-hardwood type is restricted to the lower Coastal Plain from South Carolina to southern Florida and along the Gulf to eastern Louisiana. It commonly occurs in swampy areas on seasonally-flooded, peaty soils that are often acidic and low in nutrients. These moister sites burn less fi-equently but often more catastrophically than the associated longleaf pine uplands. On these sites, the slash pine-hardwood forests seem to be a permanent type. The type also occurs along the margins of minor stream where the usual surface fires do not penetrate. This factor favors establishment of hardwoods. On the other hand, some of these sites are occasionally burned by hot fires. Those events favor establishment of slash pine.

STATISTICS

The total area of pine-hardwood forest type in the South has fluctuated appreciably in the past three decades. See table 5-1. Overall, the total acreage gradually increased from the 1950's to the 1960's, peaked in the early 1970's, and has steadily declined since then. Today, there is less acreage in this cover type than at any time since 1952.

Individual States do not all follow this region-wide trend. In fact, seven States now have more pine-hardwood acreage than in the 1950's. The significant decreases which occurred in Alabama, Louisiana, b4ississippi, and Tennessee account for the overall decline in total acreage. See table 5-1.

When acreage is reviewed by ownership pattern, interesting changes become apparent. See table 5-2. More acreage of pine-hardwood forest type now exists on national forests than 1952, or any year since. Overall, very little has changed in the acreage in the "other public" category. The pine-hardwood acreage on forest industry land increased significantly from the 1950's to the 1970's before declining during the 1980's, but it is still greater now than it was in 1952.

Only the private nonindustrial, ownership class had much less pine-hardwood acreage in 1985 than in 1952. There was an acreage increase during the 1950's and 1960's, but there has been a steady decline since 1970. The change can be attributed to land clearing (for urban areas, pasture, etc.) and to conversion to other timber types (by cutting the pine and leaving a hardwood forest or by removing the hardwood and replacing it with pine).

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Table 5-1. Area of pine-hardwood forest type, by State, for selected years.

State	Year 1952	1962	1970	1977	1985
	-------------------------		thousand acres		-----------------------------
Alabama	5,803	4,839	4,982	4,793	4382
Arkansas	2,181	2,667	2,870	2,956	2,926
Florida	751	1,137	1,558	1,464	1,357
Georgia	2,266	3,604	3,674	3,302	2,741
Louisiana	2,644	2,242	2,199	2,131	1,891
Mississippi	4,309	3,305	3,162	3,452	3,560
North Carolina	2,027	2,405	2,468	2,433	2,264
Oklahoma	607	637	672	676	595
South Carolina	834	1,454	1,794	1,728	1,656
Tennessee	2,191	1,328	1,595	1,454	1,298
Texas	2,178	2,314	2,458	2,524	2,447
Virginia	1,297	1,569	1,753	1,932	1,689

Table 5-2. Area of pine-hardwood forest type, by ownership, for selected years.

Ownership	Year 1952	1962	1970	1977	1985
	-------------------------		thousand acres		-----------------------------
National forest	1,536	1,530	1,651	1,740	1,823
Other public	954	874	972	930	953
Forest industry	4,995	5,170	6,342	6,395	5,762
Other private	19,643	19,927	20,220	19,780	18,269
Totals	27,088	27,501	29,185	28,845	26,807

6. Bottomland Hardwood Forest Type

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SITE EVALUATION

Usually one considers bottomland forest as a type of stand of trees occurring along streams, low-lying wet areas, depressions or coastal flats. The Forest Service forest survey considers bottomland hardwoods to include forest in which bottomland hardwood species, singly or in combination, comprise a plurality of stocking except where pines comprise 25 to 50 percent, in which case the plot would be classified mixed pine-hardwoods.

According to Johnson and Shropshire, bottomland hardwood forests include 19 forest cover types in 37 States. This area ranges from the Atlantic ocean, north to Canada and west to the Rocky Mountains. Their habitat includes flood plains, backwater and headwater swamps and minor drainages. Elevations are said to range from sea level to 800 feet above sea level. Annual rainfall varies from about 30 inches to 64 inches on the Gulf Coast.

As listed by Putnam, Furnival and McKnight, southern bottomland hardwoods occur from the lower Mississippi valley, lower Piedmont and southern Coastal Plain from Virginia to Texas, north to Missouri and Kentucky. Bottomland hardwoods are extremely variable and peculiar to species and site. Changes in elevation and drainage of only a few inches may determine the species or quality of a site. Species and site greatly determine the value, quality, growth and reproduction of a particular species.

Baker and Broadfoot listed four major factors in the effect of soil on hardwood growth. They are: soil origin, physical condition, moisture availability and aeration. The interaction of these soil properties make site evaluation for a species a difficult task. Also, soil types vary greatly depending on origin from clay, to organic muck, to sand. Major soil-site properties are topsoil depth, presence of a hardpan, soil texture, surface compaction and structure, geologic source, pH, topographic position, soil age, swampiness, past land use and present cover type.

The most productive sites are bottomlands of major streams. Within a bottom the soil composition varies with flooding amounts. The more frequent and prolonged the flooding, the heavier the soils. Streams originating in the Coastal Plain have lighter texture and less fertile soils that support somewhat different species than do streams from mountain or piedmont origins. Most interstream alluvial soils with prolonged flooding are generally low in productivity. Cypress and tupelo are common species where these soils are found.

For best management one should consult the Soil Conservation Service or a local hardwood forester. They will help you match soils to species or offer guidance on the most suitable hardwood species for a site, based on their careful observation of the growth patterns of native tree species.

Several publications have guides for matching species to site, including Baker and Broadfoot's *Site Evaluation for Commercially Important Southern Hardwoods.*

SPECIES

In the South there are more than 70 commercially important hardwood species, of which as many as 50 species may be found in a given locality. Diversity is common, depending on site and succession. Bottomland hardwood timber species usually can be described or broken down by habitat or interrelated species type. Several species groupings have been used to list species types. The most common description of bottomland species types are: cottonwood-willow, cypress-tupelo and mixed hardwoods.

Johnson and Shropshire state that the cottonwood-willow type is a predominantly pioneer species on new alluvial soils along major rivers. After harvest or mortality they are replaced mostly by hackberryy, sugarberry, American elm, green ash, boxelder, red maple, roughleaf dogwood, hawthorns, sweet pecan, sycamore, sweetgum, water hickory, overcup oak, swamp privet and sometimes water oak. In more northern areas silver maple is a common invader.

The cypress-tupelo type is a major species component of coastal and backwater swamps characterized by poorly drained area or standing water. Plants common to this type are bald cypress, swamp tupelo, water tupelo, red maple, sweetbay, redbay, Carolina ash and green ash. Buttonbush, swamp privet and roughleaf dogwood are common shrubs or small trees.

SOILS

Mixed bottomland hardwood stands are intolerant to wet soils and often to dense shade. Many species occur on bottomland ridges and first and second terraces. However, sediment-filled sloughs, isolated depressions and filled lakes often are distinct from surrounding, better-drained areas in vegetative composition. In these poorer-drained areas overcup oak, red maple, water hickory, green ash and persimmon are found. The most common commercial, mixed-type species found on better drained bottomlands are sweetgum, white bay, willow oak, water oak, green ash, hackberry, sugarberry, Nuttall oak, overcup oak, red maple, American elm, laurel oak, swamp chestnut oak, cherrybark oak, Shumard oak, black tupelo, winged elm, hickories, water hickory, persimmon, boxelder, pecan and, in the northern portion, silver maple.

STATISTICS

This review covers the endemic species of hardwoods on wetter sites in the South. The one exception is cypress, which is a conifer. The range map by Putnam, Furnival and McKnight (figure 1) illustrates the primary areas considered to be southern bottomland sites. Because of the varied species and sites on which they occur, it is difficult to determine precisely the volume and area of bottomland hardwoods. Forest surveys of the Forest Service list inventories by species and State, not site. The largest, single area of bottomland is along the Mississippi river delta. Putnam, Furnival, and McKnight listed this area to contain 11,600,000 acres (40 percent of the land area) in 1960. Since then, this acreage has decreased by possibly one third.

Land clearing in southern bottomland areas has claimed more than 4 million acres since 1962, mostly by nonindustrial landowners. Nonindustrial landowners may reverse this trend due to environmental controls by government and the new Conservation Reserve Program (CRP) and other reserve programs, which cost share and pay landowners for reforesting erodible and weland soils. Also, management techniques and timber values are improving, which may provide more management incentive.

In the 13 southern States more than 30 minion acres of lowland bottomland hardwoods are listed in the most recent forest surveys there. The major bottomland timber concentrations in the South are the river floodplains of the Mississippi, Red, Tennessee, Alabama, Savannah and Roanoke systems. The largest areas of bottomland hardwood in the South are found in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina and Texas.

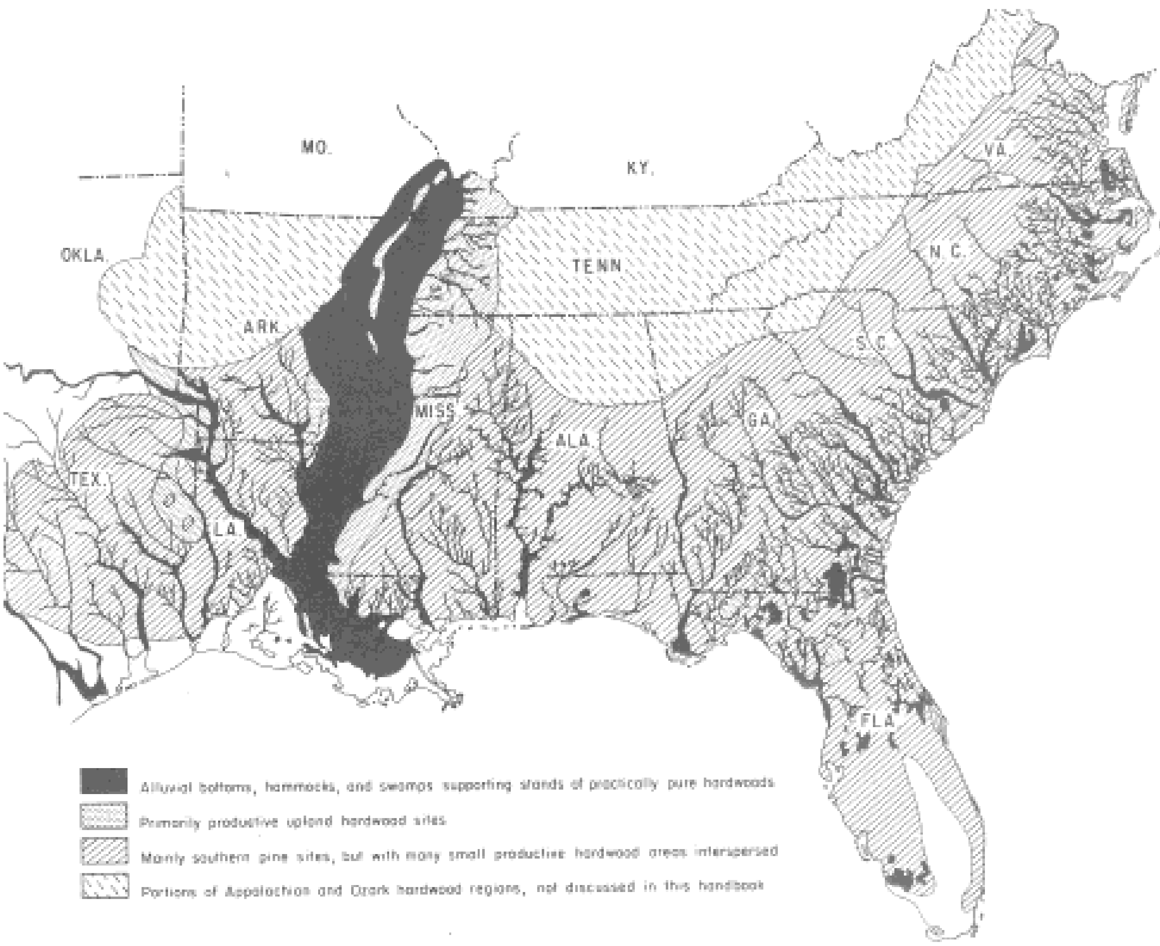

Figure 6-1. Location of southern hardwood sites. (Source: Putnam, Furnival, McKnight 1960.)

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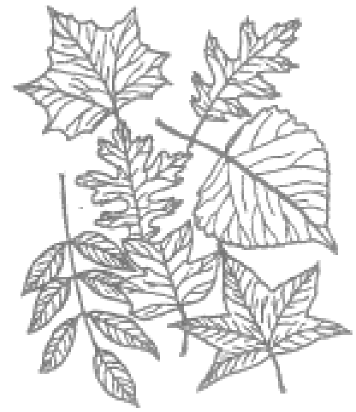
7. Mississippi Valley Forest Type



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DISTRIBUTION

The Mississippi Valley Forest Type covers an area from Cairo, Illinois, to the Gulf of Mexico. This forest type encompasses the floodplain of the Mississippi River, terraces, levees, and the loessial highlands (figure 7-1).

Currently, there are about 11.5 million acres of timber in the Mississippi River Valley forest type. Four million of those acres are in the loessial highlands, and 7.5 million acres are in the other land types. Excluding the loessial bluffs, in the mid-1930's there were 11.8 million acres of timberland in the Mississippi Valley Forest Type. Approximately 4.3 million acres of land (36 percent) were lost to other uses. This was primarily due to land clearing activities in the late 1960's and early 1970's for the production of row crops. The remaining hardwoods are growing in sites that are too difficult or too wet to farm. About 1.2 million acres lie inside levees that are prone to annual flooding. The nonindustrial, private landowner controls over 70 percent of the region, forest industry owns about 20 percent, and only 10 percent is in public ownership.

MISSISSIPPI RIVER FLOODPLAIN

This region contains some of the most productive and variable sites in the United States. A difference of a few feet can change site productivity drastically due to soil drainage. The types of trees that are present reflect the changes in soil characteristics.

Two distinct regions devide the floodplain: first bottoms and terraces. The first bottoms, which are prone to prolonged flooding, formed from current river- drainage. Terraces were formed by older drainage systems and represent old floodplains. The fluctuations in elevation result in ridges, flats, sloughs, and swamps. Ridges are the highest land form, flats are level areas between ridges, sloughs are depressions that are periodically flooded over half the year, and swamps are usually flooded except in years of extreme drought.

FOREST TYPES

The Mississippi Valley Forest Type includes the cypress-tupelo, willow-cottonwood, and mixed soft hardwood types, but these types are discussed in other sections of this manual. The rest of this section will concentrate on the mixed oak types.

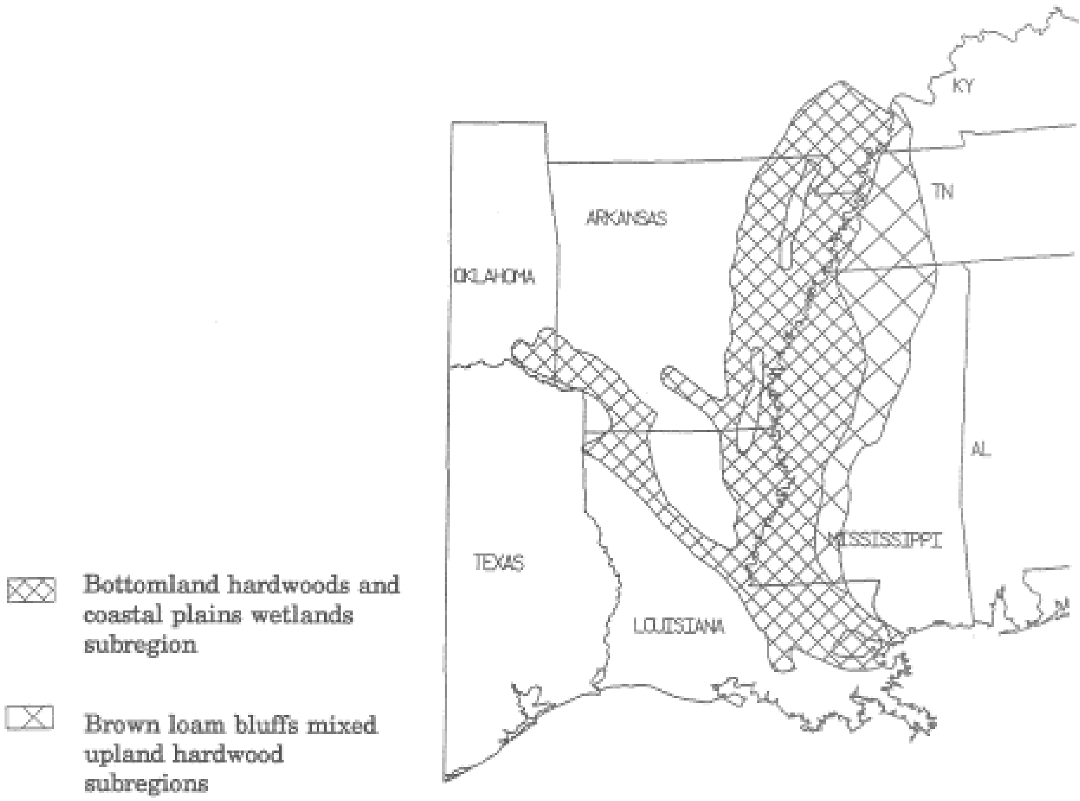

Figure 7-1. Distribution of the Mississippi Valley forest types.

Willow Oak Type

This type occurs on low clay ridges, where green ash and sweetgum. are common associates. This type produces good quality timber and growth rate of better than 4 inches of diameter at breast height in 10 years is common.

Overcup Oak-Water Hickory Type

This type occurs in sloughs and other poorly drained sites. Common associates are green ash, pin oak, willow oak, Nuttall oak, persimmon, winged elm, and red maple. Site productivity depends upon soil drainage. The high water table associated with this forest type results in poor growth rates.

Sweetgum-Cherrybark Oak Type

This is a productive forest type with the potential to produce high-quality logs. This type is found on the well-drained flats and ridges with loam or sandy loam soils. Common associates include water oak, swamp chestnut oak, ashes, hickories, and black gum. Black gum considered to be a weed on upland sites, reaches its greatest potential in this environment and can be valuable.

LOESSIAL HIGHLANDS

This region includes the Brown Loam Bluffs that occur in western Mississippi, Tennessee, and Kentucky. Also included in this region are the Loessial Plains in Arkansas and Louisiana and Crowley's Ridge in Arkansas. The majority of the loessial plains has been cleared and is used for farming. This region is considered to be prime rice soil and little is now covered in forest. In contrast to the loessial plains, the Brown Loam Bluffs and Crowley's Ridge support considerable forest. Loessial soils were formed from windblown materials blown out of glacial plains during the last lee Age. Silt deposits up to 100 feet thick are found at the western edge of the Brown Loam Bluffs and Crowley's Ridge. The soils are well-drained, highly erosive, and have good moisture-holding capacity.

Productivity of these soils relates directly to rooting depth. The soils of this area usually have a layer called a fragipan. The fragipan is very hard and not easily penetrated by roots and water. Therefore, the deeper it is to the fragipan the better the site. The ridge tops of the Loessial Highlands have a thin soil cap and support the dry land oaks such as southern red oak, white oak, black oak, and various hickories. Pine is often planted and grows naturally in association with the oaks. As the soil gets deeper, a wide variety of hardwoods are found. These are extremely productive sites, producing 400 to 500 board feet per acre per year of high-quality wood. Valuable species such as black walnut and black cherry grow well on these soils. However, species such as yellow-poplar, northern red oak, cherrybark oak, Shumard oak, basswood, ashes, and maples occur more often.

STEWARDSHIP

Bottomlands and Loessial Bluff sites provide considerable wildlife benefits. The flooded bottoms provide ideal waterfowl feeding and resting areas. Both sites provide excellent whitetail deer, squirrel, and turkey habitat. Endangered bats such as the Indiana bat roost and nurse their young in the bark and holes of large trees. Neotropical migratory warblers, such as the prothonotary warbler, nest in these areas. Woodland patches provide corridors and refuge in an area dominated by farm. land.

On the bluffs, the silt loam soil is very fragile. Without proper protection, they are very prone to erosion. Management activities should provide protection to these soils. Some bluff soils are too steep for conventional logging equipment. Cable systems or animals should be used and clearcutting on these steep slopes should be avoided. Management under the selection system is ideal, but a forester should be consulted.

DESIRED SPECIES

As you have already learned, a variety of species occur on these sites. Species value and tolerance to flooding vary considerably. Table 7-1 ranks relative value of trees and their tolerance to saturated soil conditions. Using this table, valuable trees can be matched to preferred sites.

Table 7-1. Relative tolerance to saturated soil conditions and relative value of the common bottomland hardwood trees.

Very Intolerant	Intolerant	Intermediate	Tolerant	Very tolerant
	--------------- Highest value---------------			
cherrybark oak	American sycamore	sweetgum	green ash	baldcypress
shumard oak	swamp chestnut oak	white oak	cottonwood	pumpkin ash
white ash	northern red oak	black walnut	delta post oak	
black oak				
yellow-poplar				
	------------- Intermediate value ------------			
southern red			water oak	bur oak
pondcypress			silver maple	laurel oak
swamp tupelo			nutall oak	
water tupelo			pecan	
			hackberry	
			sugarberry	
	----------------- Lowvalue ----------------			
swamp cottonwood	winged elm		cedar elm	red maple
	hickory species		American elm	willow oak
	red mulberry		pin oak	waterlocust
	blackgum		honeylocust	overcup oak
			river birch	water hickory
			persimmon	
	------------------ *Weed* species (low value) ----------			
sassafrass	boxelder			possumhaw
buttonbush	American hornbeam			
hawthorn	American hophornbeam			
planertree				
loblolly-bay				

8. Cypress Forest Type

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DISTRIBUTION

Baldcypress and pondcypress are not hardwoods but softwoods. Yet they are managed like hardwoods. In addition, cypress shed their leaves in the winter like hardwoods and have longer rotations like hardwood species.

Baldcypress grows in Delaware, extends along the Atlantic Coastal Plain to Florida, westward along the Gulf of Mexico to Texas. Then it extends up the Mississippi River floodplain as far north as southern Illinois and southwestern Indiana. Pondcypress, a variety of baldcypress, predominates in Florida and occurs with baldcypress from extreme eastern Louisiana to southern Virginia. See figure 8-1.

STATISTICS

Cypress, once the most highly prized of southern trees for its lumber, is now processed only in a few mills. Most cypress was logged during 1890-1925. The second growth of trees now being harvested are about 60 to 100 years old.

The volume of cypress growing stock on commercial forest land, according tp the most recent Forest Service surveys, totals 6.1 billion cubic feet. The surveys included live trees at least 5 inches in diameter at breast height (d.b.h.). About 21.0 billion board feet of sawtimber is available, of which 41 percent is in trees 17 inches d.b.h. and larger. More than half of the volume grows in Florida and Louisiana. Much occurs in pure or nearly pure stands in ponds, bays, river swamps and old river beds.

An accurate estimate of the number of acres in cypress is difficult because cypress is included in oak-gum - cypress forests. Estimates of the area in cypress range from 3 million to 5 million acres.

REGENERATION

Methods of regeneration and other silvicultural practices for cypress are limited. Past practices in swamp forests have been limited to commercial clear-cutting or high-grading, resulting in many small and poor quality trees, left standing. It was thought

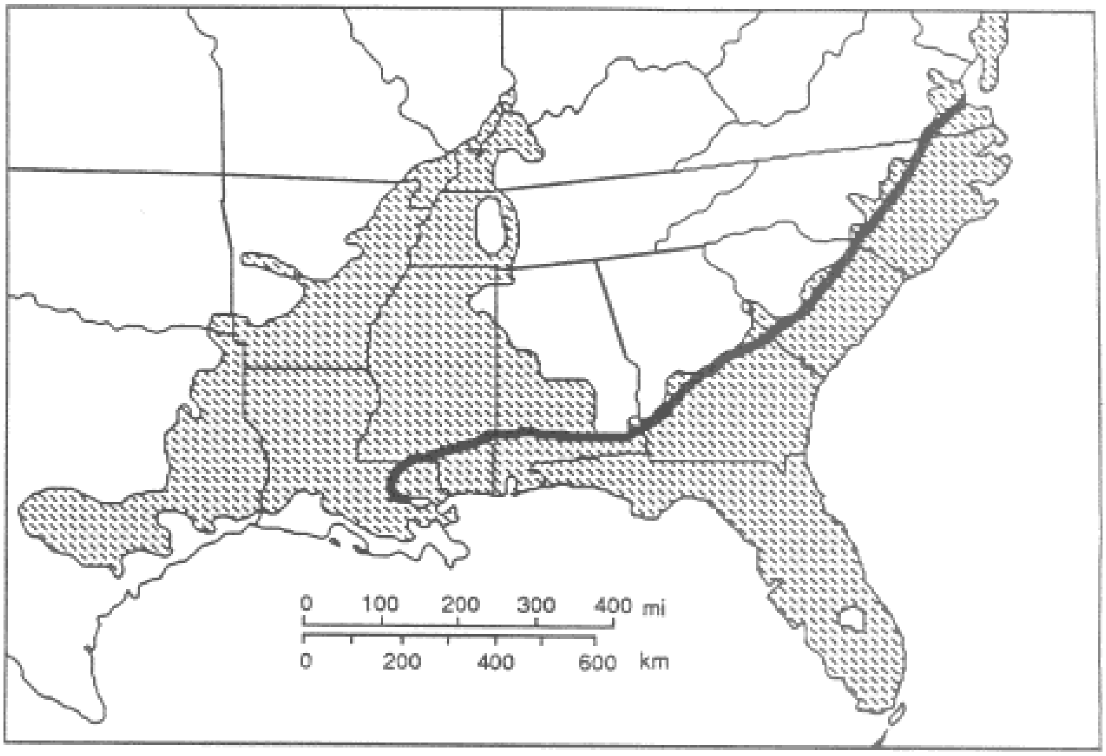

Figure 8-1. Distribution of baldcypress in the South (after Mitsch and Gosselink 1986). The dark line indicates the northern extent of pondcypress.

that clear-cutting natural stands and removing culls without intermediate thinning were the best management techniques for swamp forests. However, research shows that crown thinning may increase growth and quality of the larger, more valuable trees.

If cypress stands are thinned too heavily, epicormic branching occurs. This may reduce the value of sawtimber produced. Thinning should leave about 140 ft2 of basal area per acre. Most pine stands are thinned back to 60 to 80 ft2 for the maximum growth. Higher growth rates can be expected by heavier thinnings, but much epicormic branching occurs.

Regeneration is a problem with cypress. Natural regeneration from stump sprouts or from seedlings cannot be depended on to establish new stands of cypress. Some of the early logged areas have come back from stump sprouts. Cypress regeneration from stump sprouts or seedlings cannot develop in standing water. Research shows that sprouts do not develop into quality trees when they are subjected to prolonged flooding. Water level controls are necessary to regenerate forests from sprouts.

The natural hydrology of coastal areas has been altered. Logging, oil and gas exploration and production, flood control, navigation, residential development and agricultural practices alter overland flow patterns. Other cypress forests lie along major rivers where upstream dams or other structures control discharge. Managed discharges change river flood stages or the timing of major floods, disrupting forest growth and regeneration.

Cypress regenerates well in swamps where the seedbed is moist and competitors cannot cope with flooding. Extended dry periods are necessary however, for the seedlings to grow tall enough to survive future flooding. Young trees will grow 8 to 14 inches the fu-st season and 16 to 24 inches the second. Cypress can endure partial shading but require overhead light for normal growth.

Another method of regenerating cypress is by planting seedlings. Large 1-0 bare root seedlings can withstand flooding. The diameter at the root collar should be 1/4 inch or larger. The height should be 24 inches or more. Plant in late fall or early winter so seedlings can become established during low water periods. An 8 x 8 foot spacing is recommended. Thin the young stands (natural or planted) every 15 to 20 years to release the better stems for rapid growth.

Animal control is important in regenerating cypress. Nutria and feral pigs are problems. They destroy many planting and natural regeneration efforts. As nutria spread and pig populations increase throughout the coastal plain, other areas will have this problem. Deer and beaver also damage cypress seedlings. Deer browse on the smallest seedlings available, so size of the seedlings is important.

Cypress thrive in a variety of soils, including muck, clays and the fine sands. The best sites are well-drained, fine sandy loams with an abundance of soil moisture. Avoid planting cypress over shallow limerock, hardpan or other shallow, impervious soil layers. Although the trees may survive, growth will be slow and may never produce merchantable stands and will be at risk from severe drought.

WOOD QUALITIES

Lumber from second-growth trees with high proportions of sapwood is not decay resistant like the heartwood lumber. Cypress does accept wood preservatives well. Cypress lumber has superior working qualities, good paint retention, good resistance to wear, and nails well. The knots are small and sound. It is not used for pulpwood but can be used for posts and poles if treated.

REFERENCES

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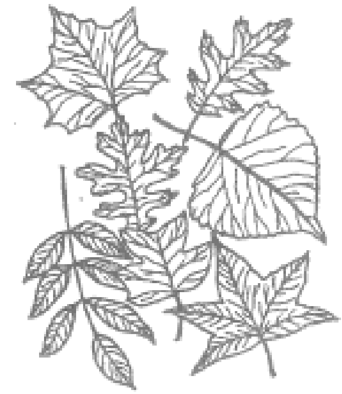

9. Tropical and Subtropical Hardwood Forest Type

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The tropical region of the South is confined to south Florida and a small area of the extreme southern tip of Texas. South Florida has the largest number (98) of native tropical species of any place in the continental United States. Of the 98 species, 60 are listed as rare tropical trees. Only three species grow in Texas. All the species grow elsewhere in the tropics: in the West Indies, Mexico, Central America, and South America. Only a few of these trees have proven value for wood products. The most widely known are West Indies mahogony and roughbark lignumvitae.

Two species of mangroves are valuable along the Florida keys and both lower coasts of Florida in stabilizing and building new coastal land surfaces.

Introduced tropical species such as India rosewood, Mahoe, eucalyptus and casuarina are widely planted in tropical areas. Casuarina is planted as a windbreak species and for stabilizing sandy beaches. Large areas of eucalyptus were planted in central Florida for their commercial potential. Lack of cold hardiness and erratic growth habits have so far limited their use for papermaking or other commercial products. Many of the other tropical species, both native and introduced, are valuable for landscaping.

The semitropical hardwoods occur up the Atlantic Coastal Plain to southeastern Virginia and west along the Gulf of Mexico to Texas. See figure 9-1. While many trees of commercial timber value grow in the plant hardiness zones 9 and 10, most that occur in zone 9 also occur in colder areas farther north.

Live oak, southern magnolia and the cabbage palmetto are the most notable subtropical species. Their range is restricted primarily to zones 9 and 10.

IMPORTANCE

With the possible exception of eucalyptus, mangrove and casuarina, the most important role of the species confined to zone 10, whether native or introduced, is for landscaping and other urban uses. Their impact on commercial forestry is often negative. Sometimes an aggressive exotic "escapes" and takes over sites that would support more valuable native trees. The cajeput tree (Melaleuca quinquenervia [formerly leucadendronl] the Chinese tallow tree (Sapium sebiferum) and the peppertree (Schinus spp.) are examples of introduced species that have become pests. Exercise caution with plantings of introduced species. Fantastic claims are often made concerning growth and yields of exotic species. A native tree will usually perform as well, or better on a given site.

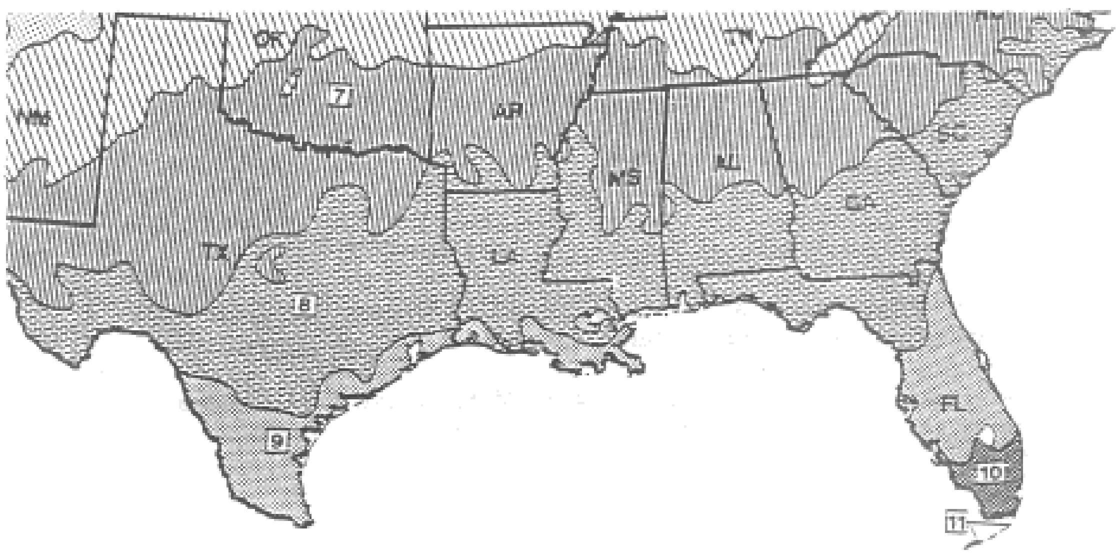

Figure 9-1. Plant-hardiness zones in the South.

10. Stand Improvement

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REASONS FOR IMPROVING TIMBER STANDS

Principal Basis

1. Some overmature trees are past the stage of reasonable growth rates. They can be sold unless needed to maintain wildlife habitat or for aesthetic reasons.
2. Disease or insect activity is destroying parts of the stand.
3. Cull trees are present that will never increase in value and are not suitable for wildlife den or nesting trees.
4. Desirable trees are present that will respond if released from competition with less desirable trees. They should be expected to grow vigorously without excessive epicormic sprouts. These sprouts reduce the quality of adjacent wood on the main stem and use energy that the Tree should put into more productive growth.
5. Better-quality trees with stems of about the same size are crowded. They are competing for light, moisture, essential elements, and growing space.
6. Species composition needs altering to increase the proportion of desired trees.
7. Owners may want to keep a continuous forest cover and remove as few trees as possible because they live on, or in view of, their woodlands.

When Timber Stand Improvement is Needed

Many established hardwood stands have a high number of undesirable trees resulting from previous management practices. When a stand has a history of high grading, for example, (repeatedly removing the biggest and best trees), it is usually left with trees of poor quality and low merchantability. Also, some hardwood stands have originated after heavy cutting without good advance regeneration. 1n either case, these stands will be poorly stocked with preferred species and contain undesirable vegetation that will not contribute to the economic value of the stand now or in the future. These stands can be rehabilitated by Timber Stand Improvement (TSI) which includes cutting out undesirable and competing tree species, either in the understory, overstory or both, and controlling other unwanted vegetation. The purpose is to give desirable trees a chance to grow better. There should be 50 to 70 good crop trees per acre for TSI work to be feasible.

Selecting Trees to Remove

]Improvement cuts may be used to harvest and salvage trees that are undesirable species, have poor form, are diseased or insect-ridden, or are slow-growing, and overmature. Trees may be sold or used by the landowner for firewood, fenceposts, or other purposes. In marking trees for timber stand improvement, the rule of thumb is "Save the best." To upgrade a stand, first cut out dead, diseased, and crooked trees. Next, remove trees with flat-topped crowns because they have poor growth potential. A tall, straight trunk with a full, rounded crown of branches indicates healthy growth. Deeply fissured bark in some species indicates good growth in older trees.

Thinning, Cleaning, and Salvage Cuts

Thinning cuts may be appropriate where groups of desirable trees are too crowded for good growth. Cleaning (removing unwanted trees overtopping desirable ones) and salvage cuts (removing diseased, dying or crooked trees) can be combined with thinnings. Thinning hardwoods is not simple, and thinning young hardwoods is not necessary. Precommercial thinning is not necessary in young yellow-poplar or other overstocked areas of seedling reproduction. Many hardwood species will express dominance without thinning because the physical site and neighboring trees determine site dominance.

As a general rule, for the first thinning, groups of hardwood trees should be old enough (at least 20 to 25 years) to allow time to ensure self-pruning of the first log (lower 17 feet of the tree) by maintaining close spacing of the trees. When hardwood thinnings begin, make them light and frequent (at 5- to 10-year intervals). Remove only a few trees at a time to avoid epicormic sprouting (sprouts that develop on tree trunks exposed to sunlight) on residual trees.

Remove trees that already have epicormic branches. Remove trees competing with crown development of selected crop trees. Leave trees with large, vigorously growing crowns. After thinning, crowns of trees should be about 4 to 5 feet apart to provide space for expansion. There is no need to remove trees with crowns well below the level of crop tree crowns. These suppressed trees can serve as "nurse" or "trainer" trees, shading the trunks of crop trees to reduce epicormic sprouts.

Upgrading Stem Quality

Epicormic branches along the trunk, fire scars, and butt rot (rot in the lowest 16 feet of the bole) reduce stem quality. Wildfire or logging damage during partial harvest can cause scars in the bark or wood of the remaining trees. The injured stems eventually may develop rot. Butt rot is avoided by eliminating logging damage during partial harvest, protecting the stand from wildfire, and by cutting trees close to the ground surface when harvesting. This encourages sprout regeneration for the new stand from near or below ground surface. Such sprouts grow more vigorously and are more likely to be structurally well-connected to the root system, avoiding future damage.

Epicormic sprouts develop on the trunks of trees exposed to sunlight when adjacent trees are removed. Dominant hardwood trees with clear trunks and large crowns are not likely to develop sprouts on the trunk. Protect intermediate-size hardwoods, especially species such as white oak that are highly susceptible to epicormic branching. Leave a buffer strip of other trees around the edges of openings and roads in the stand.

THINNING METHODS

Mechanical Thinning Methods

Simply felling competing trees with a chain saw or an ax is an excellent way to improve a stand. Selling the trees may pay for the treatment. The best trees in the area are marked to save and others are removed. Large, old trees are cut or killed regardless of species, unless they are needed for wildlife. Avoid damaging healthy residual trees while felling and removing poor trees. It may be better to leave a large tree standing and kill it by girdling or using chemicals rather than risk damaging potentially valuable residual trees. Many forms of wildlife use large dead or dying trees for dens, nests, and perches.

Girdling is one of the oldest techniques used to get rid of large unwanted trees. This method eliminates the undesirable tree, but avoids damaging the young understory trees because the dead girdled tree disintegrates slowly. The only tool required is an ax. Small unwanted trees will resprout, however, following girdling.

Brush axes and brush saws can be used to remove small unwanted trees temporarily. Such trees are less than 5 inches in diameter at breast height (d.b.h.), and have the greatest sprouting potential. Several chemicals and application methods control individual trees and understory vegetation.

Chemical Thinning Methods

Mechanical thinning methods usually result in vigorous resprouting because they do not kill the roots of hardwood trees. Herbicides can be used as an alternative thinning method that controls the entire tree including the root system. In hardwood timber stand improvement, herbicides may be applied to individual trees by injection, basal application, or stump spraying techniques. A successful herbicide application requires the selection of the best chemical, using the correct application technique, applied at the proper rate, and at the best time.

Selection of the best herbicide will depend upon the species needing to be controlled, and the cost. Table 10-1 lists herbicides labeled for individual stem application. Tree species vary in sensitivity to herbicides just as they vary in cost. For example, 2,4-D is a relatively inexpensive chemical, but it does not effectively control maples, dogwoods, or elms (table 10-2). The applicator must match target species tolerance along with chemical costs.

Flashback may also be a consideration in herbicide selection. Flashback occurs when a herbicide with soil activity (picloram, imazapyr, and dicamba) is i4ected into a tree and is transported to the root system. As the tree dies, the herbicide can be released to the soil and taken up by the roots of adjacent trees, causing moderate to severe crown damage. Herbicides that are foliar-active, such as glyphosate, 2,4-D, and triclopyr, generally do not result in flashback.

There are several methods for applying herbicides to individual stems and selecting the proper technique depends upon many factors. Tree i4ection is preferable for trees of 2 inch diameter or larger. Injection equipment can cost f1rom $200 to $300 and is available from any forestry supply company. A hatchet and a squirt bottle provide an effective low-cost alternative to this investment. Application rates for injection are provided on the herbicide label, which should be carefully reviewed prior to use. Generally, 1 n1L of the herbicide (or a diluted herbicide solution) is injected into evenly spaced cuts made through the bark and into the cambium layer. About one cut (I mL) is needed for every 2 to 4 inches of tree diameter. Injection should not be used in early spring during the period of maximum upward sap flow.

1"rees that are smaller than 2 inch diameter can be controlled by directed foliar sprays or basal bark applications. Garlon 3A or 4 (triclopyr), Accord, or Roundup (glyphosate) and 2,4-D can be used for making directed foliar sprays on vegetation that is 6 feet high or less using a backpack sprayer. Spray these herbicides on the foliage of individual crowns to the point of runoff, being careful not to treat desirable adjacent trees. Follow label directions regarding mixing percentages.

A second alternative for individual treatment of smaller stems is a basal bark application using a stream-line technique or a basal spray. A backpack sprayer is used to apply either Garlon 4 or Pathway (triclopyr) or Chopper (imazypyr) to the tree stem at between 6 to 18 inches above the ground. Garlon 4 must be mixed with diesel fuel and a penetrant such as Cide-kick in a ratio of 20 percent/70 percent/10 percent, respectively. Although more easily directed to a single tree, application costs per acre may be high when there are many undesirable trees to treat.

Sprouts can be controlled by stump treatment following a thinning or harvesting operation. The herbicide should be sprayed on the outside 2 to 3 inches of the stump surface and topmost 2 to 3 inches of the bark as soon after cutting the tree as possible. The stump begins to form callus barriers immediately after cutting and a delay of a few hours in treatment can result in significant control loss.

Usage of herbicides may vary in different States. Although they are still legal to use, the Southern Region of the Forest Service no longer recommends either 2,4-D or picloram for general use in forestry applications. Picloram's high soil morbility rate and 2,4-D's toxicology profile are cited as reasons for the reduced use of these products.

FIRE

Prescribed fire has limited utility for hardwood management. Fire is not used in established hardwood stands for timber stand improvement work because it damages the relatively thin bark of hardwood trees. Not only can fire kill smaller hardwood stems, it may damage larger stems and create openings for pest and decay organisms. Prescribed fire may be used as a site preparation tool where numerous noncommercial stems remain after harvest. A fire encourages sprouting from below ground, which places all species on a more or less equal footing when competing for site resources.

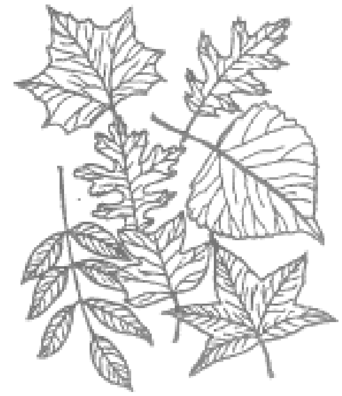
Table 10-1. Herbicides labeled for tree injection, basal application, and stump sprays in the South (1992).

Product	Active ingredient	Label Use		
		inject	basal	stump
Access	17% picloram + 32% triclopyr	N	N	Y
Accord	41% glyphosate	Y	N	Y
Arsenal	54% imazapyr	Y	N	Y
Banvel	60% dicamba	Y	N	Y
Banvel CST	17% dicamba (ready to use)	Y	N	Y
Chopper	4% imazapyr (ready to use)	N	Y	Y
Garlon 3A	44% triclopyr	Y	N	Y
Garlon 4	62% triclopyr	N	Y	N
Pathfinder	17% triclopyr	N	Y	Y
Roundup	41% glyphosate	Y	N	N
Super Brush Killer	32% 2,4-D + 32% 2,4-DP + 5% dicamba	Y	Y	Y
Tordon 101M	10% picloram + 40% 2,4-D	Y	N	Y
Tordon 101R or Tordon. RTU	5% picloram + 21% 2,4-D (ready to use)	Y	N	Y
Weedone 170	29% 2,4-DP+ 30% 2,4-D	N	Y	Y
Weedone CB	12% 2,4-DP + 12% 2,4-D (ready to use)	N	Y	Y

Table 10-2. Herbicide effectiveness on several frequently encountered hardwood species.

Species	Susceptibility*					
	dicamba	imazapyr	glyphosate	picloram	triclopyr	2,4-D
Sweetgum	I	S	S	I	S	I
Red oak	I	S	S	S	I	I
White oak	S	S	I	S	I	I
Blackgum	I	S	T	S	I	S
Red maple	T	S	T	I	I	
Hickory	T	I	T	I	S	
Dogwood	T	S	T	I	I	T
Elm	T	T	T	S	I	T
Pine	S	T	S	I	S	T

* S = Susceptible or easy to kill
* I = Intermediate
* T = Tolerant or hard to kill



11. Hardwood Silviculture: Even-aged and Uneven-aged Systems

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Hardwood silviculture is extremely complex. More than 40 commercial hardwood species make up the southern hardwood forest. These commercial species grow in association with one another and are mixed with an additional 250 noncommercial species.

Silvicultural systems produce healthy forests, regenerate new forests and stabilize the environment. Silviculture is implemented, to a large degree, with timber harvesting, which creates openings, removes competition, controls species, and regulates stand density.

There are two broad silvicultural systems based on tree ages. Even-age silviculture has trees within a stand as one or two age classes and uneven-age silviculture with three or more age classes. Figuke 11-1 graphically depicts how heights and diameters are distributed in the two types of forests. In even-aged forests the upper canopy will appear smooth because the trees are generally all in one height class. In a similar way the diameters of the trees in an even-aged stand will be uniformly grouped around an average diameter. Conversely, in unevenaged stands trees will be distributed with many heights, so several canopy layers are present. Tree diameters will vary greatly with many trees in the small diameters and continuous decreasing numbers of trees in each successively larger diameter class.

Within the two broad classes of silviculture there are five methods of forest regeneration. The variety of methods offers owners of hardwood timber flexibility in management and regulation of their forest. Keep in mind, each system is distinctly designed to carry out a specific purpose and must be based on tree biology (silvies). Also, each hardwood species has unique silvicultural characteristics that must be considered in management.

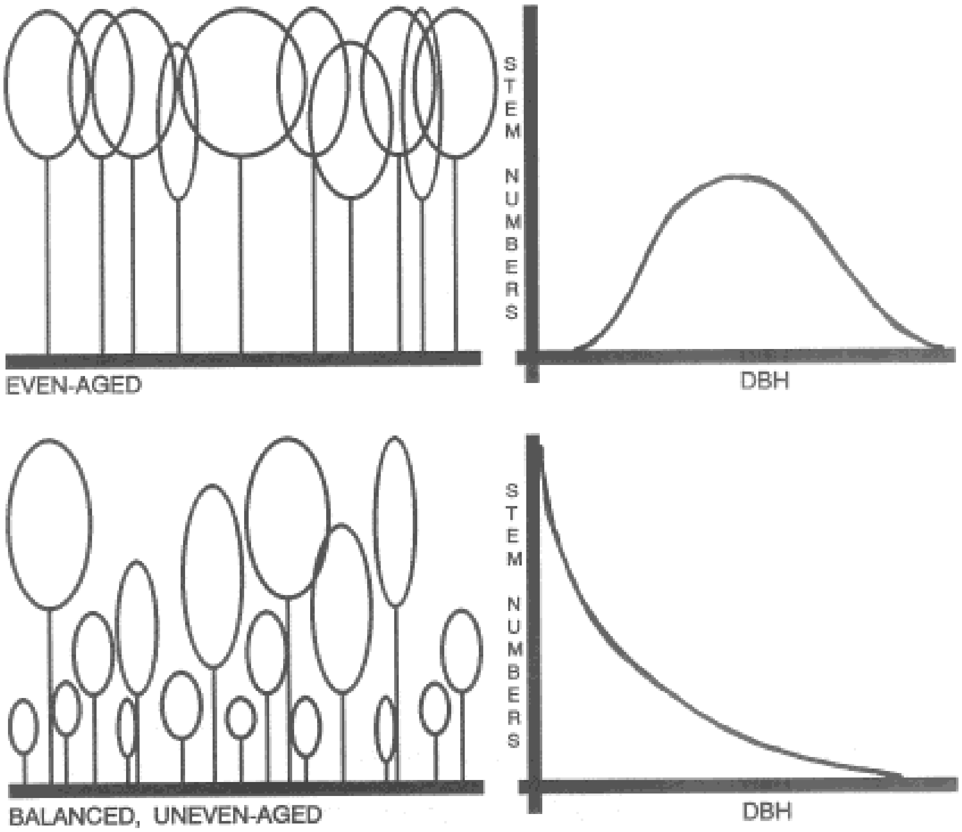


Figure 11-1. Height and diameter (d.b.h.) distributions of trees grown in even-aged and uneven-aged stands.

EVEN-AGED SYSTEMS

A stand is even-aged if the age difference between the youngest and oldest trees is less than 20 percent of the length of the rotation. For example, if an even-aged stand is managed on a 50year rotation (trees will be no older than 50 years at harvest), the oldest trees are no more than 10 years older than the youngest trees. The upper canopy of tree crowns is smooth in an even-aged stands because trees are mostly of sin3dlar heights. Tree diameters can differ greatly within a stand because diameter is affected by competitive conditions. The diameter distribution curve of these stands has a normal bell shape with many trees close to the average, and fewer trees of much larger or smaller diameter.

Methods used to produce even aged hardwood stands include clearcuts, seed tree cuts, and shelterwood cuts.

Clearcuts

In a clearcut all trees I inch in diameter at breast height (d.b.h.) and greater are cut or deadened. This method is useful for those species intolerant of shade (table 11-1). Regeneration from clearcuts normally depends on stump sprouts and seeds in place. Densities as high as 30,000 seedlings per acre have been produced in hardwood clearcuts designed for natural hardwood regeneration. Clearcuts can range considerably in size. Preferably, clearcuts should be irregularly shaped and be no larger than 40 acres, depending on terrain, age of adjacent stands and nearness to streams.

Shelterwood

In a shelterwood, the overstory is gradually removed in a series of harvests to provide shelter for regeneration. The initial harvest will remove all but 20 to 50 trees per acre. The number of trees left depends upon advance regeneration already present and species desired.

A second harvest is required after the new stand has been regenerated to remove the overstory, releasing the newly established even-age hardwood stand. Species that regenerate well in a shelterwood are intermediate in tolerance to shade (table 11-1).

Seed Tree

Hardwood regeneration with a seed tree cut requires that 6 to 15 trees per acre, evenly spaced, are left to produce seed to regenerate the new even-age stand. After establishment of the new stand, the seed trees must be removed or deadened. This method is useful to regenerate light-seeded species that are intolerant to shade.

UNEVEN-AGED SYSTEMS (SELECTIONS)

Selection silviculture was originally developed in Switzerland as a way to rehabilitate hardwood stands that had been cut heavily. Similarly, many hardwood forests in the Eastern United States have been cut heavily, by removing the largest trees (often referred to as diameter limit cuts). Diameter-limit cuts are wrong, and should never be practiced in hardwood selection silviculture. Hardwood stands that have always had only the larger trees cut produce stands that are out of *balance.* Out of balance stands need to be either brought back into a manageable state with single-tree selection, or completely regenerated with even-aged silviculture.

An uneven-aged, balanced forest is a forest of high diversity. A balanced forest managed under selection silviculture will eventually have trees of many ages, species, sizes and uses. Moreover, a balanced, uneven-aged forest is stable, so there is small likelihood of forest stress and pests eliminating the entire stand.

Single-tree Selection

This is one of two selective methods to regulate an uneven-aged hardwood forest. Single-tree selection removes trees from all diameter classes. The goal is to produce a stand with a balanced distribution of trees in all diameter classes with many small trees and a decreasing number of trees in each next larger diameter class. This process requires several harvests to bring the stand under regulation. Choosing a stewardship logger is important as damages to residual trees must be kept to a minimum. Single tree selection also requires detailed record keeping and patience. All hardwood species can be managed under this method, but those trees tolerant to shade will be favored in regeneration.

Group Selection

This selection method produces a balanced forest of stands of several ages. Group selection develops patches of even-aged stands scattered throughout the forest as groups. In group selection, groups of trees are harvested to create 0.1 to 1.5 acre openings. These openings then regenerate to intolerant species, like small clearcuts, but a forest of many different-aged stands results. Group selection relies on maintenance of an uneven-aged balanced forest.

There are pros and cons to unevenaged, selection silviculture. Table 11-2 explains the advantages and disadvantages for producing an unevenaged, balanced forest.

Table 11-1. Tolerance of hardwoods to shade is important in selecting the silviculture system to be used for natural regeneration. The listing below shows the relative light tolerance for several commercial hardwood species.

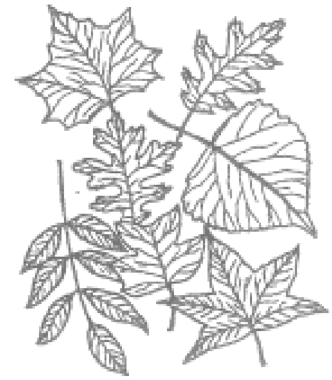
Shade tolerance

Intolerant	Intermediate	Tolerant
Red oak spp.	White oak spp.	Red maple
Black walnut	Persimmon	Sugar maple
Black cherry	Baldeypress	Hornbeam
Sassafras	Blackgum or tupelo	Beech
Ash	Hickory spp.	Magnolia
Locust		Mulberry
Yellow-poplar		Dogwood
Sweetgum		
Cherrybark oak		
Hackberry		
Cottonwood		
Willow		
Birch		

Table 11-2.Summary of advantages and disadvantages of selection silviculture for uneven age management.

PRO	CON
CANOPY	
Crowns of all sized trees, many ages produce a layered canopy for wildlife.	Prevents development of high quality oak large volume oak sawtimber.
REGENERATION	
Maintains high level of young trees at all times.	Prevents growth and regeneration of some hardwoods.
VOLUME	
Spreads wood production to trees of all sizes.	Cannot be regulated on a volume basis alone.
SIZE OF TRACT	
Suited for hardwood woodlot management smaller than 50 acres.	Difficult to regulate on hardwood tracts larger than 50 acres.
QUALITY OF TIMBER	
Produces greater variety of sawtimber.	Reduces annual production of high quality sawtimber, increases volume of small trees that may be unmerchantable.
SUSTAINED HARVEST	
Allows owners to select trees for harvest more frequently.	Requires removal of small trees that may not be salable.
RECORD KEEPING	
Accurate records for appraisal and future decision making always available.	Requires detailed 100 percent inventory of all trees more than 2 inches in diameter.
COMPOSITION	
Produces communities desirable for a wide variety of wildlife species.	Leads to eventual change in forest composition to tolerant trees that are less valuable in terms of timber.
AGE DISTRIBUTION	
Develops stands with trees of many ages.	Difficult to judge annual growth rates.
DIVERSITY	
Selection produces stands with more species, ages, tree sizes and canopy levels.	Produces stands that are more complex and therefore, more difficult to harvest and maintain.
ECONOMICS	
Spreads cash income on a more continuous cycle.	Not considered economical for hardwood management because of difficulty in record keeping and significant losses in high-value sawtimber volumes.

12. Artificial Regeneration Techniques



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Hardwood plantations are not as commonplace as pine plantations. It is generally most cost effective to naturally regenerate hardwoods following a carefully planned and executed harvest (see chapter 10). However, in cases where plantations are desirable, such are reclaiming agricultural fields, disturbed landscapes or when management for a particular species is desired, plantation establishment is possible. The first important step in plantation establishment is to carefully evaluate the potential site and determine the species or mix of species that would be suited to those site conditions. A good place to start is with soil survey maps and descriptions available for most counties from your local Soil Conservation Service office.

Use the soil survey to determine soil type, texture, and drainage for each plantation site. Over large acreages soil characteristics can change to the extent that different hardwood species would have to be planted. For example, cherrybark oak, a highly desirable red oak, exhibits best growth on first bottoms and terraces of stream and river flood plains. Soils of the terraces and first bottoms are generally medium-textured loams. These provide sufficient internal drainage to support cherrybark oak. However, fine-textured clayey soils of wetter flats adjacent to the first bottoms and terraces lack sufficient internal drainage to support cherrybark oak. On these wetter flats Nuttall oak, green ash, sugarberry and red maple would be found. Several species-site guides are available to help match the proper hardwood species to the site (chapter 2).

Be sure to clearly establish the objective for your hardwood plantation. Do you wish to produce walnut logs and nuts, oak sawtimber, provide mast production for wildlife, or simply create a hardwood forest habitat? Each set of objectives will need to be evaluated to determine which species or species mix can be considered for your site. Remember that you must match the species to the site. Planting walnut on a sandy soil in the Coastal Plain would be a poor investment. There may also be constraints on marketing if the industry is not established in your area to purchase products produced. Check with a professional forester who is experienced in hardwood markets and production in your area before planting a species not commonly utilized locally.

PLANTING

Planting is usually done in the dormant season as with pine. Through the South planting occurs from January through March. On sites where flooding into late spring prevents dormant-season planting containerized seedlings or bareroot stock that has been in cold storage can be planted after flood waters recede. Sites can be prepared for planting by mowing, disking or burning. Subsoiling along intended planting rows to shatter plowpans or hardpans may be beneficial on agricultural and pasture land. Fertilizers should only be applied when determined necessary by a soil test.

Quality planting stock is a vital link is successful plantation establishment. Hardwood seedlings are generally much larger than pine seedlings with tops of 18 inches and minimum root collar diameters of 3/8 inch. When selecting seedlings pay particular attention to their root systems. Seedlings should have a well-developed taproot with at least three to five lateral roots 1/8 inch or larger in diameter. The overall length of the root system is usually 8 inches to facilitate planting.

Hardwood seedlings cost several times more Ulan pine seedlings. To produce quality seedlings nurseries must grow them at lower bed densities than southern pines, which requires more bed space to produce a thousand seedlings. Difficulty in seeding, cultural activities and lifting and storing add to the cost of quality hardwood seedlings. Choose your nursery and source of seedlings carefully. Favor seedlings produced from local sources.

Storage and handling of hardwood seedlings can be difficult because of their greater size and bulk. Schedule seedling pickups with your nursery so that you take only enough seedlings that can be planted in several days or that can be safely stored. Ideal storage conditions would be in a cooler kept at 330 to 400 F. Seedlings can be stored in sheds or barns provided the seedlings are kept shaded, and do not freeze or experience temperatures above 500 F. Keep storage time in sheds and barns to a minimum- For storage over 2 weeks use cold storage or delay pickup from the nursery. Seedling quality deteriorates quickly when seedlings are exposed to wind and high temperatures.

Remove only enough seedlings from storage that can be planted in one day. During planting seedlings should be carried in buckets or bags to keep their roots moist. Seedlings can be dipped into a synthetic water-holding gel or packed in wet moss to prevent water loss. Do not allow planters to carry seedlings by hand, exposing roots to wind and sun.

Hardwood seedlings require larger planting holes than most pines. The KBC dibble, which has a blade 12 inches long and is triangular in cross-section, may be suitable for some hardwood seedlings. Tree planting spades, post-hole diggers and power augers are also used to plant large seedling stock. Planting machines can be used provided the coulter and planting foot allow proper placement of the seedlings. Proper planting depth is critical. Seedlings should be planted with the root-collar just below the soil surface. Planting too deep can force the roots to curl or j-root in the bottom of the planting hole. Shallow planting exposes the root-collar and roots to drying by sun and wind. Finish the planting by tightly packing the soil around the seedling roots to eliminate air pockets.

Spacings for hardwood plantations generally range from 10 x 10 feet up to 20 x 20 feet. From 100 to 450 trees are usually planted per acre. To account for mortality consider planting 300 to 400 trees per acre and then thinning to fewer crop trees later in the rotation.

DIRECT SEEDING

Planting seed directly on the site, has received a great deal of attention in recent years. Many successful oak plantations have been established in the South by direct seeding. This is an effective and economical way of establishing oak plantations. With over 1,400 seeded spots per acre, micro-site differences can be best exploited by individual seedlings.

You can purchase acorns from collectors and nurseries or gather them yourself during the fall. Select several likely seed-producing trees in the summer and monitor acorn development. Begin collection as soon as they begin to fall which, in the South is usually from. October to January. Acorns should be floated in a tub of water immediately after collection, discarding all acorns that float. Sound acorns will settle to the bottom of the tub. Drain the moisture from the acorns and pack them into a resealable plastic bag and store in a refrigerator at a temperature of 33° to 40° F.

Before the acorns are ready to plant the red oak species must be stratified. Stratification reproduces the natural process that the acorns undergo as they overwinter in cool, moist conditions until spring. Check with a forester or nursery personnel to determine if the acorns you collected need to be stratified before planting. Stratification involves soaking the acorns in water for 24 hours and then placing them back into refrigeration for 30 to 90 days, depending on the species. Acorns from the white oak group do not require stratification.

To prevent seed predation by rodents, direct-seeded areas should be at least 2.5 acres in size and be sufficiently site prepared to eliminate cover for rodents. Sow acorns 2 to 3 inches deep, 2 to 3 feet apart in rows 10 to 15 feet apart. This requires 1,450 acorns per acre. Seeding can be done by hand or by machine. Seeding can done from fall through spring. On sites where flooding persists until late spring, seeds that have been stored and stratified over winter can be sown as soon as the water recedes.

PLANTATION MANAGEMENT

After planting weeds can be controlled by mowing, disking or use of appropriate herbicides, as required. For plantations established under the Conservation Reserve Program, mowing, not disking, is allowed for weed control. Check with a wildlife specialist to determine the best time to mow to minimize disturbance of nesting birds and other wildlife. If herbicides are used for weed control, be sure to follow all label instructions concerning rates and application. Your extension forester can assist you in a herbicide prescription.

Deer, rabbits, nutria, beaver, voles and other animals can damage seedlings. On large plantations control is not practical. However, because of the sprouting potential of most hardwoods, even damaged seedlings generally survive predation. Specimen plants or small groups of mast-producing trees can be protected with fencing or tree shelters.

Thinning may be desirable to maintain acceptable growth rates or to produce certain products. Cottonwood planted on a 10 x 10 foot spacing may be thinned when trees reach pulpwood size, to a 20 x 20 foot spacing to produce sawlogs. Have your forester write a detailed management plan concerning intermediate-age treatments such as thinning.

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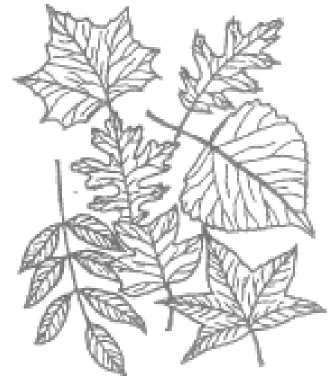
13. Economics of Hardwood Timber Management: Ranking Alternative Uses



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Landowners often ask if it pays to own and manage hardwood stands. The correct economic answer to such a question is that "it depends." Financial returns may be competitive with other investments, depending upon strength of local markets, quality of trees, stocking levels of desirable species, site quality, size and location of the tract and several other factors. The purpose of this chapter is to present the process for financial analysis used in evaluating alternatives. The intent is to help the landowner understand the framework for analysis and evaluate options presented by professional foresters and consultants.

Financial analyses are made in a variety of ways, using different assumptions, and varying measures of performance. You must have a grasp of these basic concepts to make the correct financial decisions for your particular situation. Nonindustrial private forest landowners (NIIPF) commonly ask one of two questions: "Should I buy land and manage it for timber production?" Or, "since I already own the land (and intend to keep it) should I grow trees and invest in more intensive timber management?"

The first question relates to the complete timber production investment while the second concerns the return on specific treatments or marginal analysis. The main difference between the analyses of the two questions lies in handling. Assume that a landowner does not intend to sell his or her land under any circumstances and merely wants to know whether or not to make an additional investment. Then he or she may choose to exclude land costs and consider only marginal analyses. However, the basic process of financial analyses and economic decision-making are the same whether one is considering the complete timber production investment or marginal analysis.

I. FRAMEWORK FOR FINANCIAL ANALYSIS

The first step to any financial analysis is to identify all possible options or alternatives. This may include comparisons between forestry versus certificates of deposit, stocks, bonds, mutual funds, or other investments. When you ignore the opportunity of selling the land it may also include options such as forestry versus agricultural use or different management options for a timber stand (planting, natural regeneration, precommercial thinning, commercial thinning, fertilization, weed control, or just leaving the stand to grow). Each option or alternative must be considered suitable for the landowner's or investor's goals. It must also specify a management activity schedule to accomplish that option.

The second step is to determine the yield response to each treatment. For forestry treatments, the additional quality and quantity of timber available as a result of each treatment must be forecast for estimated harvest times. The estimates of yield response require growth projections using yield models and stand tables (see Section 111D. Since there is usually uncertainty associated with these projections, it is wise to compute a range of yields based on each treatment. This way minimum and maximum financial returns are calculated.

The third step is to estimate the costs and revenues that occur with each option. These costs and revenues may be one time, annual, or periodic costs. Examples of one-time costs may be site preparation and planting. Annual management costs include those costs that are usually deductible on a yearly bans from Federal and State taxes. They include salaries, professional fees, maintenance of roads, fences and equipment, fire protection, insect and disease control, and annual property taxes. Periodic expenses may include thinning, f1brtilization and weed control. Although revenues largely accrue when the stand is harvested, revenues from commercial leases or other recreational uses and mineral revenues may occur.

The process of estimating costs and revenues over time is called developing cash flows. Each activity, when it is to be done, the amount to be done and the cost per unit value are all specified. For example, site preparation will be done in year 0 on 100 acres at a cost of $50 per acre, or harvest of 100,000 board feet of timber will occur at year 30 producing an income of $85 per thousand board feet.

***Special Note*.** Although we may know the cost and prices for each activity, the cost or price of an activity at some future time involves estimates. Costs and prices change over time due to inflation and to differences in the rates of change relative to one another. The rate of value change is usually an annual percentage change of the current value. For example, we may know that red oak is selling for $85 per thousand board feet, today. We may expect a real price increase of 2 percent per year over inflation. If inflation is included in the percentage of price increase, it is a nominal rate as opposed to a real rate. Either way to estimate costs and prices in the future is acceptable as long as they are all done consistently.

The fourth step of financial analysis is to compute financial returns. Financial returns are usually computed on an after-tax basis, or presented both before and after tax. Income tax laws and regulations can have a large effect on financial returns because annual taxes are a cost to the landowner. Some tax benefits can add to spendable income. Recent changes in the tax laws have altered the use of capital gains and affected how management costs, taxes and interest are deducted from gross income. A landowner/investor should be aware of how taxes are handled in computing financial returns.

A sensitivity analysis should also be done when computing financial returns. As discussed above, financial analyses demand that assumptions are made concerning costs, prices, yields and discount rates. Low or high estimates can lead to unrealistic calculations of financial returns and to the wrong decision. A sensitivity analysis changes each assumption and computes the returns under a range of conditions.

The final step in any financial analyses is to compare investment returns and select the best option. Landowners should remember that any one measure of financial return or performance does not convey all the important information about an investment. Although returns may look extremely profitable, an investor may not have the capital needed to make an investment. Financial analyses usually do not consider multiple forest management goals which include wildlife management and recreation in addition to timber production. In most cases some profit will be traded away to meet nonmarket goals. A landowner needs to make these goals clear and concise before financial analyses will help in decision-making.

II. FINANCIAL INVESTMENT CRITERIA

The most useful measures of financial performance recognize that money in hand today is worth more than the same money received at some future date. This "time value" of money is handled by discounting costs and revenues, which occur at different times, to the same point in time, and comparing them. It is also for this reason that treatment options must be compared for investments of the same length or for investments that extend to a common year. The "discount rate" (cost of capital) is the minimum annual rate of return that is acceptable for the investment.

The four performance criteria below are useful in deciding whether to undertake a certain forestry project and in choosing among mutually exclusive alternatives. Mutually exclusive means that you can do one or the other (plant soybeans or cottonwood trees), but you cannot maximize both on the same piece of land. Again, it is wise to remember that no measure of performance can convey all information about an investment.

Net Present Value (NPV)

In this analysis, each cost and revenue is converted to its present value using the "discount rate." For example, assume a thinning operation win cost $50 per acre 10 years from now. Then, the actual cost in today's terms (assuming a discount rate of 8 percent) is $50 divided by (1.08)'o or $23.16. The <u>sum</u> of all discounted costs (negative) and revenues (positive) is the net present value (NPV). It is the increase in the present value of the landowner's wealth from undertaking the project. A net present value greater than zero means that the project will earn a profit of the discount rate plus an amount equal to the NPV. If NPV is a positive value, then the project is worthwhile. In choosing between mutually exclusive alternatives, the project with the highest NPV is preferable. NPV is the most accurate performance criteria to use.

Rate of Return

The rate of return (ROR) is also known as the return on investment or the internal rate of return. ROR is the most commonly used measure of financial performance. It is, by definition, the discount rate that results in a net present value (NPV) equal to zero when all costs and revenues are discounted to the present. If the rate of return exceeds the discount rate, then a project is acceptable. Between mutually exclusive projects, the project with the highest ROR is chosen. A characteristic of ROR is it measures profitability as a ratio (earnings to invested capital) rather than as an absolute dollar amount (as does NPV). The ROR also assumes that any intermediate revenues are reinvested at the same rate. While ROR cannot be computed directly and must be found by trial and error, computer programs are available to simplify this task. ROR has the advantage of being directly comparable to rates of return on other readily available investment opportunities (i.e., certificates of deposit, stocks, bonds, etc.).

Benefit/Cost Ratio (B/Q

The B/C ratio is found by discounting all costs and revenues (benefits) to the present as in NPV calculations above. Then, the ratio of benefits to costs is computed. A ratio greater than LOA shows that a project is acceptable because the benefits exceed the costs. Between mutually exclusive investments, the project with the highest ratio should be chosen- A ratio of 1.2:1 means that $1.20 of benefits are produced for every $1.00 invested.

Annual Equivalent Value (AEV)

This measure is also known as the equal annual equivalent. It is simply the net present value (NPV) expressed as an annuity. AEV permits comparisons between investments that have annual returns (agriculture) with projects that generate periodic returns (timber). The project with the highest AEV is selected when comparing mutually exclusive investments.

III. FOREST MANAGEMENT EXAMPLE

The principles of financial analysis are best illustrated by an example:

Ms. Tulip Poplar is actively involved in the business of tree farming. She is thinking about adding to her holdings by buying a 100 acre tract of 20-year old yellow-poplar timber growing on a good site (site index r'0 = 100). The stand fits in well with her other property and is well-stocked with trees. However, the yellow-poplar trees are not yet big enough to support a commercial thinning. Nonetheless, the asking price of $300 per acre appears reasonable.

Ms. Poplar is 35 years old. In 30 years, at age 65, she plans to sell all of her timber properties, retire to a subtropical climate and enjoy the fruits of her labor. Thus, if she buys this tract she would plan to thin it in 10 years to 65 square feet of basal area, thin again in 20 years to 65 square feet of basal area and sell in 30 years. If she does not buy the 100 acres, she would invest her money in other forestry projects where she can expect an 8 percent return at minimum. Should she buy the yellow-poplar tract? Can she make an 8 percent or better return on it?

To help answer these questions, M]s. Poplar sat down at her microcomputer and called up the YIELDplus program (Version 2.1 by Todd E. Hepp, Office of Natural Resources and Economic Development, Division of Land and Economic Resources, Tennessee Valley Authority, Norris, Tennessee 37828)1. This program features both biological growth and yield functions and an accompanying financial analysis package. According to YIELDplus, she could expect these yields if she followed the proposed harvest plan.

Years in future	Stand age		Yield Sawtimber (MBF)	Pulpwood (cords)	Total (cords)
10	30		0	8	8
20	40		1	4	6
30	50		16	4	41
		Total:	17	16	55

[1] YIELDplus was developed by the Tennessee Valley Authority and is available from Forest Resources Systems Institute, 122 Helton Court, Florence, AL 36M.

Upon checking her records and other information available to her, Ms. Poplar made the following assumptions concerning costs, prices, tax rates, interest rates and rate of inflation:

1. Marginal tax bracket: 28 percent.

2. Average annual rate of inflation: 3 percent for all costs and prices.

3. Discount rate: 8 percent, before taxes. However, since interest is deductible, the after-tax discount rate is 5.8 percent. That is,

   After-Tax Rate = Before-Tax Rate (1 - 0
   where, t = Marginal Tax Rate
   = (. 08) (1 - .28)
   = (.08) (.72) = .058 = 5.8%

4. Annual management and taxes: $5 per acre.

5. Timber prices:
   Sawtimber = $80 per
   MBF. Pulpwood = $5 per cord.

6. Cost of land and timber:
   Land = $250 per acre.
   Timber = $ 50 per acre.
   Total = $300 per acre.

Combining the yield information with the cost and price assumptions generates the following cash flows for the tract

CASH FLOWS BY YEAR
(uninflated dollars per acre)

Year	Revenue	Expense	Net	Cumulative Net
0		-300.00	-300.00	-300.00
1		-5.00	-5.00	-305.00
2		-5.00	-5.00	-310.00
3		-5.00	-5.00	-310.00
4		-5.00	-5.00	-320.00
5		-5.00	-5.00	-325.00
6		-5.00	-5.00	-330.00
7		-5.00	-5.00	-335.00
8		-5.00	-5.00	-340.00
9		-5.00	-5.00	-345.00
10	34.06	-5.00	29.06	-315.94
11		-5.00	-5.00	-320.94
12		-5.00	-5.00	-325.94
13		-5.00	-5.00	-330.94
14		-5.00	-5.00	-335.94
15		-5.00	-5.00	-340.94

(continued)

(continued)

CASH FLOWS BY YEAR
(uninflated dollars per acre)

Year	Revenue	Expense	Net	Cumulative Net
16		-5.00	-5.00	-345.94
17		-5.00	-5.00	-350.94
18		-5.00	-5.00	-355.94
19		-5.00	-5.00	-360.94
20	30.59	-5.00	-5.00	-335.35
21		-5.00	-5.00	-340.35
22		-5.00	-5.00	-345.35
23		-5.00	-5.00	-350.35
24		-5.00	-5.00	-355.35
25		-5.00	-5.00	-360.35
26		-5.00	-5.00	-365.35
27		-5.00	-5.00	370.35
28		-5.00	-5.00	-375.35
29		-5.00	-5.00	-380.35
30	1550.62	-5.00	1545.62	1165.27

Computation of the financial returns on this investment reveals the following (per acre basis):

Net Present Value	= $178.22
Rate of Return	= 7.3%
Annual Equivalent Value	= $12.62
Benefit/Cost Ratio	= 1.3:1

Based upon the results of the financial analysis, Ms. Poplar decided that this investment is sound. N_PV is a positive $178.22. This suggests that the yellow-poplar tract will earn a profit of 5.8 percent (the after-tax discount rate) plus an increase of $17,822 ($178.22 per acre x 100 acres) in the present value of her wealth--net of taxes. The Rate of Return actually generated by this investment is 7.3 percent. This is 1.5 percent above the discount rate. Annualizing the net returns shows an Annual Equivalent Value of $12.62 per acre per year. This can be compared to annual returns from row crops on this or similar sites. According to the Benefit/Cost Ratio, $1.30 of benefits are produced for each $1 invested in yellow-poplar.

While Ms. Poplar did decide to buy the tract, she is not certain that her proposed plan is the best approach. A consulting forester presented an alternative to her. The consulting forester suggested a precommercial thinning immediately, at age 20 to 40 ft2 of residual basal area. The rest of the management *scheme would* remain the same. That is, the stand would be thinned to 55 ft2 of basal area at age 30, thinned again at age 40 to 65 ft2 of basal area, and sold at age 50. The precommercial thinning would cost $50 per acre. The remainder of the cost and price assumptions remain unchanged.

New runs on the YIELDplus program show that the following additional yields can be expected from the pre-commercial thinning at age 20.

Years	Stand	Additional Yields	
in future	Age	Sawtimber	Pulpwood
		QVIBF)	(cords)
10	30	0	-1
20	40	2	
30	50	1	1
	Total	3	0
6			

Note that the pre-commercial thinning actually produces a 1-cord-per-acre reduction in yield at age 30. However, this loss is more than compensated for in the harvest at ages 40 and 50.

Marginal cash flows from the precommercial thinning are as follows:

MARGINAL CASH FLOWS BY YEAR

(uninflated dollars per acre)

Year	Revenue	Expense	Net	Cumulative Net
0		-50.00	-50.00	-50.00
10	-5.00		-5.00	-55.00
20	160.00		160.00	105.00
30	85.00		85.00	190.00

Financial analysis of these cash-flows yields these results:

Net present Value	=	$55.99
Rate of Return	=	10.2%
Annual Equivalent Value	=	$3.98
Benefit/Cost Ratio	=	2.44:1

Ms. Poplar concludes from this analysis that the marginal investment of $50 per acre in a precommercial thinning is a worthwhile expenditure. Net Present Value and Annual Equivalent Value are positive, the Rate of Return is greater than the discount rate, and the Benefit/Cost Ratio is greater than 1.0:1.

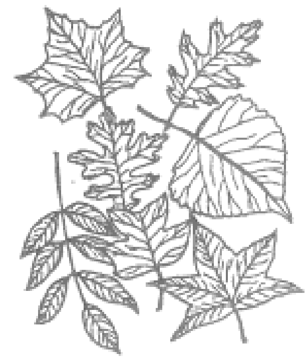
One final question that concerns Ms. Poplar is how sensitive are the results of the precommercial thinning analysis to the necessary underlying assumptions? To partly answer that question, Ms. Poplar varied sawtimber and pulpwood stumpage prices by plus or minus 20 percent from the average. That is:

Product	Price		
	High	Low	Average
Pulpwood	$6.00	$4.00	$5.00
Sawtimber	$96.00	$64.00	$80.00

She then reran the financial analysis, with these results:

Financial Criteria	Price		
	High	Low	Average
Net Present Value	$75.34	$37.60	$55.99
Rate of Return M	11.3	9.1	10.2
Annual Equivalent Value	$5.29	$2.67	$3.98
Benefit/Cost Ratio	2.90:1	1.98:1	2.44:1

Even though prices may vary by as much as 20 percent, the marginal investment in precommercial thinning is still attractive. At the low price NPV and AEV are positive, the B/C ratio is greater than 1-0:1 and the ROR is greater than the discount rate. The sensitivity of results to changes in other variables (e.g., yields, costs, discount rate, tax rates, etc.) can be examined similarly.



14. Logging Practices

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Timber harvesting is an important and necessary part of the management of a vigorous and healthy hardwood forest. A timber harvest may be conducted for a variety of economic or biological reasons. It is the major silvicultural tool available to a forest owner. However, it is important to guard against permanent damage to the forest site when carrying out a timber harvest,

Modern logging operations require careful planning and execution because of the potential for site damage with the heavy equipment currently used. Most States have developed guidelines, commonly called best management practices, that will help landowners and harvesting contractors avoid forest site damage and soil erosion. These guidelines generally include the following recommendations:

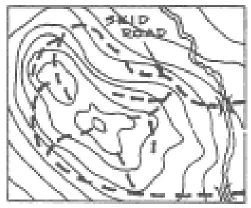
Locate logging roads to compliment natural drainage. Plan road layout in advance and keep skid trails and truck roads well away from streams and drainages. Avoid locating roads on flat ridge tops or benches where water will not drain. See figure 14-1.

Construct logging roads to maximize self-drainage. Outslope roads or construct ditches and drainage structures when necessary. See figure 14-2. Limit road grades to less than 10 percent to avoid rutting caused by wheel slip. See figure 14-3.

Install water turnouts and broad-based dips in the roadbed at strategic locations to divert water into vegetative cover. Construct water bars on skid trails and abandoned roads following harvesting. See figure 14-4.

Maintain acceptable road grades on mountain sides by using switchbacks to gain elevation. See figure 14-5.

Cross larger streams at right angles using a bridge or culvert(s). Ford small streams at points where the disturbance to streambed or banks will be minimized.



PLAN LOG ROAD LAYOUT
IN ADVANCE

Figure 14-1.

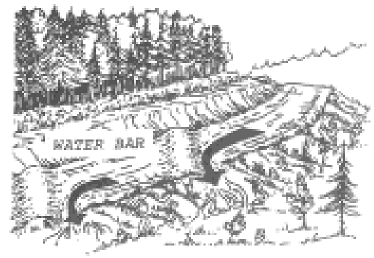
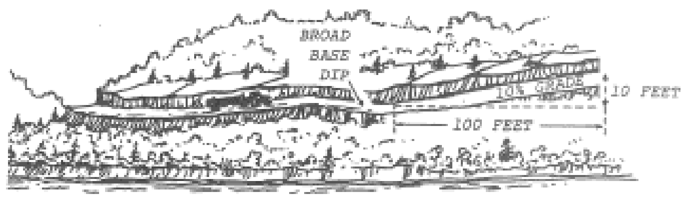


Figure 14-2.



KEEP ALL ROAD GRADES BETWEEN 2% AND 10%

Figure 14-3.

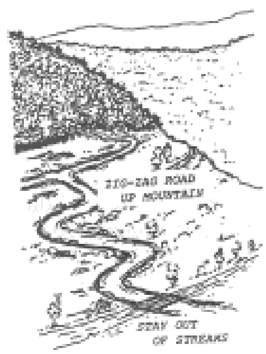


Figure 14-4.

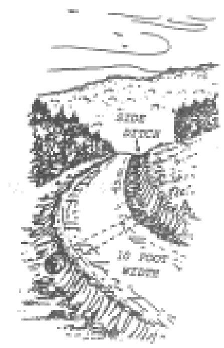


Figure 14-5.

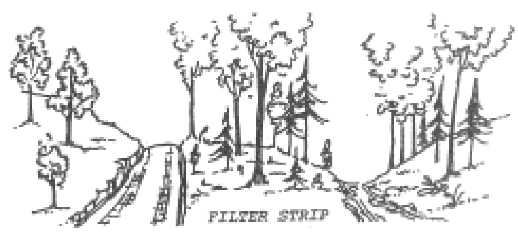


Figure 14-6.

Ffgures 14-1 to 14-6. Examples of best management practices.

Leave undisturbed filter or buffer strips of trees and vegetation in an area at least 50 feet wide on both sides of all streams and major drainages. See figure 14-6. If necessary, high-value trees may be harvested from the streamside zone by careful logging techniques that minize soil disturbance. Directionally fell trees away from the stream and keep heavy equipment out of the filter strip by using the cable and winch on skidding equipment. In all cases, maintain at least 50 percent of the overstory in the filter strip.

Stabilize the soil on log landings and skid trails following harvest by seeding with grass or legumes**.** Also, disk and seed any logging roads that will not be properly converted and maintained as permanent forest roads. (Some State and Federal programs may impact road seeding. See your local Soil Conservation Service for information.)

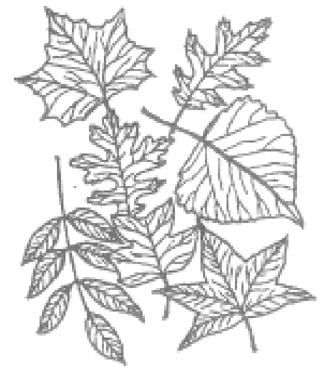
To ensure that best management practices will be used on a timber harvest include them as aprovision of the timber sale contract. While some States require loggers to follow prescribed harvesting procedures similar to those outlined above, most southern States rely on voluntary compliance. As a forest landowner, you should be aware of the laws and regulations in your State regarding timber harvesting and water quality. Contact your local office of the State forestry agency, Soil Conservation Service, or Cooperative Extension Service for specific information.

You can also protect your timberland from excessive logging damage by investigating a prospective timber buyer/logger before making a timber sale. Ask for references and inspect some recently logged sites. Note the condition of the logging roads and skid trails. Have they been properly constructed and stabilized to avoid soil erosion? If the harvest was a thinning or partial cut, are the residual trees largely undamaged? Check the logger's utilization practices by making sure that the entire merchantable portion of each harvested tree has been removed from the site. Loading areas or log landings should be free of oil cans and other trash. The land should be leveled to the original contour, and the soil stabilized. Loggers who measure up to those standards are usually concerned about the condition of the forestland harvested.

The physical entry and operation of the harvesting equipment necessary to fell, skid, load, and haul timber will always impact the forest environment. The negative effects of timber harvesting can be minimized, however, and your forest management objectives reached when proper logging practices are followed.

There are many loggers throughout the South who conscientiously follow best management practices as a normal part of their timber harvesting operations. To ensure the long-term productivity of their timberland, forest landowners should demand no less!

15. Harvesting Techniques



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Hardwood logging techniques differ little from those used for harvesting pines. However, hardwoods are often harvested from sites that challenge conventional harvesting equipment. Mountains and deep swamps, where hardwoods predominate, often force loggers to use different types of logging equipment.

A typical hardwood logging system fells the trees, delimbs and tops them in the woods, skids them a the landing, cuts or bucks each tree to a specific length, loads the wood onto a truck, and transports the load to the woodyard or mill. See figure 15-1. Equipment used in each of these harvesting functions will differ, depending upon terrain conditions and other factors.

HARVESTING FUNCTIONS

Felling

The felling process involves severing the tree and, where feller-bunchers are used, piling severed trees into bunches for a skidder. Chain saws, feller-bunchers, and directional shears are all used for felling hardwoods. In addition, mechanized high production sawheads are gaining popularity in some regions for felling hardwood sawtimber.

Modern chain saws work well for felling hardwoods, although the sawteeth typically need to be sharpened frequently. Drawbacks to using the chain saw on hardwood includes operator danger from falling limbs (widow-makers), imperfectly felled trees that might fall on the operator, and chain saw kick-back that can seriously injure the operator. Many fellers now use synthetic fiber-backed chaps or pants and gloves to protect themselves from potential injury.

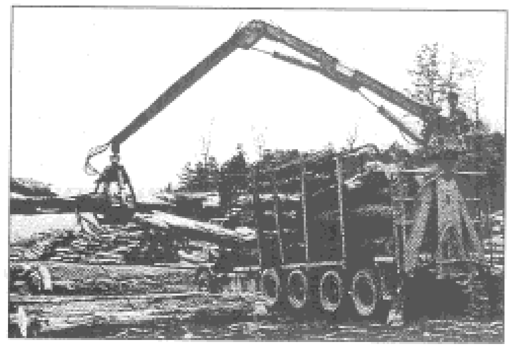
Operating a chainsaw is physically demanding and dangerous. As a result, chain saw productivity is low, averaging less than half a cord per productive operator-hour in some cases. Many logging operations have replaced the chain saw with more mechanized equipment designed to fell trees rapidly without endangering the operator.

The hydraulic shear has replaced the chain saw on many logging operations where the terrain is not too steep or swampy. Two types of shears, the feller-buncher and the directional shear, are used for felling. Both types of shears are mounted on a four-wheel drive, articulated frame, rubber-tired carrier which is usually a converted front-end loader.

Chain saw felling

Feller-buncher

Cable skidding



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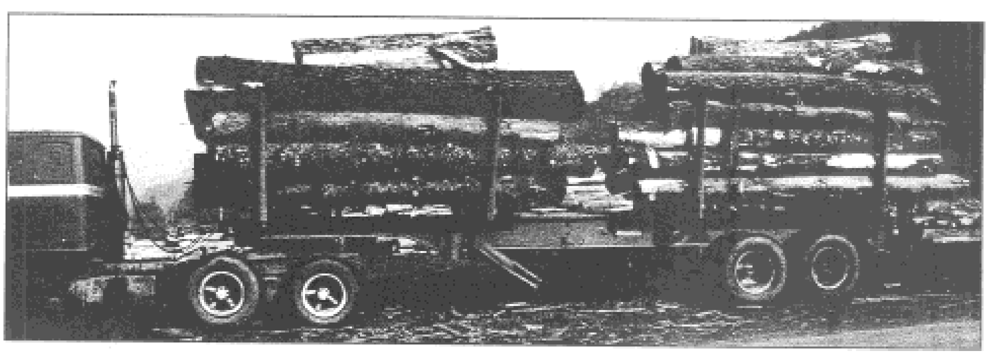


Cut-to-length transport

Figure 15-1. Elements of hardwood logging systems.

The typical feller-buncher shear cuts trees with a pair of blades that act like scissors to sever the tree at or near groundline. These machines can cut hardwoods up to 20 inches d.b.h. at a rate of 2.5 trees per minute under optimal conditions. Feller-bunchers also accumulate trees as they are severed and pile them into bunches for skidding, another feature that increases the productivity of these units.

Feller-buncher shears are often rated to cut one maximum diameter limit for pines and another, lower, diameter for hardwood, because hardwoods are typically more dense than pines. For example, a shear rated to cut 20-inch diameter pine may only be rated to fell a 16-inch maximum diameter hardwood. In swampy conditions, where rubber-tired feller-bunchers are impractical, limited area feller-bunchers that use tracks instead of tires are used for felling and bunching. The tracks provide these units better floatation on wet soils. These units also operate at extremely high speeds, with production rates often exceeding 500 cords per week. However, the expense of owning and operating a limited area feller-buncher limits its use to high-production logging operations.

Because the typical feller-buncher can harvest trees no larger than 20 to 22 inches in *diameter at* the groundline, larger trees must be felled with directional shears. These units use a single blade to sever the tree and drop it in a selected direction. Directional shears are slower and have no ability to bunch trees, but they can fell hardwoods up to 30 inches in *diameter.*

Shears often damage the butt log of felled hardwoods and are not used when valuable sawtimber is harvested. This shear-related damage in hardwood and pine has encouraged development of sawhead feller-bunchers. These new felling heads use either a high-speed chain saw or circle saw to reduce damage in the butt log.

These sawhead units are used by loggers who handle large volumes of sawtimber. Pulpwood is not significantly damaged by shears so many loggers harvesting pulpwood prefer to use the shear. Its other advantages include low maintenance requirements and rugged durability.

Skidding

The type of equipment used to move trees from the woods to the landing depends upon terrain conditions and the type of felling equipment used. Cable skidders, grapple skidders, yarders, and even helicopters are used for skidding hardwoods.

Cable skidders, used in combination with chainsaws, and grapple skidders, used in combination with feller-bunchers, are common on southern hardwood logging operations. These units are four-wheel drive, articulated frame machines capable of skidding up to a cord of wood at a time.

With cable skidders, the operator connects each felled tree to the skidder winch line, winches the trees up to the skidder, and skids the load to the landing. These units work best in mountainous areas and in swamps where chainsaws are required for felling. Because the operator must get on and off the machine to attach the winch lines, the cable skidder is considered a relatively dangerous machine, particularly when compared with the grapple skidder.

Grapple skidders are designed to pick up and skid bunched wood and work best behind a feller-buncher. A typical grapple skidder is equipped with a hydraulic grapple that allows the operator to pick up bunched wood without ever leaving the protected cab. These units are considered safer than cable skidders and, when working with a fellerbuncher, are significantly more productive.

When working in swampy sites, skidders are often equipped with wide tires, up to 48 inches across the tread, to provide better floatation on wet soil. Some loggers use dual tires, where two tires are attached at the rim, for the same purpose. Wide tires and duals allow an operation to continue working during wet conditions. And, because hardwood is often located in swampy sites, many hardwood loggers use this type of equipment to continue logging through the winter rainy season.

Other devices used to move wood from the forest to the landing include yarders and helicopters, although these machines are rare in the South. Mountain and swamp logging operations have used yarders to move wood to the landing, but a lack of well-made, cost-effective equipment limits the use of this equipment. Helicopters are used in limited applications on swampy sites and to remove extremely valuable timber from hard-to-reach mountain locations. In some applications the helicopter is the most cost-effective approach available. These units work best on sites where road building may be impossible or impractical.

Delimbing and Bucking

Hardwoods must be delimbed and where required, cut into merchantable lengths. Most logging operations use chainsaws to delimb and buck hardwoods. Trees are delimbed either where the tree is felled or at the landing. Trees are almost always bucked at the landing to insure proper size, length, and product merchandising.

Because these operations involve using the chainsaw, they are considered the most dangerous jobs on a logging operation. The chainsaw is placed into positions that increase the chance of kickback, while operator movement is often blocked by tree limbs. And, unlike pines, hardwoods cannot be delimbed using a "gate" delimber and do not process well with mechanized delimbers. Until new machines are developed to handle delimbing and bucking hardwood, the chainsaw will be the most practical option available.

Loading and Transport

Most modem logging operations use a hydraulic knuckleboom or heelboom loader for loading harvested wood onto trucks. These loaders are relatively safe, dependable, and easily repaired. Weight capacity for these units will vary and lift capacity ranges between a maximum of 5,000 and 40,000 pounds per lift.

Knuckleboom and heelboom loaders are similar. The heelboom unit is designed to load tree-length material by balancing the butt end of the log against a "heel"' attached to the main boom of the loader. The knuckleboom has no heel and simply holds the log suspended until it is loaded. The knuckleboom loader works best with cut-to-length wood or small tree-length material. On some hardwood logging operations, a small knuckleboom loader is mounted on the haul truck to load the wood. This type of setup is common on operations loading cut-to-length hardwood onto single tandem trucks.

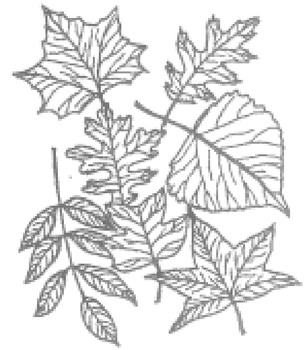
Hardwood is either transported as cut-to-length material, where the tree is bucked into measured lengths before transport, or tree-length, where the whole stem is transported to the mill. Tree-length hauling of hardwood is common in the Piedmont and Coastal Plain flatwoods, but rare in the mountains where these long loads cannot maneuver.

Single tandem or tri-axle trucks capable of handling 20,000 to 60,000 pounds gross vehicle weight are often found on mountain logging operations where the roads are narrow and difficult to travel. These units can haul between 4 and 8 cords of hardwood per load, depending on the truck capacity. Tri-axle trucks provide slightly better traction during wet or frozen conditions.

Diesel powered tractor-trailers capable of hauling up to 10 cords of wood are typically used to haul tree-length hardwood. Hauled wood can extend past the vehicle up to 20 feet beyond the rear of the trailer. A large portion of the hardwood hauled in the Piedmont and Coastal Plain is in tree-length form. Tractor-trailers also haul cut-to-length hardwood and cut hardwood pulp.

CONCLUSIONS

Harvesting operations that remove hardwood timber in the South often rely on conventional logging equipment to get the job done. On steep terrain and in swamps, more specialized equipment is required. Projected increases in demand for southern hardwood species may encourage further specialization in harvesting equipment to meet the raw material needs of the forest industry.



16. Hardwood Products and Uses

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There are many "products" of southern hardwood forests, from the aesthetic charm of the trees to the wildlife that uses them for food and shelter. Of course that list also includes the woody raw material that develops inside the "bark-covered cylinders." Of the great variety of southern ' hardwoods, not all are preferred raw material for wood products. Those most commonly used will be described here. Although most individual hardwood species can be identified when standing as trees, the *wood* from many similar species cannot routinely be separated. These trees are lumped into "species groups" when describing wood properties and uses. The terms used in the following pages are defined in the glossary at the end of this chapter.

In hardwoods, long continuous conducting channels, called pores, run up and down through the trees. These channels are made of short, hollow cells with open ends, stacked on top of one another. Based upon wood appearance, hardwoods can be divided into two groups. The first includes those whose early wood in each annual ring contains large pores, easily visible to the eye on cross sections. These are called *ring porous* hardwoods. If the large pores occur exclusively in the earlywood, it is called "typically ring porous." However, if large pores make up a significant part of the latewood also, it is called *semi-ring porous.*

The other group consists of woods whose pores are very small, numerous, and scattered throughout annual-growth rings. These woods are called *diffuse porous* hardwoods. Woods whose rings are so uniform as to be nearly indistinguishable from one another are called typically *diffuse porous.* Woods that have distinctly larger earlywood pores, are called *semi-diffuse porous.*

Because of their larger pores certain variations in density and cell arrangements can give diffuse porous woods definite grain "figure." Ring porous woods have a much more distinctive grain pattern than diffuse porous woods. Large pores of ring porous woods give them a coarse texture.

Hardwoods vary in structure and heartwood color. Sapwood is almost uniformly light or white-colored, regardless of the species. Some woods have light-colored heartwood, making it difficult to separate from sapwood at times. Although durable heartwood usually is dark, not all dark-colored heartwood is durable.

WOOD DESCRIPTION

Ash

Several species of ash grow in southern timberlands. Their wood is very similar, and most are cut and sold as white ash. White ash and green ash make up about three-fourths of the species cut.

Ash heartwood is light to dark brown, with occasional very-dark-brown streaks. It is ring porous. Small latewood pores are embedded in patches of light colored tissue forming irregular horizontal lines in the outer part of each annual ring. On longitudinal surfaces, large earlywood pores form long bands of irregular vertical streaks, darker than the background. The wood is known for straight grain.

Basswood

This wood is softer than most softwoods. Of the several existing species, American basswood provides the most lumber.

Little color difference exists between sapwood and heartwood, both being yellowish-white to yellowish-brown with a faint pinkish tinge. It is diffuse porous. Ray flecks are fairly distinctive as light reflects off them differently than the wood. Gram is characteristically straight. The wood can have a disagreeably dusty odor.

Beeches

The only native beech is American beech, and it is a commercially valuable species.

Beech heartwood ranges in color from pinkish to light brown. It is diffuse porous. Dense-looking bands of light-colored tissue end each annual ring. Rays are large and easily seen on cross sections as distinct light-colored radial lines producing a distinctive ray fleck. Wood grain is characteristically straight to interlocked.

Sycamore

Sycamore shows little difference between heartwood and sapwood. Sycamore is diffuse porous. Its wood looks sinii1ar to beech. A band of dense but light-colored tissue with few pores separates rings. Rays are broad and easily seen on cross sections, forming a distinctive ray fleck. On tangential surfaces, rays appear as numerous, crowded, short, dark vertical lines. Wood has irregularly interlocked grain.

Cherry

Several cherry species exist, but commercial lumber comes from black cherry. Although not an abundant tree, its beauty and desirability make it worth mentioning.

Heartwood in cherry is a distinctive red, but varies from light to dark reddish-brown. Sometimes a faint greenish tinge may be apparent. The wood is diffuse porous. Pores usually occur in a single row at the beginning of each ring. Rays can be seen easily in heartwood cross sections as light lines against dark wood. Ray flecks are distinctive, being light colored against dark wood. Wood grain usually is straight.

Cottonwood

Many trees are in the cottonwood family. However, only eastern cottonwood and swamp cottonwood are important for timber. Because their wood is so similar, these two are cut and sold together.

Heartwood of cottonwood is light pinkish to gray. This wood is semi-diffuse porous. The wood has straight grain, and can have a disagreeable odor when moist.

Willow

Black willow wood may be confused with cottonwood.

Heartwood is gray or brown. It can be extremely variable, including red or purple. Wood is semi-porous. Wood grain is usually straight.

Elm

The most important elm timber species is American elm. Other elms include red or slippery elm, cedar elm, and winged elm. The wood of American and slippery elms are similar and often sold as soft elm. Cedar and winged elms have similar wood, both being "hard elms" and distinctly different from soft elms.

Elm heartwood is light brown, sometimes tinged with red. Elms are ring porous. Rings are more distinct in those species with the most earlywood pores. In all elms, small latewood pores form wavy bands on cross sections. Interlocked grain is normal.

Sweetgum

Sweetgum is also known as redgum. Two classifications of lumber are available: redgum and sapgum. No structural differences exist between them, but redgum is cut from the colored heartwood, while sapgum comes from nearly white sapwood.

Heartwood ranges from dark pink to dark brown. Irregular, grayish-brown streaks occur throughout heartwood. The wood is diffuse porous with interlocked grain.

Tupelo

Black tupelo and water tupelo heartwood ranges from a light greenish to brownish-gray. A diffuse, porous wood with extremely small pores, like sweetgum. Interlocked grain is prominent.

Hackberry

This wood is produced from two trees, sugarberry and common hackberry. The wood resembles elm.

Heartwood is pale-yellow to grayish-green, frequently stained with bluish streaks. The wood is ring porous. Small latewood pores form wavy bands throughout latewood as in elm. Rings are easily separated. Interlocked grain is common.

Hickory

The species represented by this group are also known as "true hickories", compared to pecan hickories. Trees are shagbark, shellbark, mockernut, and pignut hickories.

Heartwood of hickory is dark reddish-brown. Very dark streaks frequently occur. On longitudinal surfaces, earlywood pores appear faintly but distinctively yellowish against the latewood background. Hickories are considered ring porous. On cross sections, many fine lines run through latewood parallel to ring boundaries, but seldom earlywood. Wood grain usually is straight.

Pecan Hickories

The four species producing pecan wood are: pecan, water hickory, bitternut hickory, and nutmeg hickory.

Heartwood has a reddish-brown color, sometimes with dark streaks. Pecan wood is semi-ring porous. Numerous, fine, light-colored, parrellel lines are evident on cross sections throughout earlywood and latewood. Rings are easy to separate. Grain is generally straight.

Holly

Produced from American holly. Heartwood of holly is white and diffuse porous. Sometimes a bluish tinge occurs in holly, staining the light-colored wood slightly. Straight grain is common.

Magnolia

Southern magnolia and sweetbay magnolia provide lumber. Wood from a third relative, cucumbertree, resembles yellow-poplar lumber, and is often sold as such.

Magnolia heartwood is light to dark brown with a yellowish-green tinge. On cross sections, growth rings are easily separated by an obvious light band. It is a diffuse porous wood. Rays are visible, and a definite fleck can be seen on radial surfaces. Grain is straight.

Yellow-poplar

Also known as tulip-poplar, or tulip tree, is a member of the magnolia family.

Yellow-poplar heartwood is striking green mixed with brown, blue, or black h is a diffuse porous wood. A narrow, light-colored band of tissue separates rings. Rays are numerous and thin, but easily seen on cross sections. Ray flecks on radial surfaces is distinct. Grain is usually straight.

Hard Maple

Because of differences in hardness, maple lumber is divided into hard and soft maples. Hard maples are an important component of hardwood lumber in the upper South, and includes sugar maple, and black maple.

Hard maple has heartwood that is light reddish-brown. It is diffuse porous. Rays are narrow; the largest rays are wider than those in soft maples, being fully as wide as the largest pores. On radial surfaces, a distinctive ray fleck can be seen. Grain is usually straight, with some interesting figures occurring at times.

Soft Maple

This group includes red maple, silver maple, and boxelder.

Soft maple is a light-colored wood with a pinkish-brown cast. Heartwood is slightly darker than sapwood. Soft maples frequently are attacked by insects that leave small holes in the wood. Dark, elongated, streaks often extend up and down several inches from these holes. The wood is diffuse porous. The ray fleck appears dark against a light background. Although straight grain is typical, special figures such as "curly grain" or "birds eye" are not uncommon.

Red Oak

Lumber from the oaks is divided into three categories. Within each group, there are many species. The principal trees from which red oak is cut are: southern. red, cherrybark, Shumard, black, water, willow, laurel, northern red, pin, scarlet, blackjack, and Nuttall.

Red oak heartwood has a distinct reddish appearance. Dark streaks may be found in it. The wood is classically ring porous. Latewood pores are few enough to be "countable". Rays are large, being the major oak characteristic. Ray flecks gives radial surfaces a distinctive figure. Red oak wood, when first cut, has a harsh, sour odor. Straight grain is common.

White Oak

White oak lumber species are white, post, swamp chestnut, bur, chinquapin, chestnut, and swamp white.

Heartwood is gray to brown instead of pinkish as in red oak. White oaks have less color variation than red oak. Wood is typically ring porous. Earlywood pores in heartwood typically fill with crystalline-appearing structures called tyloses. Latewood pores are numerous and small. Large rays are present, producing large and distinctive ray flecks. Straight grain is common.

Live Oak

This species is the hardest and heaviest wood available from southern forests. Wooden ships used it for its special strength characteristics.

Heartwood has a gray color. Wood is neither ring nor diffuse porous. Pores are arranged as in latewood of red oaks, but no large earlywood pores occur. Rays are very wide, forming large flecks. Grain is irregular.

Walnut

Black walnut heartwood varies from light brown to a dark, almost purplish-brown. The wood is distinctly semi-ring porous. On longitudinal heartwood surfaces, pores appear as long, black lines. Has unique grain figures. Can have a distinctive odor.

Many other southern hardwoods yield lumber that is used in a variety of products. However, their commercial contributions are not great. Woods such as honeylocust, sassafras, red mulberry, persimmon, and dogwood, all have interesting and useful properties for certain specialty items.

WOOD PROPERTIES

Wood quality is determined by how well its properties suit the requirements of products made from it. Raw material value depends upon many other factors. Sometimes styles popular to the buying public provide the major influence on demand. However, basic properties or traits will ultimately determine how successfully a raw material can be used.

Because wood is a natural product, it is inherently variable. Variation among species provides wide choices for an assortment of products. Variation *within* a species makes careful quality control necessary. This is to insure that product requirements are met by the wood chosen.

Materials can be described in many ways. Most properties used are related to current uses. As new uses are found, new descriptive tests are developed. The Forest Products Laboratory of the Forest Service has produced the *Wood Handbook,* in which many wood properties are published. Physical properties describe the way wood looks and feels, and how it reacts to such things as water, heat, sound, and electricity. Strength properties indicate how it supports loads or resists stresses applied to it.

In tables 16-1 to 164, white oak is used as a standard for comparison with other woods. Many properties are presented only as rankings, from "high" or "good" down to "low" or "poor".

Table 16-1. Physical properties of common hardwoods, using white oak as the standard of comparison.

Species11	Density 2 (Sp. Gv.)	Ave. HW M.C.	Ave. SW M.C.	Vo1. shrnkg	General Strength
White oak	.67	64%	- 78%	16.3%	High
Ash	85%	72%	65%	77%	High
Basswood	55%	127%	171%	97%	Low
Beech	96%	86%	92%	106%	High
Cherry	75%	91%	...	71%	Moderate
Cottonwood	60%	253%	187%	85%	Low
Elm	82%	127%	99%	94%	Moderate
Gum	78%	123%	176%	97%	Mod. Low
Hackberry	79%	95%	83%	85%	Mod. Low
Hickory	107%	109%	5%	110%	Very High
Holly	85%	---		104%	Moderate
Magnolia	75%	125%	133%	77%	Moderate
Hard maple	90%	102%	92%	88%	High
Soft maple	75%	91%	124%	75%	Moderate
Red oak	96%	127%	96%	92%	High
Pecan	96%	139%	74%	83%	Very High
Sycamore	73%	178%	167%	87%	Moderate
Tupelo	75%	186%	149%	83%	Moderate
Walnut	82%	141%	94%	79%	High
Willow	58%	...	...	85%	Low
Yellow-poplar	63%	130%	136%	78%	Mod. Low

[1]**Physical properties relative to white oak** - percentages for each species may be multiplied by actual values for white oak to obtain values by species.
[2] **Density** - a measure of weight for a particular volume. When it is expressed as specific gravity, water is used as the comparison standard.
SW - sapwood; **HW** - heartwood
MC - moisture content, expressed as the weight of water in wood compared to the dry weight of wood.
Vol. **shrnkg.** - volumetric shrinkage. The total change in volume when dried from the fresh condition to an oven-dry or bone-dry condition.
General strength - an expression combining the relative values of properties such as bending strength, compressive strength, shearing strength, etc.
--- - no information found

Table 16-2. Some uses of common southern hardwoods.

Species	Common uses	Miscellaneous uses	Composites made from it
White oak	furniture, flooring, trim, doors	boats, barrels, handles, crossties	veneered panelling
Ash	handles, sporting goods, furniture	cabinets, trim, solid panelling, barrels	veneered panelling
Basswood	blinds, doors, furniture, cabinets	carvings, bee hives, food utensils, excelsior	crossbands in veneered panels
Beech	furniture, flooring, woodenware	toys, handles, turned items	veneered panelling
Cherry	furniture, woodwork, electrotype blocks	caskets, patterns	veneered panelling
Cottonwood	boxes, baskets, excelsior, pallets	musical instruments	pulpwood, waferboard, strand board
Elm Gum	furniture, boxes, barrels boxes, furniture, wall panelling	caskets, pallets barrels, crossties, pallets	veneered panelling pulpwood, veneered doors, strand board
Hackberry	furniture, boxes	pallets	veneered panelling
Hickory	handles, ladder rungs, athletic goods	meat-smoking fuel, pallets	...
Holly	inlaid furniture, fancy turned items	...	...
Magnolia	painted furniture, blinds, woodwork	boxes	pulpwood, strand board
Hard maple	flooring, furniture, solid panelling	woodenware, charcoal, musical instruments	veneered panelling, pulpwood
Soft maple	furniture, flooring, solid panelling	woodenware, boxes	veneered panelling, Pulpwood, strand board
Red oak	furniture, flooring, trim, doors	handles, barrels, crossties	veneered panelling
Pecan	furniture, handles, pallets	...	veneered panelling
Sycamore	furniture, boxes	crossties, butcher blocks, barrels	...
Tupelo	boxes, furniture	crossties	Pulpwood, strand board
Walnut	furniture, woodwork, gunstocks, cabinets	...	veneered panelling
Willow	furniture cores, boxes, caskets	charcoal	pulpwood, strand board
Yellow-poplar	painted furniture, boxes	caskets, dimension lumber, pallets	veneered furniture, pulpwood, strand board

Table 16-3.Use ratings of common hardwoods.

SPECIES	Driving	Machining	Gluing	Fastening	Durability	Heat Value
White oak	Difficult	Good	Satisfactory	Good	High	High
Ash	Easy	Good	Satisfactory	Moderate	Low	Mod. high
Basswood	Easy	Poor	Easy	Good	Low	Low
Beech	Difficult	Good	Satisfactory	Poor	Low	High
Cherry	Moderate	Excellent	Satisfactory	…	High	Moderate
Cottonwood	Difficult	Poor	Easy	Very Good	Low	Low
Elm	Difficult	Moderate	Well	Good	Low	Moderate
Gum	Difficult	Fair	Well	Moderate	Low	Moderate
Hackberry	Moderate	Good	Well	Moderate	Low	Moderate
Hickory	Difficult	Good	Satisfactory	Poor	Low	Very high
Holly	Difficult	...	...	...	Low	Moderate
Magnolia	Moderate	Moderate	Easy	Good	Low	Low
Hard maple	Moderate	Moderate	Satisfactory	Poor	Low	High
Soft maple	Easy	Fair	Well	Mod. poor	Low	Mod. high
Red oak	Difficult	Excellent	Satisfactory	Good	Low	High
Pecan	Difficult	Excellent	Satisfactory	Poor	Low	Very high
Sycamore	Difficult	Poor	Well	Good	Low	Moderate
Tupelo	Difficult	Poor	Well	…	…	

Table 16-4.General ratings of common southern hardwoods relative to processing procedures, exposure to the elements, and heat value.

SPECIES	Drying	Machining	Gluing	Fastening	Durability	Heat value
White oak	Difficult	Good	Satisfactory	Good	High	High
Ash	Easy	Good	Satisfactory	Moderate	Low	Mod. high
Basswood	Easy	Poor	Easy	Good	Low	Low
Beech	Difficult	Good	Satisfactory	Poor	Low	High
Cherry	Moderate	Excellent	Satisfactory	…	High	Moderate
Cottonwood	Difficult	Poor	Easy	Very good	Low	Low
Elm	Difficult	Moderate	Well	Good	Low	Moderate
Gum	Difficult	Fair	Well	Moderate	Low	Moderate
Hackberry	Moderate	Good	Well	Moderate	Low	Moderate
Hickory	Difficult	Good	Satisfactory	Poor	Low	Very high
Holly	Difficult	…	…	…	Low	Moderate
Magnolia	Moderate	Moderate	Easy	Good	Low	Low
Hard maple	Moderate	Moderate	Satisfactory	Poor	Low	High
Soft maple	Easy	Fair	Well	Mod. poor	Low	Mod. high
Red oak	Difficult	Excellent	Satisfactory	Good	Low	High
Pecan	Difficult	Excellent	Satisfactory	Poor	Low	Very high
Sycamore	Difficult	Poor	Well	Good	Low	Moderate
Tupelo	Difficult	Poor	Well	Moderate	Low	Moderate
Walnut	Easy	Mod. good	Well	Mod. poor	High	Moderate
Willow	Easy	Fair	Easy	Good	Low	Low
Yellow-poplar	Easy	Fair	Well	Good	Low	Low

Drying difficulty-relates to how rapidly the wood dries, and to its tendency to warp and check.
Machining-indicates how well the wood can be planed, turned on a althe, bored, sanded, etc.
Gluing-describes how easy it is to produce strong glue joints. The rankings progress from "easy", to "well", to "satisfactory", to "difficult".
Fastening-relates how successfully the wood can be joined with nails and screws without splitting.
Durability-an indication of the ability of untreated heartwood to consistently resist deterioration when exposed to conditions favoring damage by insects and decay organisms.
Heat value -suggests the relative amount of heat that will be released when buring air-dry wood.
--no information found.

GLOSSARY

Annual (growth) ring: A growth sheath produced during one growing season.

Check: A split or crack in the surface of a log or lumber. Small, minor checks may even be difficult to see, and major checks can turn into wide splits.

Cross section: A wood surface formed by cutting perpendicularly across a log or board.

Diffuse porous: A description of woods with pores that are numerous, scattered throughout growth rings, and are too small to see without magnification. On cross sections, woods with rings that are so uniform as to be nearly indistinguishable from one another are called "typically diffuse porous". Woods having rings with distinctly larger earlywood pores are called "semi-diffuse porous".

Earlywood: The part of a growth sheath that forms first. It makes up the inner portion of each sheath (ring).

Figure: A distinctive grain pattern.

(Ray) fleck: The appearance of the "wide faces" of rays on radial surfaces. Some species have characteristic ray flecks.

Grain: The direction in which major elongated cells are oriented in a piece of wood. Logs or lumber with "straight grain" have these cells aligned with the length of the log or board. Sometimes the term is used to describe ring widths too. "Open grained" describes wood with wide rings, "close grained" is wood with narrow rings.

Green: The condition of being "fresh cut". More specifically it means having wood moisture content above the point where shrinkage begins.

Growth ring: A cross-sectional view of a growth sheath. It contains both earlywood and latewood, and on a whole cross section it forms a complete ring.

Growth sheath: A layer of new wood produced beneath the bark, over the entire "surface" of a tree. This woody sheath is continuous from tree top, to near branch and root ends.

Heartwood: The innermost or central core of a tree in which all cells have died, and in which a variety of natural chemicals has been deposited. It is generally darker than sapwood. Sapwood "matures" into heartwood, although wood structure remains the same. However, deposition products may make heartwood heavier and more decay resistant. Wood moisture content usually differs from sapwood to heartwood, being higher or lower depending on species.

Interlocked grain: An alternating pattern of spiral grain. Moving from the center of a tree outward, the grain spiral fluctuates periodically from an "S" helix to a "T' helix and back again.

Latewood: The part of a growth sheath which forms last. It makes up the outer portion of the sheath (ring) and is characteristically denser, harder, stronger, etc. than earlywood.

Longitudinal surface: Wood surface produced when cutting along the length of a log.

Moisture content: A measure of the amount of water in wood. It is expressed as the percent water contained, by weight, compared to the dry weight of the wood alone.

Plainsawn lumber: Lumber with wide faces that are predominately tangential surfaces.

Pores: The long conducting tubes in hardwoods, made up of continuous stacks of cells called vessel elements. Some are quite large and easily seen on a cross section. Others are too small to see without magnification.

Quartersawn lumber: Lumber with wide faces that are predominately radial surfaces.

Radial surface: A longitudinal surface produced when cutting lengthwise, but across (along a radius of) growth rings. On the end of a board, growth rings run perpendicular to this surface.

Rays: Ribbon-shaped structures in wood composed of storage cells, running radially across growth rings. Their narrow edges appear as radii of growth rings on cross sections. On radial surfaces, the wide faces of large rays form distinctive patterns called flecks. On tangential surfaces, the ends of rays may be seen as separated vertical lines, more or less obvious depending on ray size.

Ring porous: A description of woods containing large, easily-seen pores. On cross sections, earlywood of "typically ring porous" woods is formed predominately of these large pores. Latewood contains only small pores. In "semi-ring porous" woods, large pores are seen throughout ring cross sections, usually decreasing in size toward latewood.

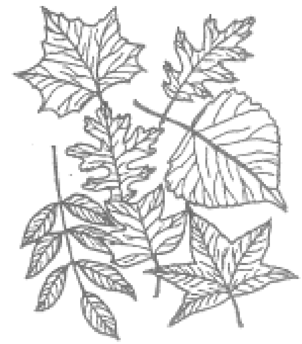
Sapwood: The outer layer of wood in a tree, containing functioning conducting cells, as well as some living storage cells. Conducting and supporting cells in all wood are dead, even in sapwood. Their cell wall structures provide conducting paths and strength, though.

Spiral grain: A grain orientation created as the elongated wood cells are laid down during growth at some angle to the long aids of a tree. This creates a spiral pattern around the tree from bottom to top, made visible in a log by checks that follow the grain. When the spiral goes "from lower right to upper left" on the surface of a standing log, it is called an "S" helix or spiral. If it goes "from lower left to upper right" it is a "Z" helix. On tangential surfaces of a board, spiral grain runs across the wide faces at an angle instead of straight up and down along its length.

Tangential surface: A longitudinal surface produced when cutting lengthwise, but tangent or "parallel" to growth rings. On the end of a board, growth rings run "parallel" to this surface.

Texture: Describes pore sizes. Woods with small pores are called "fine textured", those with large pores being "coarse textured". It is also used to describe uniformity of pore sizes. Woods with similar size pores are called "even textured", and those with widely differing sizes are called "uneven textured". It also may be used to describe the "hardness" or "weight" of wood, with hard, heavy, strong, elastic woods called "tough textured". Soft, light-weight, weak woods would be called "soft textured".

17. Product Quality and Marketing



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INTRODUCTION

Product quality is all important to the management and sale of hardwood timber. In virtually every case forest landowners should strive to manage their timberland for the highest quality material. Obviously, at the time of a timber sale, high quality products will command a better price than low quality products. Beyond this, though, high grade trees tend to be healthier trees, better able to heal wounds, withstand insect and disease attacks, and the force of strong winds. During times of extreme climatic conditions a tree's good health can help it survive stress. Possibly the only instance of a low quality tree being favored is in the wildlife management practice of providing hollow trees as dens for small game.

Unless the wood is truly rotted, all hardwoods have value. This value, however, will vary depending on your species, diameter, clearness of the bole surface, straightness of the bole, and the soundness of the material. The low end-value has been traditionally defined as firewood or pulpwood and the high end as veneer. The middle ground is material described generally as sawlogs. Note that this is how the market place values these products under normal market conditions.

There may be times when a normally low-value product will bring a higher dollar value. An example of this would be if the demand for pulpwood drove pulpwood values to exceed those of sawlogs. These situations, when they do occur, are usually a local phenomena and short lived. A forest landowner should thoroughly research local market conditions before making a timber sale. The landowner has a lot invested in the timber and should receive the highest return possible. To begin, obtain an accurate stand inventory of volume by species and product -- pulpwood, sawlogs by grade, specialty products and veneer. With this information in hand, along with market price information, a landowner can get an idea of the worth of the standing timber.

Numerous publications are available to help identify trees by species and measure the tree volume in board feet. There are also commercial publications reporting on current price levels of stumpage. The more difficult task is to identify the product to which the tree is best suited. A major object of log classification is to separate all the logs out into those suitable for the manufacture of a given product or class of products.

It is not the intent here to detail explicitly all hardwood product grading systems. Such a task could cover volumes in itself. Since over half of all hardwood log production is destined for factory lumber, this chapter will concentrate on describing a system of grading for this product alone. This type of log is adapted to the production of boards that later can be remanufactured so as to remove defects and yield smaller strips of clear wood. An examination of almost any piece of solid hardwood furniture will demonstrate how these strips have been further utilized by edge-gluing to produce drawer fronts, table tops, chair seats and bed rails. It is important to note that any log suitable for sawing into factory lumber may also be suitable for firewood, pulpwood, veneer, or specialty products. It cannot be emphasized enough that a thorough investigation of local market conditions is necessary in order to know which log classification will generate the highest income and return on investment.

Some people judge the usefulness of a grading system by simplicity or ease of application. This is not a sound approach. Whether grades are suitable for a given objective depend not upon how easy they are to use, but upon how well they meet stated performance standards. The USDA Forest Service developed a log-grading system which, by grade, predicts the quality of lumber that can be sawn from the log. The grades of lumber cut from such logs are determined by specification of the National Hardwood Lumber Association grading rules for standard lumber.

Lumber grades specify the minimum yield of defect-free material obtainable from boards in each grade. High grade boards are relatively free of defect. A defect is any irregularity occurring in or on wood that may lower some of its strength, durability, or utility. Defects in boards include irregularities such as knots, holes, deep surface checks, splits and stain.

There are six established standard grades of hardwood factory lumber. They are: FAS, Selects, No. 1 Common, No. 2 Common, No. 3A Common, and No. 3B Common- FAS boards yield the most defect-free wood. For a board to qualify as FAS, its surface must be at least 83-1/3 percent clear. A Select board, which is a cross between an FAS and No. 1 Common board, must also yield 83-1/3 percent. A No. 1 Common board must be 66-2/3 percent free of defects. A No. 2 Common 50 percent; a No. 3A Common 33-1/3 percent; and a No. 3B Common 25 percent clear. The comparative values of these grades of lumber reflects the fact that the clearer the board the more it is worth.

The USDA Forest Service's standard grades for hardwood factory lumber sawlogs predicts that a grade No. 1 log will yield 60+ percent 1 Common and better lumber. This means that at least 60 percent of the volume of the lumber produced from that log will be in grades FAS, Select, and 1 Common. A grade No. 2 log will yield between 40 to 60 percent 1 Common and better lumber, and grade No. 3 logs yield 20 to 40 percent 1 Common and better lumber. Any log that does not meet the specifications for a factory grade No. 3 log is termed "below grade." Again, this designation does not mean that the log does not have value. R means that it would be uneconomical for a sawmill to saw this log because not enough grade lumber would be produced to pay its way through the mill. R may, however, have value as a railroad tie or mine timber, firewood, pulpwood, or for local use such as in farm buildings.

Because the log grading system is intended to predict lumber quality, hardwood logs are graded in much the same way hardwood lumber is graded and the specifications between log and lumber grades are closely con-elated, i.e., log grades are based on the percentage of clear area on the surface of the log. Because log quality is intended to predict lumber quality, the percentage of clear area required is the same. Both the FAS board and a No. 1 log are required to be 83-1/3 percent clear-, a No. 1 Common board and a No. 2 log are both required to be at least 66-2/3 percent clear; and a No. 2 Common board and a No. 3 log must both be at least 50 percent clear.

LOG GRADING

The major factors that affect the quality of factory lumber logs are: (1) position of the log in the tree (butt or upper log); (2) size of log, especially diameter; (3) straightness; (4) amount and distribution of scalable defects; and (5) defects in the useable wood outside the heart center. Table 17-1 describes the specifications for the grades:

Table 17-1. Forest Service standard specifications for hardwood factory lumber logs.*

Grading Factors		Log Grades: F1			F2				F3
Position in tree		Butts only	Butts & uppers		Butts & uppers				Butts & uppers
Diameter, scaling		[1]13"-15"	16"-19"	20" +	[2]11"	12" +			8" +
Length without trim		10' +			10' +	8-9'	10-11'	12' +	8' +
Clear cuttings[3] on each 3 best faces	Length, min.,	7'	5'	3'	3'	3'	3'	3'	2'
	Number, maximum	2	2	2	2	2	2	3	No limit
	Fraction of log length required in clear cutting[4]	5/6	5/6	5/6	2/3	3/4	2/3	2/3	1/2
Sweep and crook allowance (maximum) in percent gross volume	For logs with less than 1/4 of end in sound defects	15%			30%				50%
	For logs with more than 1/4 of end in sound defects	10%			20%				35%
Total scaling deduction including sweep and crook		[5]40%			[6]50%				50%

[1]Ash and basswood butte can be 12 inches if they meet all other No. 1 requirements. [2]Ten-inch logs of all species can be No. 2 if they meet all other No. 1 requirements. [3] A clear cutting is a portion of a face free of defects, extending the width of the face. [4] See Table No. 1. [5] Otherwise No. 1 logs With 41-60% deductions can be a No. 2. [6] 0therwise No. 2 logs with 51-60% deductions can be No. 3.
*Source: U.S. Department of Agriculture, Forest Service (1966).

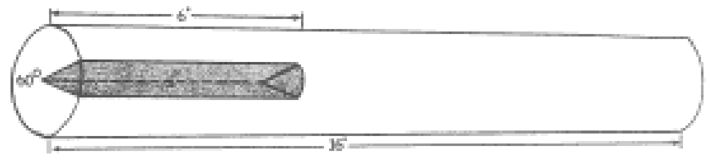
There are four basic steps in grading hardwood factory logs for standard lumber: (1) scale the log, (2) establish the grading face, (3) identity the clear cuttings on the grading face, and (4) examine the log ends.

1. **Scale the Log**

Scaling the log is the first step in grading. It not only gives an estimate of the content, but also gives some data needed to apply grade specifications. Average diameter inside the bark on the small end of the log is used in scaling and grading. The length for figuring the necessary clear cuttings is dropped to the full foot, but cuttings are allowed to include the overlength. Scaling a log includes making deductions where an irregularity in the log reduces its usable volume. Figure 17-1 describes the common methods of making scale deduction.

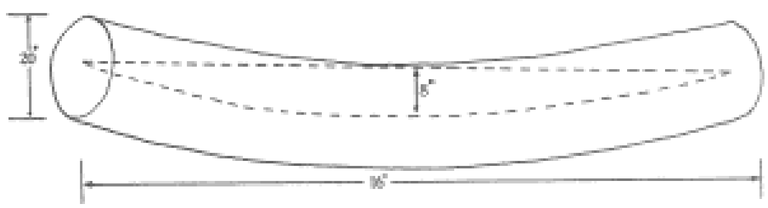
Defect section (rule 1):

Percent deduction $= \frac{4}{16} = 25\%$



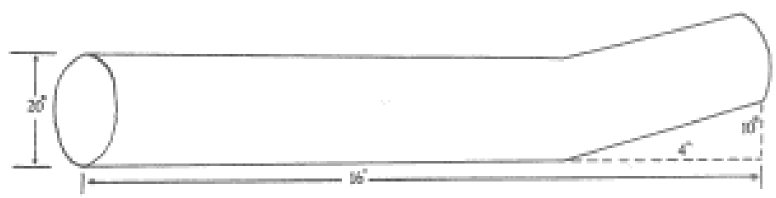
Defect section (rule 2):

Percent deduction $= \left(\frac{6}{16}\right)\left(\frac{60}{360}\right) = 6\text{-}1/4\%$



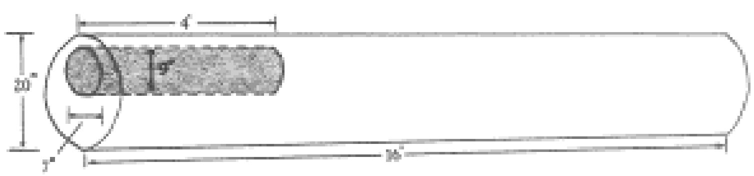
Sweep (rule 3):

Percent deduction $= \frac{8-2}{20} = 30\%$



Crook (rule 4):

Percent deduction $= \left(\frac{10}{20}\right)\left(\frac{4}{16}\right) = 12\text{-}1/2\%$



Interior defect (rule 5):

Percent deduction $= \frac{(8)\ (10)}{(20-1)^2} \times \frac{4}{16} = 5\text{-}5/9\%$

In practice each elipse axis can be divided by $(20 - 1)$ and rounded to nearest tenth if desired.

Thus $\frac{8}{19} = .4$, $\frac{10}{19} = .5$, and $(.4)\ (.5)\left(\frac{4}{16}\right) = 5\%$

Source: Grosenbaugh (1952)

Figure 17-1. Methods of determining scaling deductions, examples are based on a 16-foot log with 20-inch scaling diameter

2. Establish The Grading Face

After measuring the log, the next step is to visually square the log full length into four faces so oriented as to give the largest possible number of good faces. Confine any given defect to one face wherever possible instead of permitting it to extend over two faces unnecessarily. The grade of the log will be established by the poorest face of the best three remaining faces. In other words, disregard the poorest face on the log, and grade the poorest of the remaining three faces. This is the grade of the log. See figure 17-2

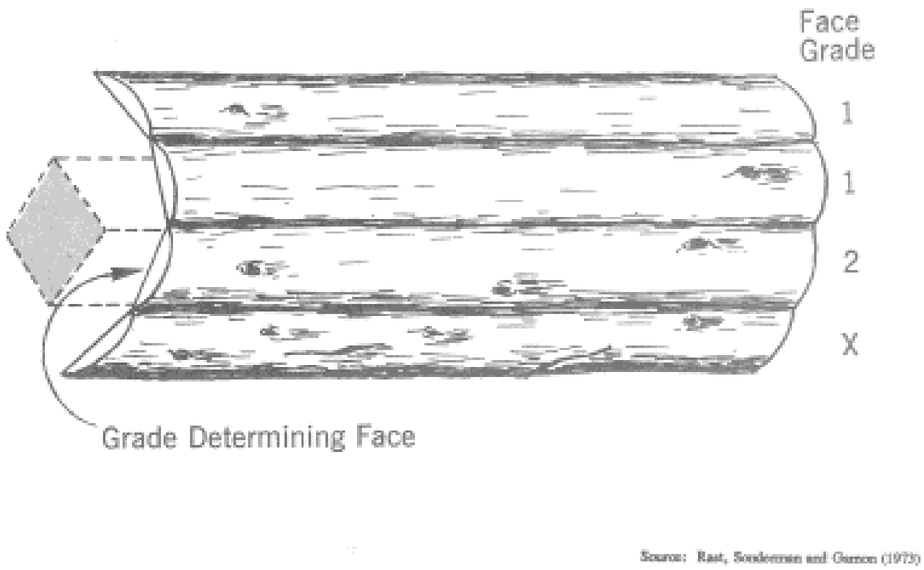


Figure 17-2. Selecting the grade face.

3. Identify the Clear Cuttings on the Grading Face.

The grade of a face is established on the basis of clear-eutting requirements. Clear cuttings are portions of the length of the face that lie between defects or between the ends of the logs and defects, and extend the full width of the face. See figure 17-3.

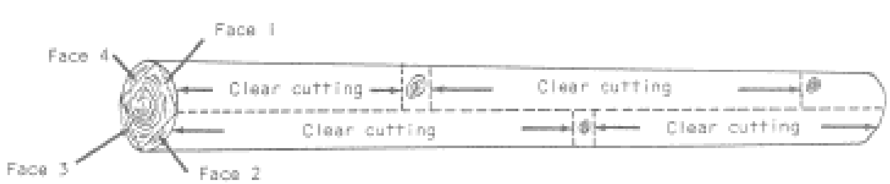


Figure 17-3. Identifying clear-cuttings.

The challenge in grading factory-lumber logs is to locate clear cuttings. This requires the proper evaluation of surface indicators of defects. Branch stubs and knot overgrowths are clearly evident, so they present no problem. But the grader usually needs some training and experience to detect and evaluate accurately other less obvious indicators.

Note from table 17-1 that a log grade No. 1 must yield 5/6 or 83-1/3 percent of the length of the grading face clear. Log grade No. 2 must yield 2/3 of the length of the face clear and log grade No. 3 must be 1/2 clear. Table 17-2 helps you to determine what 5/6, 2/3, and 1/2 is of various log lengths. For example 10 feet is 5/6 of a 12-foot log; 9 feet 4 inches is 2/3 of a 14-foot-long log; and 5 feet is 1/2 of a 10-foot-long log. The amount permissible to lose can also be used and is listed in the table.

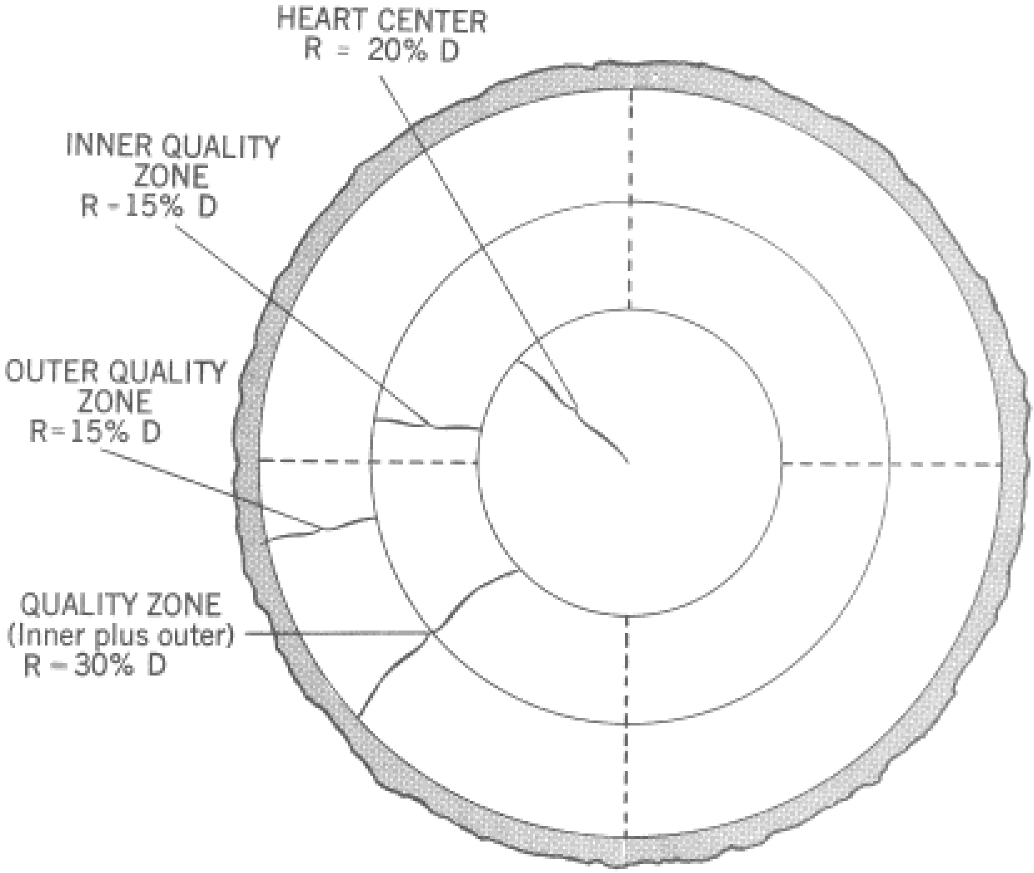
Table.17-2. Total Cutting Lengths for Hardwood Log Grades

Log Length (feet)	Log Grade					
	1 (5/6 yield)		2 (4/6 yield)		3 W2 yield)	
	Clear	Lose	Clear	Lose	Clear	Lose
10	8'4"	1'8"	6'8'	3'4"	5’	5’
12	10’	2'	8’	4’	6'	6’
14	11’8"	2’4”	9'4"	4'8”	7’	7’
16	13'4"	2'8”	10’8”	5’4”	8’	8’

4. Examine Log Ends

Once the faces have been graded, the log ends must be examined for grade defeat indicators that may not show on the log surface. All abnormalities, regardless of type, can be disregarded when they are confined to the heart center. Heart center is considered to be a core in the center of the log with a radius equal to one-fifth of diameter. Only when the abnormality enters the quality zone, that portion of the log from which grade lumber is produced, does it become a problem.

The quality zone of a log is that portion of the log outside the heart center. R is further divided into the inner quality zone and the outer quality zone, each having a radius equal to 15 percent of the diameter of the log. See figure 17-4. If an abnormality is confined to one quality zone in a quadrant of the log end it can be disregarded as a defect. However, if the defect is found in both the inner and outer quality zone it must be considered a defect in the quarter and face involved See figure 174. If it is determined that the defect extends the full length of the log, no clear cutting can be taken on the face overlying the defect.



Source: Rast, Sonderman, Gammon (1973)

Figure 17-4. Location of end figures in hardwood factory lumber logs.

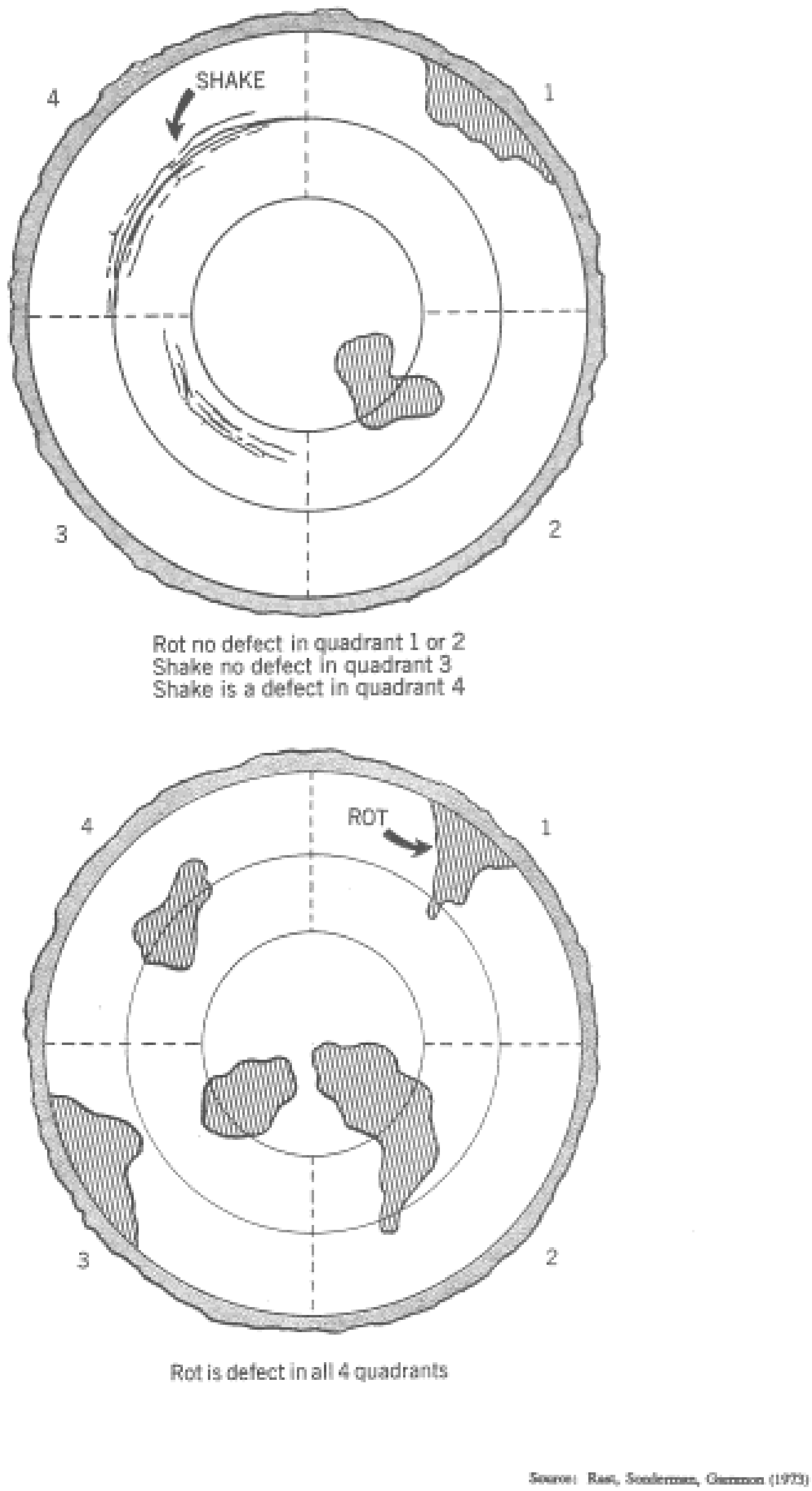


Figure 17-5. Evaluation of rot and shake in hardwood factory lumber logs.

Figures 17-6 to 17-8 display examples of the three factory-lumber log grades.

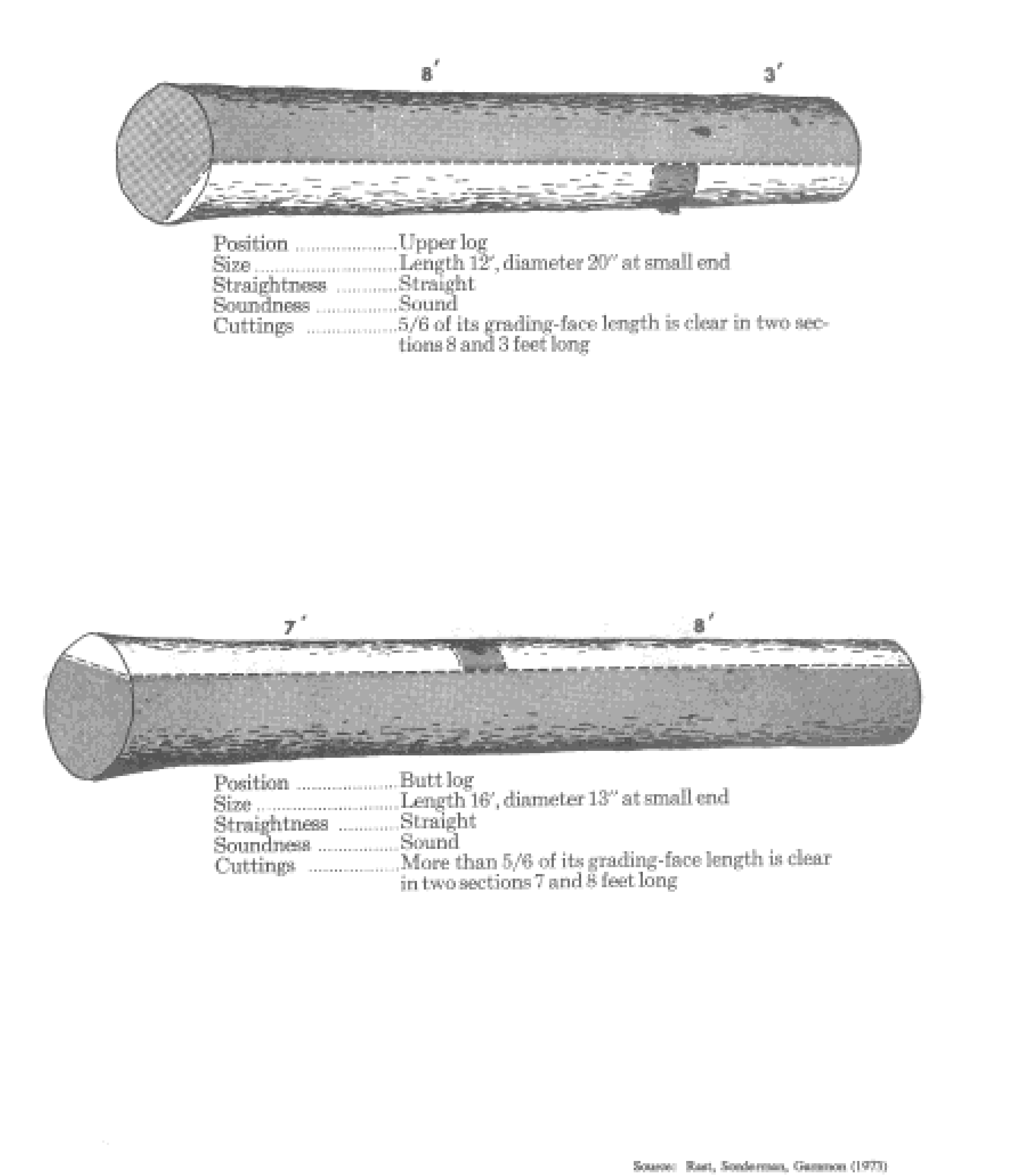
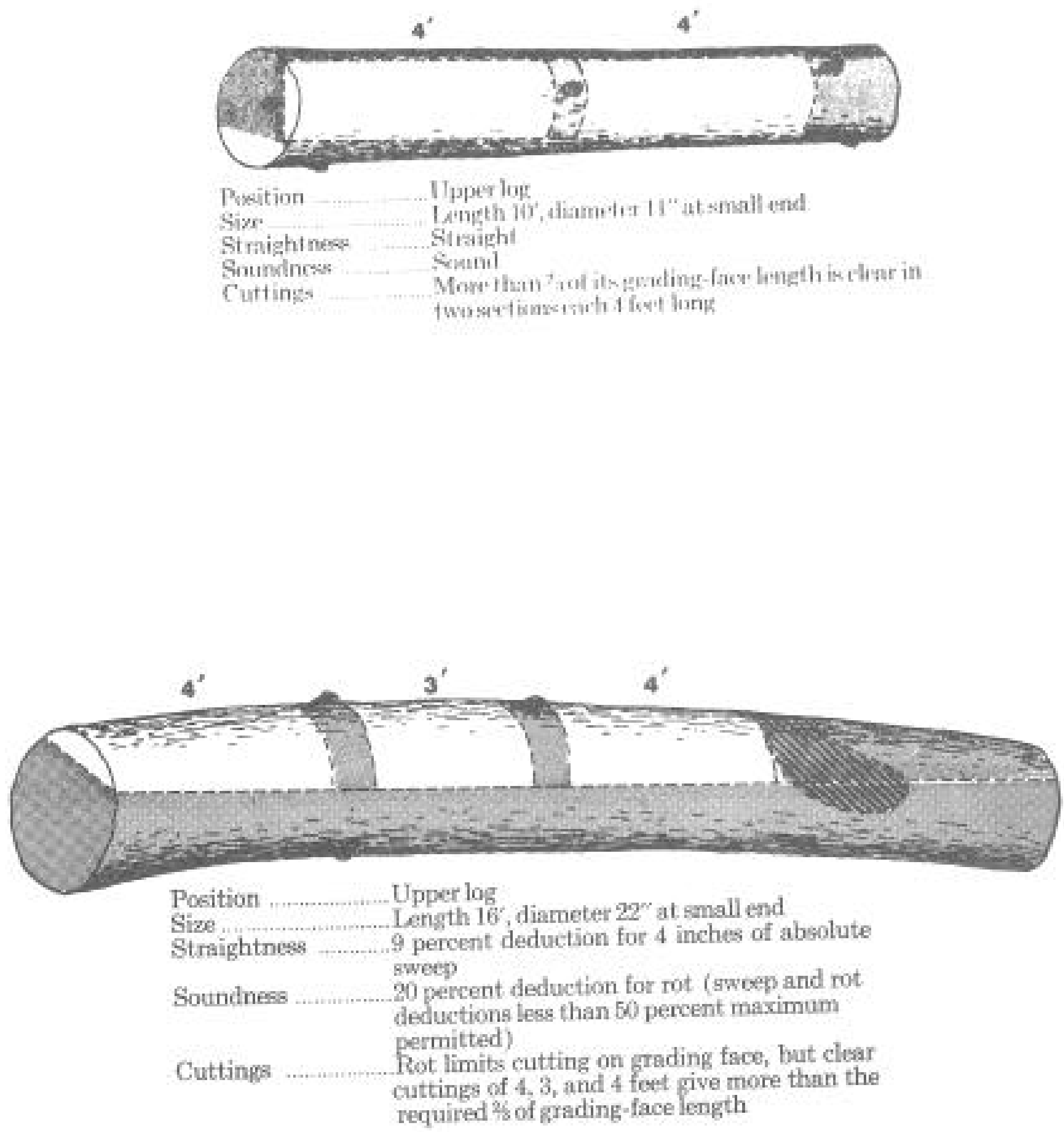
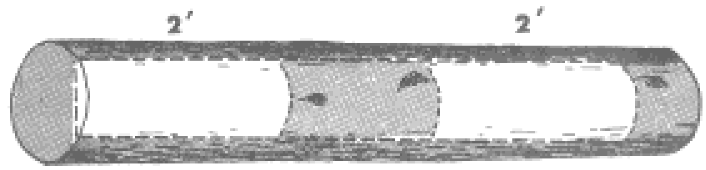


Figure 17-6. Examples of hardwood factory grade 1 logs.

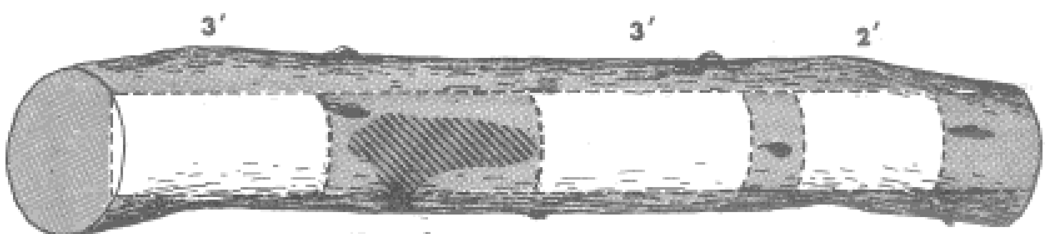


Source: Rast, Sonderman, Gammon (1973)

Figure 17-7. Examples of hardwood factory grade 2 logs.



Position ....Upper log
Size ....Length 8′, diameter 8″ at small end
Straightness ....Straight
Soundness ....Sound
Cuttings ....One-half of its grading-face length is clear in two sections, each 2 feet long



Position ....Upper log
Size ....Length 14′, diameter 22″ at small end
Straightness ....12 percent deduction for 6″ x 3′ of crook on both ends of log
Soundness ....15 percent rot deduction (crook and rot less than 50 percent maximum deduction)
Cuttings ....More than ½ of its grading-face length is clear in three sections, 3, 3, and 2 feet long

Source: Rast, Sonderman, Gammon (1973)

Figure 17-8. Examples of hardwood factory Grade 3 logs.

TREE GRADES

The Forest Service's grades (Hanks 1976) were developed for use on standing sawtimber. Those already familiar with the log grades will immediately see a great similarity between the two grading systems. Table 17-3 contains the specifications of the tree grading system.

Table17-3. Hardwood tree grades for factory lumber.

Grade factor	Tree grade I			Tree grade 2		Tree grade 3
Length of grading zone (feet)		Butt 16		Butt 16		Butt 16
Length of grading section[a] (feet)		Best 12		Best 12		Best 12
Dbh, minimum (inches)		16[b]		13		10
Diameter, minimum inside bark at top of grading section (inches)	13[b]	16	20	11[c]	12	8
Clear cuttings (on the 3 best faces :[d]						
Length, minimum (feet)	7	5	3	3	3	2
Number on face (maximum)		2		2	3	([e])
Yield in face length (minimum)		5/6		4/6		3/6
Cull deduction, including crook and sweep but excluding shake, maximum within grading section (percent)		9		9[f]		50

[a] Whenever 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.

[b] In basswood and ash, dib at top of grading section must be 12 inches and dbh must be 15 inches.

[c] Grade 2 trees can be 10 inches ib at top of grading section if otherwise meeting surface requirements for small grade is.

[d] A clear cutting is a portion of a face free of defects, extending the width of the face. A face is one-fourth of the surface of the grading section as divided lengthwise.

[e] Unlimited.

[f] 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 clear cuttings 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.

* Source: Hanks (1976)

These specifications are applied in much the same way that logs are graded. First, the tree's size is determined by measuring the d.b.h. to the nearest inch. The grader then walks around the tree to identify the location of all defect indicators on the surface of the butt 16-foot log. As in log grading, as many defects as possible are grouped into one face because the worst face can be disregarded. The second worst face is then identified and graded. The grade of this face is the grade assigned to the tree. See figure 17-9.

In grading the second worst face of the butt 16-foot log, at least 12 feet must be graded. This is known as a "sliding 12-foot section." For example, if the defect indicators are clustered in the top 4 feet of a 16-foot log, grade the bottom 12 feet. In another instance, rot may be noticed at the base of the tree. The grader then has the option of grading the upper 12 feet. See figure 17-10.

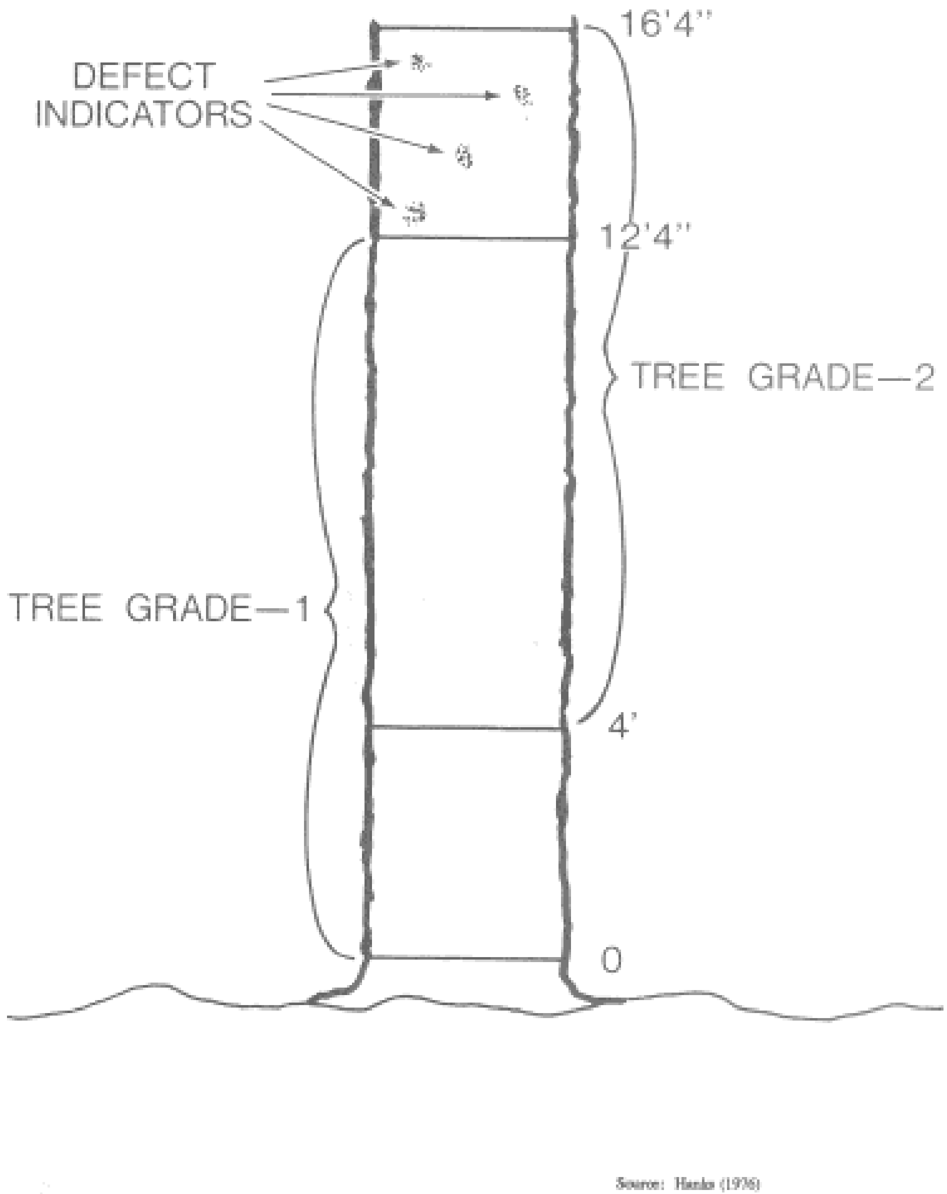
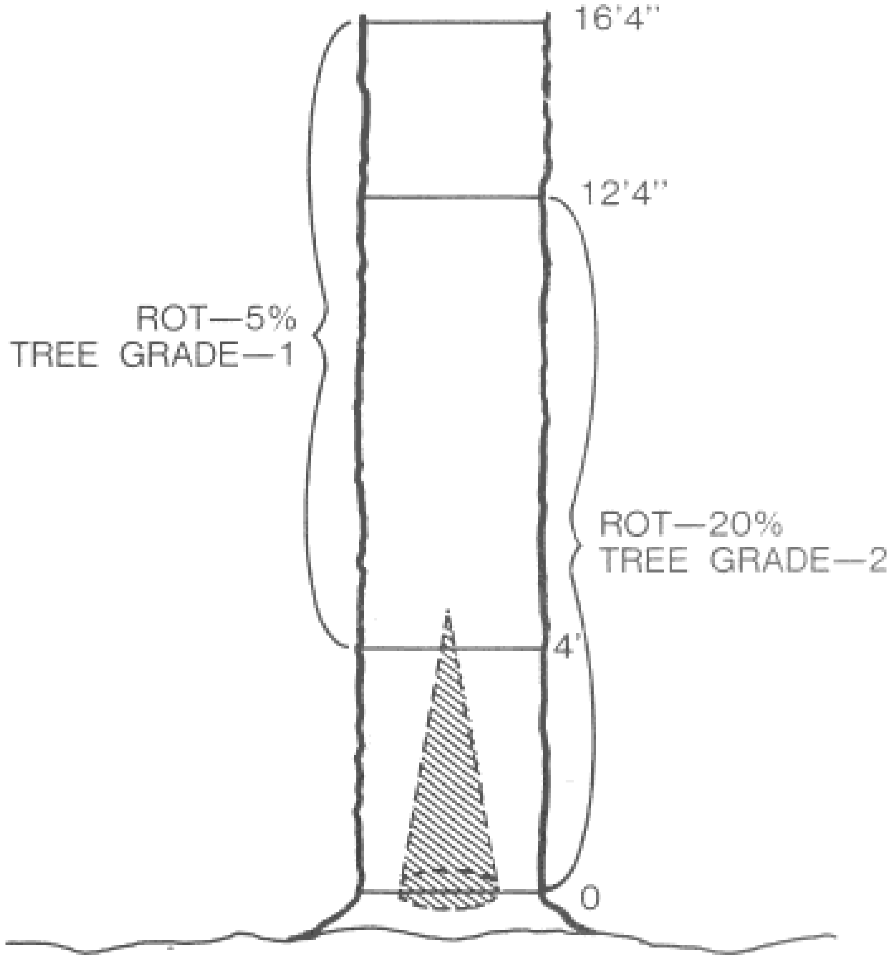


Figure 17-9. Defect indicators clustered at top of grading zone. The best 12-foot section is the butt 12-feet.



Source: Hanks (1976)

Figure 17-10. Large rot at base of tree. Because of rot, the grade of the butt 12-foot section is 2. By grading the top 12-foot section, the tree's grade can be raised to 1.

The flexibility to slide the 12-foot grading section of the grading face accounts for one big difference in specifications between log and tree grades, which is scalable defect limitations. Grade 1 logs may contain up to 40 percent defect while the grading section of grade-1 trees is limited to 9 percent. The reason for this is that the influence of a large defect in a tree may be eliminated by grading the best 12-foot section, while the log grader is required to grade the log in its entirety.

Table 17-4 compares the value of the lumber sawn from two trees of the same size but different tree grades. Using *Hardwood Market Report* prices for September 1992, and lumber yields from the publication *Hardwood* Tree *Grades* for Factory Lumber we find that the difference in the value of lumber sawn from these two trees is $77.43.

Table 17-4. Comparison of the value of the lumber[1] sawn from a Forest Service Grade I and Grade 3 tree.

Grade One Tree:

Lumber Grade	$/BF	X	BF	Lumber Value
FAS	.810	X	63	$51.03
IF-SEL	.800	X	47	37.60
#1 COM	.705	X	97	68.39
#2 COM	.360	X	98	35.28
#3A COM	.300	X	40	12.00
#3B COM	.200	X	11	2.20
			356	$206.50

Grade Three Tree:

Lumber Grade	$/BF	X	BF	Lumber Value
FAS	.810	X	9	$7.29
IF-SEL	.800	X	17	13.60
#1 COM	.705	X	64	45.12
#2 COM	.360	X	81	29.16
#3A COM	.300	X	71	21.30
#3B COM	.200	X	63	12.60
			305	$129.07

1 Size: 20", 2-1/2 logs. Species: northern red oaks.

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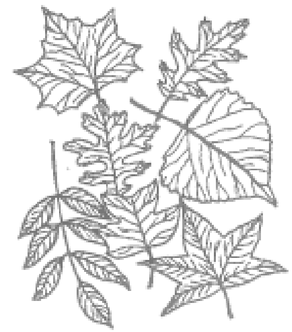
18. Water Management Regulations in Forestry



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INTRODUCTION

Environmental concern has resulted in more regulation of water management practices in forest lands over the past decades. Landowners, consultants and foresters cannot ignore these without expecting some form of penalty. It is difficult for regulators to distinguish the initial phases of land development from silviculture. Therefore, it behooves forest landowners to clearly establish the ongoing nature of their normal silvicultural operations. It is the responsibility of foresters to educate new public officials about the nature and standards of normal silvicultural operations. This is especially true for silviculture in wetlands.

Wetlands are those areas that are frequently and long enough saturated or flooded to regenerate and support vegetation adapted to those conditions (during the growing season). Examples are tidal marshes and mangrove swamps, normally inundated freshwater marshes and peat bogs, and seasonally-wet floodplains and forest swamps. Wetlands are legally defined by their plant, soil and hydrologic characteristics.

The following summary presents the major laws, regulations, and permitting requirements of water-related Federal and State agencies as they apply to wetland forest management. State and local governments may regulate standards more stringently than does the Federal government. However, State laws may not be weaker than the Federal standards.

FEDERAL REGULATIONS

Common law for water use in the nation is mostly based on court cases. First come, first right of water transfer and use developed in western jurisdictions. However, in eastern jurisdictions the landowners own the water rights. The more recent administrative laws based on reasonable-beneficial water use have been established for Federal reservations and by some States through the legislative process (Carriker, 1985).

Section 10 of the 1899 Rivers and Harbors Act prohibits any obstruction of navigable waters up to the ordinary high-water line. The U.S. Army Corps of Engineers administers this control of dredge and fill for all projects in navigable waters. The dredge-and-fill rule of the Rivers and Harbors Act was also the basis for the Water Pollution Control Act (VVTCA) of 1948. This act went beyond navigable waters to include all waters of the United States. The 1972 amendments put teeth in the WPCA by creating the Environmental Protection Agency (EPA) to enforce pollution laws. The EPA defined industrial and municipal point-source effluent limits for section 404, and diffuse nonpoint-source pollution for section 208 of the WPCA. The regulation of dredge-fin for section 404 was left with the Corps. However, court action expanded its authority beyond the ordinary high-water line to include wetlands as waters of the United States. The 1977 amendments of section 208 identified Best Management Practices (BMP) for nonpoint-source pollution control, and section 404 was amended to allow dredge-fill exemptions for normal silvicultural activities. In 1986, the EPA created the Office of Wetlands Protection to reduce net losses of wetlands in the United States. Section 319 of the 1987 WPCA amendments authorized funding for State non-point source pollution control programs (Cubbage et al., 1987).

Other Federal laws related to wetland management include the Coastal Zone Act of 1972, requiring all construction to be approved by Coastal Zone Management (CZM) programs of the States, the Fish and Wildlife Act of 1956 and the Endangered Species Act to protect aquatic environments for fish and wildhfe resources, and the Wild and Scenic Rivers Protection Act.

Section 402 of the WPCA authorized EPA to control point-source discharges to implement the National Pollutant Discharge Elimination System program. The EPA set water pollution standards and deadlines for water pollution control, but program development and implementation were delegated to the States. The EPA accepted BMP's for nonpoint-source pollution control as substitute performance standards for water quality. Pesticide use is regulated more stringently by the EPA for the Endangered Species Act, including aquatic species.

The Corps developed regulations and permitting thresholds for all waters of the United States, including wetlands and floodplains having important functions. A nationwide general permit exempts normal activities of an established silvicultural operation. A silvicultural operation ceases to be established when the land is idle long enough to require alteration of the hydrologic regime for renewed operations. To simplify the process, the Corps instituted regional permits for activities with minimal impact in areas of similar site and use conditions. The evaluation of individual permit applications for non-exempt projects includes impacts on wetland importance, functions and values, the cumulative effect of all wetland alterations in the area, possible mitigation of impacts, and an economic review.

To be exempt, normal silvicultural activities may not modify a wetland from its present state for crop conversion, nor jeopardize threatened-endangered species, fish and fowl migration, shellfish production, public water supplies, or designated wild and scenic rivers (U.S. Army Corps of Engineers, 1986). Normal silviculture in wetlands includes harvesting, site preparation, and minor drainage. Harvesting means cutting and removal of trees from the site, but does not include forest road construction. Site preparation includes soil cultivation, plowing-bedding and seeding-planting to improve crop growth, quality or yield. Minor drainage includes ditching-damming to control water levels for harvesting, site preparation and forest crop growth.

Forest road construction in wetlands has to follow State-approved BMP's to be exempt. This includes a minimum number of stabilized fill roads of minimum width and length. They must be located away from open waters and properly culverted for unimpeded flood flow. Nontoxic road fill preferably comes from upland sources, with minor crossings allowed less than 200 cubic yards within 100 ft beyond and below the ordinary high-water line.

STATE REGULATIONS

The EPA delegated regulation and implementation of the WPCA to the States, while retaining oversight authority. In contrast, the Corps retained all its authority, but eased the permitting process with nationwide and regional permits, and a joint application procedure with State agencies and CZM programs for individual permits. Local county government can regulate more stringently than the State and Federal agencies. Land use zoning, specific tree cutting ordinances, and setback zones next to open waters and wetlands are some examples.

Some States in the South already had legislation for water pollution control before 1972 that applied to the Federal WPCA, and other States enacted new legislation. Most of the legislation is broad enough to address silvicultural operations if necessary, but little more detailed regulation has been developed. A few States have enacted specific wetland legislation to replace the 404 dredge-and-fill regulations of the Corps. A summary of State legislation and regulatory agencies is presented in table 18-1. All the States rely on voluntary BMP's and 208 plans assembled with the aid of grants from EPA. Several forestry associations in the South have formulated BMP's specifically for wetlands.

The silvicultural BMP's for roads and lands in the States have many standards in common. Permanent roads should be on highest ground. They should have ditches, drainage dips, and turnouts or wing ditches to dissipate runoff. Culverts and bridges may not change the high-water channel. Culverts need to be placed to pass fish at normal low-water levels. Fill below the ordinary high-water line is discouraged and approaches need to be protected against erosion. Fords should only be constructed on solid streambed. Temporary roads should avoid fragile areas and have minimum construction and use impacts on drainage. Log landings should be above the ordinary high-water line. Runoff from landings and firelines should be diverted into the forest.

Harvesting on forest lands below the normal high-water mark is discouraged. No trees and slash should be left in channels. Skidding should avoid changing natural drainages and crossings made of temporary culverts, log bundles or portable bridges. Skidding should be toward uphill landings to form a pattern that disperses runoff. Wet-weather harvesting should be limited to high and sandy soils. Skidding should be spread over many trails in sandy soils, but concentrated on few trails in organic or clay soils. The water management system should follow natural drainage patterns. Stormflow should be slowed by wetlands, ponds and porous coffer dams. Ditch spoil and road sidecast should be placed away from open channels and immediately stabilized to reduce erosion. Ditches and crossings should be kept clear to prevent washouts of structures.

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Cubbage, F.W.; Siegel, W.C.; Haines, T.K. 1987. Water quality laws affecting forestry in the eastern United States. In: Nix, S.J.; Black, P.E., eds.; Symposium on monitoring, modeling, and mediating water quality. Bethesda, MD: American Water Resources Association.: 597-609.

U.S. Army Corps of Engineers. 1986. Final rule for regulatory programs of the Corps of Engineers; Part 323--Permits for discharges of dredged or fill material into waters of the United States. Federal Register. 51(219):41206-41260.

Table 18-1. Legislation and agencies for water quality control and wetland management of the States in the South.

STATE	STATUTE	AGENCY	ADDRESS
ALABAMA	Water Pollution Control Act, 1972	Alabama Department of Environmental Management	Water Division 1751 Dickinson Drive, Montgomery, AL 36130 (205)271-7700
ARKANSAS	Arkansas Water and Air Pollution Control Act, 1949, and Stream Obstruction Act	Dept. of Pollution Control & Ecology	8001 National Drive Little Rock, AR 72219 (501)570-2130 FAX (501)562-4632
FLORIDA	Environmental Control Act; Henderson Wetlands Act, 1984	Florida Department of Environmental Regulation (plus 6 water management districts)	2600 Blair Stone Road, Tallahassee, FL 32399-2400 (904)488-9334
GEORGIA	Georgia Water Quality Control Act	Georgia Environmental Protection Division	Water Protection Br. 7 M.L.K. Drive Atlanta, GA 30332 (404)-656-4905
KENTUCKY	KRS Chapter 224, Environmental Protection	Kentucky Division of Water	14 Riley Road Frankfort Office Park Frankfort, KY 40601 (502)564-3410
LOUISIANA	Environmental Quality Control Act Stream Obstruction Law, and Natural and Scenic River System Law	Louisiana Department of Environmental Quality Louisiana Department of Wildlife and Fisheries	P. 0. Box 82215 Baton Rouge, LA 70884 (504)765-0634
MISSISSIPPI	Mississippi Air and Water Pollution Control Act	Office of Land and Water Resources	P. 0. Box 10305 Jackson, MS 39286 (601)961-5650
NORTH CAROLINA 1951, and Stream Obstruction Act	North Carolina Air and Water Resources Act,	North Carolina Department of Environmental Health and Natural Resources (919)733-4984	Div. of Water Resources P. 0. Box 27687 Raleigh, NC 27611

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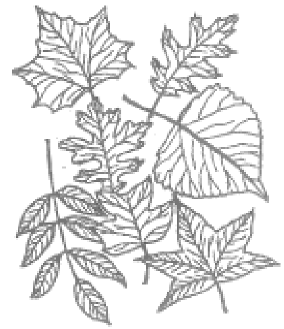
Table 18-1, continued

STATE	STATUTE	AGENCY	ADDRESS
OKLAHOMA	Oklahoma Pollution Control Coordinating Act	Department of Environmental Quality	1000 N.E. 10th Oklahoma City, OK 73117 1-800-522-0206
SOUTH CAROLINA	South Carolina Pollution Control Act, Scenic Rivers Act, 1974, Stream Obstruction Act, and Stream Clearing Act	Department of Health and Environmental Control	2600 Bull St. Columbia, SC 29201 (803)734-5360
		South Carolina Wildlife and Marine Resources Department	P. 0. Box 167 Columbia, SC 29202 (803)734-4006
TENNESSEE	Tennessee Water Quality Act, 1971, and Scenic Rivers Act	Dept. of Environment and Conservation, Water Pollution Control Division	401 Church St. 6th Floor, L&C Annex Nashville, TN 37243-1534 (615)532-0625
TEXAS	Texas Water Quality Act, and Stream Obstruction Act	Texas Water Development Board	P. 0. Box 13231 Austin, TX 78711 (512)463-7847
VIRGINIA	Virginia Water Control Law, Erosion and Sediment Control Law, Stream Obstruction Law, Scenic Rivers, Storm Water Management Control Law	State Water Control Board	P. 0. Box 11143 Richmond, VA 23230 (804)527-5158
		Va. Div. of Soil and Water Conservation	203 Governor St. Suite 306 Richmond, VA 23219
	Chesapeake Bay Preservation Act	Chesapeake Bay Local Assistance Dept.	805 E. Broad St. Suite 701 Richmond, VA 23219 1-800-243-7229

19. Integrating Wildlife Considerations With Hardwood Forest Management



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INTRODUCTION

Because of their great variety, hardwoods have exceptional value as wildlife habitat. The habitats associated. with them can be very diverse and develop a high degree of permanence especially as compared to southern pines, which tend to be replaced by hardwoods as years go by and forests mature. This summary describes some of the ways to help desired wildlife in hardwood forests as well as ways to reduce damage done to hardwood habitat by timber harvest.

The term hardwoods in the South refers to a couple hundred or so species of broad-leaved trees. Wildlife in its broadest sense means all that is wild -- plants and animals. For this article, wildlife means a thousand or so species of birds, mammals, reptiles, and amphibians.

Forest Succession and Wildlife Management

A forest is always changing. Change is most rapid when the forest is young, such as after a wildfire or clearcut. Young seedlings and sprouts compete for light, water and essential elements. There are winners and losers -- some kinds of trees and other plants increase while others decline. Because wild animals directly or indirectly depend on habitat, the numbers and kinds of animals using the land will change as well. This process of change through time, where one living community replaces another, is called ecological succession. Animals that roam widely may visit all forest growth stages that are within their home range. In general, however, undisturbed, mature forests with well-developed understory vegetation and midstory shrubs and trees, as well as occasional openings, offer the greatest diversity of wildlife. In a Louisiana study, for example, 13 species of songbirds were most abundant in early regeneration, 5 were most abundant in seedlings, 1 in pole-size trees, 1 in sawtimber and 31 in mature forests.

Timber Site Quality vs. Wildlife Habitat Quality

Stands of timber and the sites occupied by these stands are evaluated based on how well trees produce wood and the value of the wood in the trees. All variables can be measured in terms of how much wood a stand can produce. Generally, the quality of wildlife habitats is not as easily measured--one does not normally equate wildlife to meat the way trees are equated to wood. Poor habitats for some animals may be excellent for others. Excellent stands of timber may be poor habitat for certain wildlife species, while poor stands of timber may be excellent for other species. Deep sands, for example, may make poor soil for timber but they are excellent for gopher tortoises and other animals associated with sand hill habitat.

In general, forest habitats that are wetter tend to be more productive. That is, they contain more total living material or "biomass." Likewise, forests that produce more wildlife food in the form of browse, nuts or fruits tend to be considered "better" than those that do not. Mature forests and maintained forest clearings generally tend to be "better" wildlife habitat for many favorite game species. However, certain "poor" habitats may be ideal for some kinds of wildlife. Intermediate successional stages may be preferred for relatively fewer favorite game animals and fewer species of nongame birds.

Animals can also be classified according to their habitat needs as edge species, interior species, specialists, and those that need large areas of generalized habitat. Quail in forest habitat are edge species. They tend to be common in diverse forest habitats featuring lots of edge. A black-throated blue warbler is an interior species. R lives in the interior of large blocks of forest. A gopher tortoise is a specialist. It needs special sandhill habitat. Bears are one of those species that need large areas of almost any kind of forested habitat.

Values of Hardwoods for Wildlife

Food production is the most obvious way to value trees as supporters of wildlife. All trees have food value for wildlife. Some food values of trees such as oaks are well known. The value of elms is less known. If you see a squirrel or a flock of goldfinches feeding on elm seeds in the spring then you will know two of the values of elms for wildlife. Table 19-1 shows some commonly known wildlife food values of selected trees.

Sometimes the value of trees as food support for wildlife is indirect. For example, in some years, red mulberry leaves support a good crop of caterpillars in September. Summer tanagers, tufted titmice and migratory warblers feed on these caterpillars. Likewise, the leaf litter under hawthorns provides a valuable foraging habitat for white-throated sparrows and towhees in winter. These little birds need little leaves to scratch in. Large coarse leaves such as those of sycamore offer little scratching habitat for small birds.

A bird watcher might value a certain grove of hardwoods because every spring it attracts a high number of migrating warblers. The warblers follow leaf opening as the season advances northward, providing opportunities to feed on insects. Another place in the forest may be a traditional roost for wild turkeys during the spring -- a fact which only a landowner might know.

APPROACHES TO WILDLIFE HABITAT MANAGEMENT IN FORESTS

Four general approaches are commonly used to manage forest habitat:

1. Protect and maintain habitats as they occur naturally: Let nature take its course and maintain plant and animal communities in more or less intact ecosystems.
2. Coordinate timber management activities to also achieve wildlife habitat enhancement.
3. Manage for timber and accept whatever wildlife is adapted to that habitat. Keeping these approaches in mind, consider your forest as a painting. Do you like the way it looks? Is it full of interesting habitats and animals? If so, you can leave it just the way it is. There is no need to try to improve on nature. However, if you wish to make some changes in the "painting," the main tools at your disposal are chainsaws, fire, plows, seeds and seedlings.
4. Manage a forest for wildlife as a primary goal. If wildlife management is a primary goal you can:
   a. Manage featured species.
   b. Enhance diversity.
   c. Protect and maintain natural communities.

Manage Featured Species

This approach to habitat management is to emphasize a particular species. Suppose you have a uniform stand of old trees and you want more ruffed grouse and rabbits. You can

Table 19-1. Some wildlife food values of common trees.

Trees do not necessarily have high or low value for wildlife. A stand of any kind of tree has wildlife value--especially if the trees are mature.

Species	Remarks on Value of Wildlife
Apple, Crab	Fruits eaten by many games species. Sprouts preferred by deer.
Beech, American	Highly ranked as a food source (nuts, buds, catkins). Nut production in south is inconsistent and unreliable. Manage to increase crown development. Often a good cavity tree.
Cherry, black	Important because of the long fruit-ripening period and frequency of good seed years. Needs full sun or dominant position to thrive.
Dogwood	Because it is widespread, with fruit that persists on the tree into the early winter, it is very important for many game species, especially turkeys and squirrels, as well as songbirds and mice.
Elm, American winged	Produces seeds relished by squirrels, goldfmches, and certain other birds in early spring when other tree seeds are scarce. Seedlings and half cut trees make good deer browse.
Gum, black (tupelo)	Fruit is important, but remains on the tree for only a short period after ripening. Good fall color.
Hickory, bitternut mockernut pignut shagbark	Shagbark and mockernut are considered preferred mast producers for wildlife, especially squirrels. Bitternut is the least preferred. Hickory nuts provide a food source from late summer to the spring. Favor shagbark and mockernut over bitternut when thinning hickories.
Hornbeam, American	Seeds eaten by squirrels.
Hophornbeam, eastern	Valued as a seed producer in midstory.
Maple, red	Produces seeds preferred by squirrels and quail in early spring. Important because of its widespread occurrence.
Mulberry, red	A good food source in midspring. Fruit is available for only a few weeks.

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Table 19-1. Some wildlife food values of common trees.
(continued)

Species	Remarks on Value of Wildlife
Oak black post southern red swamp chestnut water white willow	Oaks rate high as producers of wildlife food because many animals eat acorns. Water, willow and cherrybark oaks near streams and ponds are important as a food source for ducks. On drier sites, a good balance of species in the white and red oak groups will help maintain a consistent level of mast production. Cherrybark, swamp chestnut, and white oaks are top timber species.
Persimmon, common	Favorite fall fruit for many game animals. Fruit is persistent on tree during years of early frost.
Pine, loblolly shortleaf Virginia	Seeds of southern pines are an important food source for quail, turkey, songbirds and squirrels. Pine hardwood forest provides a great variety of wildlife food.
Sugarberry	Fruits are an important food for turkey and many summer and wintering songbirds. An important seed producer. Thrives on moist sites.
Sweetgurn	Songbirds and quail eat seeds; some birds eat buds. Deer, sweetgum sprouts. A preferred food of beaver. In some areas, sweetgum may outcompete more desirable trees.
Yellow-poplar	A prolific seed bearer. Seed will persist in cone and can be used by many birds and some mammals in winter. Deer browse seedlings.
Locust, honey, black	Fallen honeylocust pods are a favorite deer food. Birds and rodents also feed on pods. Seedlings and sprouts are preferred deer browse.
Walnut, black	Nuts are favorite food of squirrels. Fallen nuts keep well. Some last 2 or 3 years.
Ash white pumpkin	Seeds are eaten by a variety of wildlife.

temporarily increase the carrying capacity for these animals by harvesting patches of woods. Thickets that develop in these man-made openings will make the forest better for grouse and rabbits than a forest having only large well spaced trees. The effects would be temporary as the trees grow large. Over time, the thickets, rabbits and ground cover plants will disappear or change. On the other hand, don't cut the forest if gray squirrels are the target species. Gray squirrels prefer mature forests with large oak trees.

Enhance Diversity

A second approach to habitat management is to enhance diversity. This often appeals to small landowners in love with their land and who do not have a favorite species. The greater the variety of trees and plants, the greater the variety of animals that will live there. When removing trees the "scarcity factor" is a major consideration. For example, on land where oaks are common and magnolias are rare, favor the magnolia. Rare species may be particularly important components of the forest ecosystem, and indicators of overall forest health.

Protect and Maintain Natural Communities

A third approach to habitat management is to maintain and protect outstanding natural communities already present on the land. For example, if there is a spectacular stand of a particular forest type, or a grove of picturesque trees, try to maintain them, especially if they harbor desired wildlife populations. Scarce habitats such as sandhills, Carolina bays, streamside forests or forested wetlands can be kept as they are with minimum interference.

THINNING A FOREST FOR WILDLIFE

Thinning means cutting out some trees so the remaining ones can thrive. Many trees must die as a forest develops from seedlings to saplings and then on toward maturity. Thinning will take place naturally if no one interferes. Numbers of trees will decline from perhaps tens of thousands of seedlings per acre down to perhaps a few hundred large trees, in a century or so. This is the normal course of plant succession.

During the decline in numbers of trees, landowners can steer plant succession by removing the less desirable trees to favor those that support preferred wildlife. What is less desirable or more desirable depends on the person's point of view and knowledge. Making decisions as to which trees to remove is relatively easy in a young, managed forest. As a young forest grows, wildlife management considerations can help guide the thinning process. For example, in a mixed forest, removing sweetgums while leaving oaks would favor deer and squirrels. Deer and squirrels dislike sweetgum. as a food source, but both animals relish acorns. Beavers and goldfinches on the other hand, prefer sweetgum. Beavers like the bark and goldfinches eat the flowers and seeds.

Even age stand management for timber can reduce habitat layering. As thinning takes place, the timber producer tends to try to channel as much sun energy and elements into timber producing trees. This tends to reduce vertical layering and habitat variety. This layering is often best developed in old wild, unmanaged forests which have the most diverse wildlife, especially bird life. A natural forest tends to have diverse ground cover, shrub layer, midstory layer of small to medium sized trees with an overstory of dominant trees.

Flowering dogwoods, shadbush, red mulberry, rusty blackhaw, and sparkleberry are examples of small midstory trees that are especially valuable for wildlife.

In general, when thinning a forest with wildlife in mind, look at each tree and ask yourself what is its future as a part of a wildlife habitat. You can cut the tree or leave it, according to your judgement.

When thinning a forest to enhance wildlife and aesthetic values there are no simple rules. The greater the knowledge of the wildlife manager, the more things there are to complicate decisions on what trees to remove. Consider all the potential wildlife values when you look at a tree--seeds, fruit, forage, insects that live on the tree, and the potential for nests and dens. Also consider a tree's individual beauty of form and color changes during the season. Consider especially the edges of the forest and how the finished job will look from a distance. When thinning for wildlife and aesthetics consider that the forest need not be cut down when it is "finished", but rather, it may remain for lifetimes.

A thinning can be accomplished by selling timber, which removes a tree completely, or half cutting. Half cutting involves partly severing a trunk and then pushing a tree over. Some half cut trees will live for years and provide good ground-cover. Trees can also be cut and left to rot there, providing habitat for animals that need dead wood.

CONFLICTS AND TRADE-OFFS BETWEEN MANAGING WILDLIFE AND TIMBER

Does a young, healthy forest mean healthy wildlife? Modem forest management for timber tends to favor young, vigorously growing trees. Large trees are usually cut when they are economically mature and the land is "rotated" back to the seedling and sprout stages. Such young forests contain abundant wildlife of certain kinds.

Forests of old decadent, diseased trees with their rots and holes, on the other hand, do not mean poor wildlife habitat. Old forests make better habitat for certain wildlife than do young healthy trees. Old forests in a wild condition are becoming rare because they are being replaced by younger, managed forests. If you have an old hardwood forest, you may find management decisions are difficult. This can be especially true if a forest has developed without management. Large, old "decadent" trees may have cavities suitable for squirrels, raccoons, owls, or wood ducks, but the tree likely has little timber value. Old trees use space that productive young timber trees could use. A beautiful, old forest may be crowded with trees that are unproductive economically and yet be a paradise for a diversity of wildlife. Aesthetic qualities, in addition to wildlife benefits, may make timber harvest unthinkable to the landowner even though a forester might recommend harvest to meet economic goals and improve the timber quality of the forest. The conflict is between preserving something culturally or aesthetically valuable versus exploitation for commodities. Therefore, some landowners choose to protect rather than manage their forest for optimum economic return. Even in an intensively managed forest, a few acres of old, unmanaged forest makes an interesting island in time to serve as a reference point and comparison with young forests managed for timber.

ROADS AND WILDLIFE HABITAT

Many kinds of favorite wildlife may be common in forests with roads. However, roads usually do not improve wildlife habitat. Roads tend to facilitate access for vehicles and removal of forest commodities while they can damage wildlife habitat. Making roads is generally the first step in the habitat fragmentation process. Fragmenting habitat into smaller pieces by roads and development can reduce or eliminate wildlife species that uses large blocks of forest. Roads change rainfall run-off patterns and increase the speed of run-off and erosion. Roads along stream tend to be particularly undesirable, due to potential increased sedimentation of stream . Roads can encourage casual visitors, littering, and hunting from vehicles. In general roads decrease wildness.

Roads maintained with broad borders can mitigate some losses by functioning as forest clearings. Roads for occasional use by light vehicles can be made simply by removing enough trees and shrubs to make a passageway. Such roads will last indefinitely without disturbing the earth if they are used only by light vehicles during dry weather when the soil is firm.

DEER AND FOREST MANAGEMENT

Whitetail deer are popular animals with hunters and wildlife watchers. They are adapted to all Southern forest environments. Likewise, deer are compatible with most timber production practices. Almost any timber harvest can be argued as being beneficial for deer because deer use forests at all stages of succession- Early forest stages can provide browse, intermediate stages provide cover for hiding; mature forests can provide preferred foods such as acorns. All harvests, including clearcuts, create more browse, although this benefit is temporary. Harvest of oaks and other fruit and nut trees may hurt food production. Only when deer management becomes intense do trade-offs with wood production normally create conflicts. In general mature hardwood forests with abundant oaks provide plenty of food for deer in fall. This food declines during the winter. Mature forest habitat is often fair to poor for deer in spring and summer.

NEST BOXES

Timber management emphasizes sound, healthy trees that have commodity value. In such forests, lack of nest and den sites may limit certain wildlife populations, so the use of nest boxes will likely be beneficial. Table 19-2 gives specifications for wildlife nest boxes. If nest sites are a limiting factor, nest boxes can increase populations of raccoons, squirrels, certain owls, and some hole nesting songbirds.

MAKE A MANAGEMENT PLAN FOR WELDLIFE AND TIMBER

Most landowners have diverse goals for their forests which include both protection and integrated wildlife and timber plans, depending on the habitat. If you are an experienced forest manager and you spend a lot of time on your land, you can keep your management plan in your head. But because there are so many possibilities for managing a forest to favor wildlife and timber, it pays to make a written plan. Basically, a forest management plan for wildlife, timber and other values includes identifying the features of the land and the plans to protect or manage each part.

What Does a Management Plan Do?

A management plan considers all aspects of land management. It helps you achieve goals, avoid losses and helps keep you from falling behind in your work. It can be simple or complex. The more care and thought you put into your plan, the more you will get out of it. Working on a Plan makes you think about your forest. Planning helps you enjoy your forest more.

A management plan is an inventory. It is a summary of the current condition of the land and all its resources of interest to the landowner. An inventory can include geographic, recreational and wildlife features. It should include more than trees. An inventory is a kind of snapshot of a changing condition. It serves as a reference point against which you can view change and measure success.

A management plan predicts changes and includes predictions based upon past growth rates and estimates of site indices, for example. Also, it includes your own personal plans.

A management plan schedules tasks to achieve goals. Goals might be to improve timber stands, regenerate new trees, preserve special areas, cut firewood or timber, or establish food plots for wildlife. To make a management plan you need knowledge and skills. If you are short of skills, get information and help from the Extension Service, or state forest or wildlife agencies, private consultants or other professionals. As time goes by, experience will increase your capabilities.

Tips for Making Your Management Plan

1. Inventory Your Resources

Start management plan by making notes as you roam around your forest. Identify boundaries. Get a topographic map, a soil map and an aerial photograph. These may be available from U.S. Geological Survey, ASCS office or Soil Conservation Service offices. Next make a map that shows details of the land: roads, trails, fences, power lines, buildings, and stands of trees according to species and size.

Also make note of streams, marshes, ponds, rocky outcrops, sandhills, animal burrows, den trees, nesting sites of unusual birds, rare plants, old house sites, Indian artifact sites and anything else that interests you. Identify features on the map with names or numbers. Make notes on the

Table 19-2. Summary of specifications for some wildlife nest boxes. Nest boxes can substitute for tree cavities for many birds and mammals. Note - entrance holes do not need to be round - square or triangular holes are ok.

Birds	Hole size diameter	Approximate box dimensions
	---------------------------------inches	----------------------------
House wren	1	5 x 5 x 10 high
Prothonotary warbler	1 1/4	5 x 5 x 10 high
White breaded nuthatch	1 1/4	5 x 5 x 10 high
Chickadee	1 1/8	6 x 6 x 12 high
Eastern bluebird	1 1/2	6 x 6 x 12 high
Crested flycatcher	1 3/4	6 x 6 x 12 high
Flicker	2 1/2	7 X 7 X 24 high
Screech owl	3	9 X 9 X 16 high
Wood duck	3" high, 4" wide (oval hole)	11 x 11 x 24 high
Barred owl	8	13 x 13 x 24 high
Mammals		
Gray and fox squirrel	3	8 x 8 x 15 high
Flying squirrel	2	8 x 8 x 15 high
Raccoon	5 high x 9 wide	13 x 13 x 24 high

ecological development of your stands or habitats. For example, you might note dates and locations Of previous fires or grazing, beaver damage, soil erosion, soil type, timber harvest, and areas of young seedlings. List wildlife species that are likely to occur on the land, with notes on where these animals occur. The greater your appreciation and knowledge of wildlife the more decisions you need to make. If you need help, hire a qualified wildlife biologist.

After your map is complete, make a cruise of each stand of trees. A timber cruise details the number of trees of each kind and size class bearing the name or number of the section of the map to which it applies. The cruise gives the volume and value of your wood products. It enables you to show a timber basis value so you can deduct the cost of your timber at the time of land purchase from future sales. Hire a professional forester if you are uncertain about your ability to cruise timber.

2. <u>Predict Changes and Make Plans</u>

After your inventory is complete, determine your goals for each forest stand, habitat type or special area. These are your management units. Consider these factors when you choose your management goals for each management unit.

a) How rare is the habitat?
b) What is the present timber value?
c) What is the timber potential?
d) What present and potential wildlife does it support?
e) What are your recreational interests on this property?
f) What is its value for subdividing and building?
g) How long will you own the land?
h) What are likely to be the goals of children, future owners, or buyers?

Some management units may be for income production, while others may be for recreation, preservation, or other goals.

3. <u>Schedule Tasks to Achieve Goals</u>

Make a list of jobs for each management unit. For example, a stand of young hardwoods might need thinning. Estimate how many years will elapse before a stand needs cutting, based on current growth. Plan for access roads. Plant groves of mast-bearing trees, or thin an existing forest to make a grove by taking out all but the desired species. Plan for nest boxes if den trees are scarce. Schedule regular seasonal jobs such as planting wildlife food patches, hay mowing, and equipment maintenance.

Some places in your forest don't need work. They need protection. Streamsides and water edges need special care. A rocky outcrop surrounded by picturesque oaks and wildflowers might be such a place. Do you have a favorite swimming hole or picnic spot? Plan to exclude logging equipment from favorite spots during timber harvests.

After you select management practices for a stand, write them down. Update the management plan every 5 to 10 years. A complete management plan for a diverse tract of land might be a large complex document. On the other hand, an informal management plan could be as simple as an annotated sketch map.

PRACTICES THAT MAY FAVOR WILDLIFE

No simple wildlife management practices will work in all situations. Here are some suggestions to consider, depending on your wildlife habitat management goals.

1. Design timber harvest to favor wildlife diversity. Identify what wildlife communities you wish to perpetuate.
   a) Harvest, thin, or protect certain areas from timber harvest, depending on wildlife to favor.
   b) Plan edges of cuts to be wavy and irregular to increase the amount of habitat edge.

c) Leave forests uncut along stream and drains to maintain corridors of undamaged streamside habitat. Keep logging equipment away from streams to protect stream banks and maintain water quality.
d) Leave forest corridors for wildlife travel lanes between patches of woods and along roadsides.
e) Leave a few clumps of large trees in clearcuts.
f) Leave den trees. Large den trees are much more rare and valuable than small ones.
g) Spare some good seed- and mast-producing trees such as persimmons, crabapples, dogwoods and oaks during harvest.
h) Pile logging slash to make brush piles.

2. Use prescribed fire in openings. Set back plant succession and maintain browse plants.

3. Plant roads, clearings, odd areas, and log loading decks to wildlife foods.
   a) Plant clovers, ryegrass or wheat or other cool season crops in late summer to produce fall, winter, and spring forage.
   b) Plant browntop millet or sorghum or other warm season crops for summer and fall wildlife food.
   c) Plant field borders or clearings to bicolor lespedeza, to make thickets and feeding areas for quail.
   d) Plant nut and fruit trees in permanent wildlife food patches and clearings. Oaks, persimmons, pears, chestnuts, and crabapples are good choices. Pick trees adapted to your area. Protect seedlings with a wire mesh cylinder when young or deer and rabbits will eat them.

4. Use good harvest systems.
   a) After harvest or thinning, leave piles of logging slash unburned. Bobcat, fox, raccoon, rabbits, and other small game will den in those places.
   b) Protect fragile or rare groundcovers. Consider natural regeneration in such areas. In hardwood forests, ground covers of Lycopodium, certain wild flowers, or rare plants may be damaged by logging.
   c) Avoid site preparation or other soil disturbance near stream , gullies or other erosion-prone sites.

5. Install artificial nest boxes for owls, songbirds, wood ducks, squirrels, raccoons, and other cavity-nesters. Nest boxes can increase populations in areas where den trees are -scarce. Get plans from your county agent. Don't put nails into trees with timber potential. Attach next boxes to branches, not main stems.

6. Inventory and protect rare animals or plants and their habitats.

7. Protect grapevine and other fruit-producing plants useful to wildlife.

8. Harvest deer during the hunting season to maintain deer populations at a level where they won't harm the habitat.

9. Ask a qualified wildlife biologist for advice on specialized management problems. "Certified wildlife biologist" is the professional designation for qualified wildlife managers.

10. Read books and articles on wildlife management.

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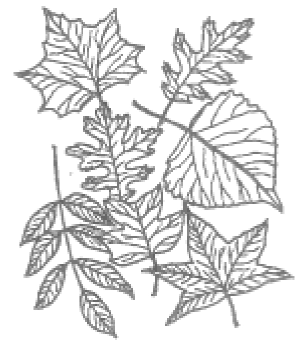
20. Alternative Forest Products



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In planning hardwood forest management there are a number of nontimber products that should be considered. They are in no way just "minor forest products." Some of them, such as recreation, could produce substantially greater income and involve more acreage than timber production. Nor can we categorize them as "nontraditional forest products" for several of have long traditions in the United States and elsewhere. The term "alternative forest products" comes to mind, as one or more of these opportunities may be available to provide a welcome supplement to timber income in hardwood regions of the United States.

Among the alternative forest products that provide substantial income in hardwood regions of the East are: forest recreation including hunting, fishing and other recreational leases; maple sugar production, beekeeping, ginseng collection and cultivation and shiitake mushroom cultivation. Other products such as deer tongue *(Carphephorus paniculatus),* blueberries, Spanish moss, Christmas greens and nut crops may also be of local importance. While many of these sources of income may occur naturally on your forest land, there are practices that can substantially improve their profitability.

Generating income from any of these endeavors will depend to a large extent on marketing. Profitability of many of these products will also be affected by labor intensity, capital investment, and good record keeping. You must be willing to invest some "sweat equity", and study production and marketing, to develop a successful operation. If, you are interested in dabbling in a new venture and are in a position to invest some time (and some capital), you may be pleasantly surprised.

City stores and country markets alike sell products generated from America's forestland at prices that would amaze you. Ginseng roots may retail for over $100 per pound. Shiitake mushrooms sell in some areas for $28 per pound. A boutique in Florida sells 10-pound bags of mesquite wood (a pest species in the west) for $25 each. Wood shavings swept off your workroom floor can be mixed with some fragrant spices and oils, leaves from bay trees and a few rose petals to sell for $1 per ounce! Marketing is the "magic" ingredient in most cases. Knowledge of production then maximizes profitability.

Alternative forest Products may have a place in your forest management Plan. You are limited only by your knowledge, imagination, and resources. This chapter should increase your knowledge base. the imagination is up to you, family members and friends. Production considerations on a number of alternative possibilities are presented along with general marketing suggestions.

As forestland owners You may utilize natural resources as they are found, cultivate existing products or introduce products not found naturally on your property.

GINSENG

Ginseng is an herb with medicinal values long recognized in the Orient. Since the 18th century, American ginseng, *Panax quinquefolium* L., has been harvested for export to the Far East by southern land owners. For example, combined miles of wild and cultivated ginseng in Kentucky yields close to $5 million annually.

Growth and Reproduction

Ginseng grows naturally in rich hardwood stands in the eastern United States and Canada. The ginseng Plant has growth requirements similar to those of jack-in-the-pulpit and wild ginger, so you may expect to find wild ginseng plants in shady, moist but well-drained locations with soil high in organic matter.

Severe over-exploitation of ginseng in the 1800's resulted in drastic reduction of populations of the wild plant. Wild ginseng, where available, currently sells for as much as $100 per pound. Cultivated American ginseng may bring over $50 per pound. Uncontrolled collections have brought the plant to the brink of "threatened and endangered" status in some areas.

Before harvesting, check the Ginseng Harvest Act, passed in 1985. Key provisions of the act require a landowner's permission to remove ginseng grown on private land. No digging of wild ginseng is allowed between August 15 and December 31. Plants with green berries may not be harvested, nor may plants with less than three prongs (younger than 3 years old). If a plant has red berries, the berries must be planted in the vicinity when the root is harvested.

If considering trade in ginseng, it would be wise to plan for cultivation of the plant from purchased seeds. The 6- to 8-year “rotation". for ginseng allows multiple cropping between hardwood harvests. Ginseng requires shade, and the shifting shade of overstory hardwoods promotes an ideal microclimate for growth. The best Sites include rich, moist but well-drained soil, supporting long-lived hardwoods such as oak, hickory, beech or walnut. Moist north or northeast slopes are preferred over drier South-facing slopes.

Cultivation

Seeds or roots can be planted in beds where weeds and understory growth have been removed and soil has been cultivated to a depth of 6 inches or more. Soil testing should be done in advance since high fertility may produce top-heavy plants. General procedure involves stratifying seeds, spacing and mulching plants, weeding and pest control. It takes 18 months for plants to emerge from seed. Ginseng cultivation is labor-intensive since most weeding must be done by hand. At this time there are no herbicides labeled for ginseng cultivation.

Harvest

Sufficient Seeds for harvesting will probably be available at the end of the second growing season of the new ginseng plant, and every subsequent year before the root is harvested. Seeds must be depulped and properly stored to prevent drying. Yields of 150 to 200 pounds per acre have been reported. At market values of $50 to $70 per pound, seeds can bring $7,500 to $10,000 per acre once the plants are 5 to 6 years old.

The ultimate harvest, however, is the harvest of roots, which may occur between 4 and 10 years of age, depending upon size, market conditions and personal preference. Several years of seed production provides additional income. Roots generally do not grow substantially beyond marketable size after the 8th year of growth.

Undersized roots can be replanted. Whole roots bring much higher values than broken pieces, so careful harvesting with a hand tool is recommended. Roots should be dried naturally, not oven dried (which reduces quality). Store them in a dry, rodent-proof area until ready for sale.

Current prices for cultivated roots in the South fluctuate around $50 per pound. Rates vary from year to year so check your markets before harvest. Yields of 1,500 to 2,00 pounds per acre, dry weight, can be expected with good management.

Consideration

Theft, pests, intensive labor requirements and rotations of at least 4 years must be considered before embarking on ginseng production. The return on your investment can be significant and the flexibility of realizing your income for tax purposes or personal financial planning is desirable. Even a small backyard ginseng patch (1/10 acre or less) can yield substantial supplemental income.

SHIITAKE MUSHROOMS

Another alternative forest product from hardwood forests, like ginseng, arose in the Orient, where environments similar to those of eastern deciduous forest are found. Shiitake or forest mushrooms *(Lentinus edodes)* are native to Japan and China. Changing dietary habits of Americans, including gourmet and Oriental cuisine, have resulted in a definite growth opportunity in production of these distinctive mushrooms. Although most shiitakes consumed in the United States are still imported, there is a growing market for domestically produced shiitakes. They are high in some vitamins and essential amino acids. Japanese medical research indicates that eating these mushrooms tends to reduce blood cholesterol levels.

Growth and Reproduction

The shiitake mushroom is a wood-destroying fungus that feeds on specific hardwood trees. In their native Japan, shiitakes have been cultivated for centuries. They typically grow larger than the white, button mushrooms common in supermarkets. Shiitakes vary from honey-colored to chocolate brown.

Shiitake culture may provide a profitable use for logs of many tight-barked hardwood species that are of precommercial size (2.5 to 8 inches) or low timber quality cultivated on-site under partial shade.

The basic steps:

1. <u>Market Location</u>

Explore your area to determine whether or not there is a market for your product. Gourmet or French restaurants, Oriental food stores, natural or health-food stores are good potential markets. If none of these exist in your area, you may need to build a market by educating local consumers and restaurant chefs about the flavor and nutritional qualities of shiitakes. Try demonstrations, newspaper articles or promotion in a local grocery store. Demand will determine your price. Local markets could be flooded easily, so check with other potential growers and consider cooperative marketing. This may allow sufficient volume to sell to supermarkets, which would need a constant supply greater than one grower could handle, or to produce wholesalers in nearly urban centers.

2. Plan Ahead

Gather current information on mushroom culture from you State Cooperative Extension Service. Research on shiitake mushrooms is being conducted at several universities, and recent findings may help you avoid pitfalls and improve production.

3. Select Yarding Area and Logs

Locate a shady area for stacking and storing inoculated logs. Select the trees to be cut. White oak appears to be a preferred species, but mushrooms have been cultivated on sweetgum, hickory, maple and other oaks. Logs with a diameter of 2.5 to 8 inches and a length of 3 to 4 feet will provide sufficient sapwood for good growth while remaining small enough to move around.

4. Ordering Inoculum

The active material, or spawn comes in two forms: dowel spawn (spores pre-injected into small dowels), or sawdust spawn (usually packed in blocks which are then broken down into loose sawdust for inoculation). Spawn should be ordered a month or more in advance of planned inoculation.

There are several strains of shiitake, which vary not only in size and color of mushroom, but also in, speed of fruiting and optimal fruiting temperature. Depending upon the climate m your area, different strains may prove more successful than others. Shiitakes are now grown as far north as Canada and as far south as Florida. Contact your Extension office for strains appropriate for your area.

5. Cultivation

Once the appropriate strains are identified and ordered, harvest trees for the logs. Ideally, trees should be cut late in the dormant season when sugar content in the wood is highest. Mushrooms need a high carbohydrate content in the sapwood to grow well. Late winter is probably best, ranging from late January in the South to late March in the North. Trees should be cut into approximately 3-foot lengths. Inoculate the logs no later than 1 to 2 weeks after harvest to avoid infection by other fungal species.

To inoculate the logs, drill rows of 1/2 inch holes about 6 inches apart along the entire length of the log. If you select dowel spawn, holes may need to be slightly larger to accommodate the dowel. Rows may be evenly spaced every 1 1/2 to 2 inches around the log. Offset the alternating rows to provide maximum room for growth of mushrooms in the resulting diamond pattern.

Inject or hammer the spawn into each hole and then seal the inoculation site to prevent bacterial or fungal competitors from entering the log. Styrofoam. plugs and hot wax have been used successfully. Hot wax will kill *the top* layer of spawn, but it will also sterilize the area, preventing growth of unwanted competitive fungi. The spawn not contacted by the wax will still be able to grow.

Market Location

As in any business venture, the first step is to analyze your potential market. Although it is possible to sell honey in bulk to processors, your profit per pound of honey is generally higher if you sell retail. For this reason, your major strategy should be to develop a local market. Many of the same promotions mentioned with mushroom marketing will apply.

Roadside stands, local farmers markets, local grocery and health food stores all may be suitable outlets for your product. If you can sell direct to the consumer you gain the profits the middleman (store owner) would otherwise reap. It pays to advertise!

Examine Investment Requirements

If you own your own land, but are not interested in capital outlay for equipment and supplies, (hives, bees, medicines, food, honey containers, etc.) you may be interested in leasing your land to someone who is already involved in beekeeping. In the national forests in Florida, bee leases go for about $24 per quarter acre (50 hives) per year, on one forest, to nearly $45 per quarter acre, on the most productive forest. Offer leases to nearby beekeepers and negotiate a reasonable charge.

If you have money and time to invest, explore your land and learn where bees might be most productive. If you have suitable sites and the motivation to invest, send for A *Study in Profitability for a Mid-sized Beekeeping Operation.* This circular will provide you with investment information, estimated costs and projected profits to assist you in decision making. Copies are available from the Florida address below the title of this chapter.

Contact your county Cooperative Extension Service for information on bee culture in your State. Climate, available nectar and pollen sources, local agricultural practices and local pests and problems (high populations of bears, for example), may make beekeeping more or less feasible. In the South, where growing seasons are long, bees can produce honey and more bees much of the year. In more northern climes, dormant hives are not productive for several months and, in fact, may require supplemental feeding by the beekeeper in severe winter weather.

If Beekeeping Looks like a Good Bet

Build your first hives, order your wax and bees and give it a try.

Be wary if you find that beekeeping is made to look simple in many popular articles and books. The reality is that it is perhaps more difficult to be successful in beekeeping than in other forms of agriculture. This is because of the number of variables over which the beekeeper has little or no control.

So begin your experiment, armed with current information and a conservative outlook.

Keep Records

A permanent record-keeping system where you record investments, productivity of each hive, seasonal variation in productivity, time of blossoming of various nectar plants, health and numbers of bees, income from sales and time invested in labor will help you to streamline your operation and to make a profit, where others may fail. If you know that hive #9 in the northeast clearing consistently outproduces every other hive, you are in a position to determine what factors make it productive.

Relocation of other hives and/or requeening with a queen of the same quality and temperament may improve your overall productivity substantially.

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Keep Watch

Frequent inspections of hives are necessary to assure health and productivity of the bees, and to prevent unwanted swarming. Constant communication with neighbors, especially those involved in agricultural or horticultural endeavors, is a necessity. Unprotected hives subjected to nearby pesticide applications can be destroyed. If neighbors are going to spray or the mosquito commission is going into action, you need to know it.

Keep it Small

A few successful hives can produce some added income with little risk of financial disaster, even if frost hits early or the local bruins raid your hives. Once you have established a successful small business and a reasonable local market, explore possibilities of expanding both. Experience and good records are your most valuable assets in beekeeping. Building on these cornerstones can bring the sweet taste of success.

MAPLE SYRUP

A strange subject in a guide for southern hardwood management? Yet, in some regions of the South, especially at higher elevations in Kentucky and Tennessee, ecological and climatic conditions for maple *syrup* production do exist. While all maples produce the sweet sap that eventually may become syrup, it is only the sugar maple and black maple that are generally tapped. At least 75 percent of all commercial maple sugar comes from sugar maple trees because they are the species with the highest sugar content in their sap. If you have mature sugar maples on your land and the seasonal variations are conducive to good sap flow, maple sugaring may be a viable source of income.

The characteristics of good sugaring trees are different from. those of good timber trees. In a sugar bush (a maple stand managed for syrup production) trees should be fairly widely spaced, so they will develop wide crowns and increase diameter *without gaining great height.* Trees with crowns greater than 30 feet in diameter can produce as much as 100 percent more syrup than those with narrower crowns. Their sap may also be as much as 30 percent sweeter. Before thinning a stand, it is important to evaluate individual trees, so that you do not thin out the trees that may be your best producers. A professional forester with sugar bush experience can help you in initial tree selection.

Tree Selection

Sugar maple is the preferred species and trees over 10 inches d.b.h. (diameter measured at 4.5 feet above ground level) are required for tapping. Average sugar maples contain about 2 percent sugar in the sap. Higher sugar content will mean more syrup from less sap, so select for trees with high sugar content. Sugar content is measured by drawing off a sample of sap and floating an instrument called a hydrometer in the sample. The hydrometer is marked in degrees of Brix. Brix measurements are temperature-dependent and readings must be adjusted according to the following temperature ranges:

Temperature	Brix Adjustment
32-50	-0.4
51-59	-0.3
60-68	-0.1

The adjusted Brix measurement indicates that the sap has the density (and therefore the percent sugar content) equal to the Brix reading. A 2 Brix indicates that the sap is about 2 percent sugar. Trees with less than 1 Brix should be culled from your sugar bush. If thinning is required, keep the trees with the highest Brix readings. Tapped trees should be remeasured annually and records kept to assure continued maximum production.

Twenty-five to thirty productive trees per acre are ideal for a modest, commercial, maple-syrup operation. Crown spacing should be wide enough to allow at least 6 feet between crown edges of trees. Reduce competition from other canopy and understory trees by cutting them, but maintain ground cover between trees to prevent erosion. Keep wood from the trees you have cut to provide fuel for boiling the sap. Do not plan to graze cattle in your sugar bush, as soil compaction is likely to damage trees and reduce their productivity.

Sap Collection

Sap is removed from trees through spiles, which are specialized metal tubes inserted into the tree. A tap hole is drilled about 3 inches into the tree with a V16 inch drill bit at a slightly upward angle. If the tree has been tapped before, locate new holes at least 6 inches to one side and 4 inches lower or higher than the old hole. After drilling, tap the spile gently into the hole with a hammer.

Trees under 10 inches d.b.h. may be damaged by tapping. Larger trees may support more than one tap. The following guidelines are advised.

Tree diameter *(inches d.b.h..)*	Number of trees
10-15	1
16-20	2
20-25	3
Greater than 25	4

Sap may be collected in buckets, plastic bags or plastic tubing from a vacuum system. Buckets should be covered to prevent contamination and dilution of sap. Vacuum-tube systems are the high technology method, requiring an increased level of capital investment, but lower labor intensity in sap collection. The sap is also kept cleaner and the system may increase sap production significantly. Detailed information on tube-collection systems is available from the Cooperative Extension Service in several New England States where the cost/benefit ratio makes such investments commonplace. In the South, such capital investments need careful analysis of your ROI (return on investment).

Sap will generally begin to flow in the spring when daytime temperatures approach 45 to 55 degrees and nights remain cool (20 to 35 degrees). This is generally in February or March in "sugar country", but you should have your equipment ready and clean anytime after the new year in southern regions. Boil your sap as soon as possible to prevent it from *fermenting. If* the sap run stops, do not leave sap in the bucket. It will spoil and ruin the next run.

Processing the Syrup

If you have processed sorghum, you will find "sugaring off" to be very familiar. The ideal location for evaporator pans is inside an enclosure that is well ventilated. Do not try to process syrup M a home kitchen, however, because vast amounts of moisture given off by evaporation may damage your home and furnishings. Small-scale processing may be accomplished outdoors, but a roof and walls will keep the operation cleaner and more comfortable. In the shed or sugar house you will need steam vents in the roof and air intake and exhaust vents for smoke from a wood fire.

Before processing, store the sap in an insulated tank. The evaporating pan sits over a firebox, the source of heat for evaporation. When you start boiling the sap, keep adding more sap to the pan as the water boils away. Maintain at least 1 inch in the pan or it may burn. You can pour cold sap into boiling sap, but in more sophisticated setups, sap is heated before it is added to the evaporating pan. It will take a lot of boiling to reduce the sap to syrup. Generally, about 10 gallons of sap will yield 1 quart of maple syrup. As the syrup boils, you will need to take Brix readings from time to time. When Brix reaches 55 to 60, remove the sap to a finishing pan and continue boiling until it reaches 66 Brix. Syrup of an appropriate sugar content weighs about 11 pounds per gallon. If your syrup weighs more than this, its sugar content is too high, and it may crystallize in the bottom of the container. After syrup reaches 66 Brix, it may be cooled, filtered and then reheated to boiling or, if the syrup is pure and free from danger of crystallizing, it may be bottled immediately.

Equipment must be thoroughly cleaned between batches to prevent sediments or old sap from contaminating a new batch. Syrup should be stored in a cool place. A freezer is ideal because properly-prepared syrup will not freeze, and if the syrup is not properly sealed, it is less likely to spoil.

Marketing

Pure maple syrup is a very popular and valuable forest product. Local marketing of your syrup should be painless if it meets USDA standards. Outlets similar to those listed for honey and mushrooms should be appropriate for maple syrup also. Information on grading and additional information on processing may be obtained from the *Maple Syrup Producers Manual, Agriculture Handbook* 134. Although out of print, it is available from a library.

Considerations

In much of the South, maple trees are not within their ideal range for maximum growth. Geographic and climatic factors do not lend themselves to high quality maple syrup production as they do in Vermont, New Hampshire and Maine. Should you have sugar maples on your property, tap one or two trees for testing and family consumption before investing heavily in equipment and time. If you find your syrup is sweet and amber, you may proceed to sweeten your forest income. If, however, you are prone to enjoy early spring on the ski slopes or southern beaches, remember that sugaring off requires constant work and critical timing. To *paraphrase one of the great truths of life, "Time and sap wait for no one."--Maple Syrup Producers Manual.*

FOREST RECREATION

As in other ventures, the profitability of a forest recreation business will depend on the marketability of your "product". Forms of forest recreation, including hiking, camping, hunting, fishing, nature study or picnicking are popular with many Americans. Often, opportunities to enjoy these forms of recreation are available without fee, and they will not support a business activity. If you expect to operate a successful business enterprise, you must find a way to profit from people's recreational interests. This may involve charging for access to your land. If similar land is open to them without charge, you may still establish a profitable business by selling supplies or charging for services in conjunction with the recreational opportunity.

There are six basic steps you should take before establishing a forest recreation business. Once these steps are completed, you will know better whether to develop your land for recreational use or select an alternative land use.

Conduct Site Evaluation

The characteristics of your property will determine, to a large extent, the feasibility of establishing a recreational business. Your forest land must be composed of a mixture of wooded and open land that can tolerate recreational impacts. Soils should be well-drained, respond well to treatment and not be subject to compaction due to normal recreational use. If vehicles will be allowed, paving or other protective techniques must be possible and affordable. Too many "pest" plants, (poison ivy, greenbriar, poison sumac, palmetto) reduce the suitability of your land for recreational use.

Most profitable sites will have great natural beauty and/or be located near a major recreational attraction such as a beach, ski area, theme park, or national park. The site must also be within reasonable driving distance of large population areas to assure a market. Not only must the distance be reasonable but also the access roads must be good. “Privacy" and "secluded" are not the same as "inaccessible ". Location may be *the* critical factor. Undesirable neighboring businesses, poor access roads, dense populations, and high traffic may be real deterrents to establishing a positive recreational experience. If there isn't a large population of possible customers within an acceptable distance, it may cost more to attract them through advertising and promotion than the business can generate.

For camping, you will have to provide water for drinking and washing as well as sanitary facilities. If soil percolation is a problem, you may want to investigate some of the waterless toilet options. Other utilities will be needed if you allow recreational vehicles.

Picnicking is a very popular forest recreational activity. Few people, however, are willing to pay for use of a picnic site, unless sites are very scarce or special features accompany it. The combination of a number of activities (swimming, picnic sites, game area, hiking trails) may present a strong enough attraction that sales of food and supplies will generate income on a sustained basis. Such an operation is usually successful only when there is high demand, a large local population or an established campground/resort.

Differences in the natural resource base on your land will affect the types of recreational business opportunities possible there. Flat land with large water bodies is excellent for fishing, swimming, boating and other associated recreation, Hilly or mountainous property will provide more of a challenge and variety for hikers, backpackers and many birdwatchers. Mountain stream may be excellent trout fishing spots, but may also be ecologically fragile and therefore not suitable for heavy use.

Recreational consultants may prove to be of great value in surveying your property. Potential problem sites can be discovered early and avoided or treated during development. Consultants can point out areas where high traffic may require paving or mulching to prevent destruction of the soil and, in other cases, you may have to restrict some sensitive areas from public use. A consultant looks at the area with a fresh perspective, seeing opportunities you have overlooked.

Diversity in your land, such as a mixture of natural wooded areas and open spaces, makes it more attractive. A variety of mature and uneven stands, with an occasional snag to provide food and nesting sites for wildlife will prove more attractive than. vast evenaged stands or plantations. A certain degree of tidiness is important in wooded areas: removal of dead limbs and fallen trees on trails will reduce hazards to hikers.

Topography, as well as forest cover, will affect sun-shade patterns. The aspect (or compass direction faced) of a slope may make it too hot for comfortable summer hiking, while the same southern exposure may be very pleasant for winter hikes and camp sites. Slope will influence microclimate, as well as susceptibility to erosion and ease of walking.

Determine Business Potential

If, after a thorough evaluation of the site, you think your land has recreational potential, you must analyze the *business* potential of your site. The principal problem is determining if the right mix of natural resources exists to develop and operate a successful business. One method of determining this is to study areas similar to the one you wish to develop. If you select businesses with which you will not be directly competing and explain your purpose, you will usually find them cooperative. A few tips for your study tour follow:

* Select and visit at least three businesses that relate to your conditions. You will find different operational procedures at each and learn much more.

* Look for the kinds of information that make a difference in managing the business. The "surface" conditions evident to the average camper often have little to do with successful business management.

* Prepare a list of questions that have to do with your site, or which deal with specific information you need.

* Listen carefully and do not waste your hosts' time. Take careful notes or record the session with your hosts' permission.

* Talk to the customers. Ask what they like about this particular site. Don% be negative or disrespectful to your hosts or their facilities.

* Ask the manager what aspects of the business are most profitable, least profitable (and why), most labor intensive and most costly to maintain.

* Finally, ask your business hosts what they would do differently if they were building another such business.

By the time you have finished, you should have a good idea of what venture capital is required, what your prospective returns may be and what is required to manage customers. You may also have decided that such a business is a lot more work than you expected! The amount of work involved will vary substantially with the type of forest recreation that you decide to manage. A staffed campground will require more labor and capital than will leasing land on which to hunt or fish. Maintaining hiking trails in rough terrain may involve more work than will maintaining a nature trail through a well-drained forest ecosystem.

Recreational opportunities may include hunting, fishing, camping, resort recreation, photography, nature study, hiking, cycling, off-road-vehicle use, horseback riding, swimming or target shooting. In each instance, a fundamental understanding of how a business may be based on the recreational activity is necessary. Using hunting as an example: a successful business may have sufficient animals for fees from hunting to exceed costs of doing business. With the exception of some migratory waterfowl species, this will involve either intensive wildlife habitat management or purchase of birds to be shot. You must have knowledge of habitat management, hunting, the requirements of target animals, as well as business management skills and people skills needed to deal with clients. Charging a fee for hunting wild boar is drastically different from operating a quail shooting area. As with any business venture, good records of expenses and income will help in improving profitability or minimizing loss.

Review People Management Requirements

If you aren't people oriented, if you do not enjoy working with people of all sorts, and if you are unable to use tact and good judgment in the face of all kinds of problems, stay out of the recreation business. No matter how well your land lends itself to recreational development or how much you may learn about the business, recreational business involves serving people. You need to be able to cater to the whims of customers, create and enforce reasonable regulations concerning pets, noise, drinking and vandalism. If hunting leases are your bread and butter, you need to be able to control trespass and shooting near livestock, pleasantly but firmly, as well as to protect yourself from liability in case of accidents.

You could also live elsewhere and hire a manager, but here too, you will need to interact effectively and knowledgeably with your employee. Hiring someone to do the work, of course, reduces your net income from your recreational business venture.

Exploring Marketing Potential

You are not selling a bar of soap. Instead, you are offering a campsite, a wild-game shooting opportunity, or perhaps a hiking experience through a part of scenic America. As in more conventional product sales, the quality of what you offer is vital. Your customers must be able to see immediately the level of recreational experience possible at your site. The quality relates dramatically to the likelihood of their returning and referring other customers to your business. If they are put off by potholed roads or shoddy buildings, they may never discover the excellent fishing experience provided by your well-managed lake.

Appropriate pricing is another element of business that must be considered. You must clearly understand your customers' evaluation of the experience at similar facilities, the time of year, the quality of their surroundings, will all enter into their evaluation of your site. Even when your price is right, external factors such as weather or competition from a new recreation option may reduce the number of “buyers".

Advertising (purchased messages), publicity, direct contact and promotional events may all be used to attract customers to your site. Radio, television, newspapers and appropriate magazines are all useful forums for getting out the word that you are in business and have a quality experience to offer. Brochures, posters and billboards can also be informative. Target your promotions to your intended clientele in order to attract the customers you want. Then you must select the appropriate formats or medias in which to advertise.

Unlike a fairly localized marketing program for products like honey or mushrooms, recreational marketing may involve a large geographic area, possibly statewide or even national in scale. The following are marketing options, from basic to sophisticated.

Word-of-mouth referral-- communication among individuals; usually involves a high level of trust, personal receptivity and feedback; limited in numbers of audience reached.

Direct Mail -- allows recreational area owner to convey specific information to a specific audience. Bulk mail or individual letters may be sent to appropriate individuals or organizations.

Newspapers -- Advertisements may resemble direct-mail fliers, but reach a larger, less specific audience at less expense. News articles featuring your site may be of even more value. This may vary from a visiting dignitary to use of your location for some event of community concern. The bagging of record deer, turkey or fish by one of your customers will be legitimate news of great value in your marketing program.

Magazines -- Provide access to more specific audiences such as readers of hunting, fishing or camping magazines. Magazines provide an opportunity to mix articles with advertising. Quality of presentation in magazines is usually higher than in other print media.

Radio -- Messages can be targeted to specific audiences (such as country music or classical), at specific times of day (after-work commuters ready for a relaxing weekend), in localized areas (via local stations) and may be repeated on other stations with variations for other audiences.

Television -- The most colorful and most general medium. National airtime is extremely expensive, but local stations may be within your budget. The high credibility and opportunity to embellish your message may make television worth the price.

To assure that your potential customers receive the message you want to get across, you must have a clear idea of what you are offering them and what you want them to know about your area and facilities. Once you establish the image you want to portray, you can develop a marketing plan more efficiently and accurately. Most of the media listed employ sales people with whom you may consult. Visit with them and see what each has to offer.

Outline Development, Operation and Management Procedures

Development, construction, operation and management of different types of forest recreation each had its own peculiarities, but fundamental concerns are common. Most important is a clear understanding of what kinds of experiences result in employment, what type of structure may be necessary to support activities, and what constitute the differences between outstanding and second-rate recreational experiences.

Secondly, you must plan for development, often under adverse conditions (such as steep slopes or erodible soils) very different from a typical subdivision situation. Yet, with added constraints, you must be able to "develop" without destroying the natural beauty of the environment to which your customers are attracted.

Finally, you must develop a resource management plan, including both the natural resources of your site and the financial resources attached to it. Financial record keeping (including the value of the long hours and hard work you invest) must be accurate and consistent in order to determine the actual worth of your enterprise.

Project Feasibility

No matter how carefully you do your research, success is not guaranteed. Before you commit yourself to a recreational development venture you must research it thoroughly to eliminate guesswork. Set out all the development, construction, promotion, finance, operation and labor costs you can project. Be liberal with cost estimates. Then develop a conservative estimate of probable returns from sales and fees.

With this cost-income estimate before you, you are in a reasonable position to decide if the time, effort, money and personal costs to you and your family are worth the probable returns. It would be worth your time to calculate your actual expected profitability or return on investment (ROI). The ROI indicates what return, as a percent of your investment, you might expect to achieve. A good basic economic text can provide formulas for ROI that can be applied to any business venture.

Considerations

A successful recreational business can provide substantial income and satisfaction, but a business so dependent upon external factors that you cannot control is not a wise venture for those in marginal financial situations. It may take several seasons for even the best recreational facility to "catch on" with your potential customers. Poor weather conditions during your peak season may cut income below your breakeven point several years in a row. For these reasons, a recreation business, like most other businesses, should be approached conservatively. Also, taxation treatments, licensing, and liability insurance should be major buying concerns.

An overall plan for your ideal recreational center should be prepared ahead of any investment, but a modular development/investment plan can allow you to build gradually, one segment at a time. Leave something for your customers to look forward to next time they come, (the new swimming dock, the wetland boardwalk, the laundry room, the paved parking area, the advanced hiking trail) so you need not invest all your funds "up front". Let your customers know what they may expect next reason if all goes well.

OTHER OPTIONS

Southern hardwood forests have produced food and other products useful or essential to human inhabitants for thousands of years. While you may be able to find all the necessities of life at your local market, there is someone who made a profit getting them there. You may be the one to garner the profits by providing necessities or luxuries others are willing to buy. The following list of additional forest products may include items associated with your land. These are items that people may be willing to purchase. Most simply need to be gathered and marketed. On a small scale, local stores or markets may be your best outlet. In some cases a seasonal roadside stand will suffice.

If you have a product you think may be marketable, contact your county Cooperative Extension Service and ask for advice. The agents will be able to assist you or put you in contact with someone who can provide you with recommendations or assistance with resource management, business skills or marketing.

Potentially Marketable Products

Nuts:	Black walnuts, pecans
Roots:	Sassafras
Berries:	Blueberries, blackberries, raspberries, holly berries
Greens:	Holly, laurel, ground pine or partridgeberry, bay (for cooking, seasonal decorations or floral use)
Wood:	Unusual species or forms (burls) for carving, ship building and crafts, locust wood (for fence posts)
Fruits:	Cherries, persimmons, apples, crabapples, pawpaws, and wild grapes
Spanish moss:	For floral use and crafts
Vines:	Wild grape or kudzu for craft
Deer tongue:	Aromatic additive to tobacco products

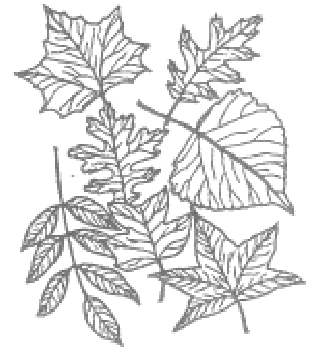
REFERENCES

Baughman, M.J. 1989. Financial analysis of shiitake mushroom production. In- Proceedings, Shiitake mushrooms, symposium and trade show; 1989 May 3-5, St. Paul, Minn. St. Paul, MN: University of Minnesota: 169-178.

English, J.E.; Roberts, C.R.; Stoltz, L.P.; Love, H.G.; Hartman, J.R.; Townsend, L.H. 1989. Cultivating ginseng in Kentucky. ID 60. Lexington, KY: University of Kentucky, College of Agriculture, Cooperative Extension Service. 12 p. (Available from the Agriculture Distribution Center, College of Agriculture, University of Kentucky, Lexington, KY 405460229.)

Leatham, G.F. 1982. Cultivation of shiitake, the Japanese forest mushroom, on logs; a potential industry for the U.S. Forest Products Journal. 32(8):29-35.

21. Forestry Assistance



Michael J. Walterscheidt
Extension Forestry
Texas A&M University
College Station., TX 77843

Accurate and precise answers and recommendations about your specific forest property are available from several sources, and you are encouraged to contact them. These sources can provide educational, technical and, in many instances, cost-share financial assistance to nonindustrial landowners throughout the South. Following is a list of the different sources.

1. Cooperative Extension Service -- Extension Services are responsible for the public educational and informational activities for the land-grant universities located in each State. Working cooperatively between the U.S. Department of Agriculture, the universities and colleges, and cooperating local governments, Extension specialists and agents provide educational programming for all interested groups and individuals. Educational programs and materials are available on all aspects of natural resources management and utilization. Extension, in cooperation with Forest Farmers Association, offers a woodland management correspondence course. Extension's assistance is available through your local Cooperative Extension Service agent listed in the telephone directory, under local government. Extension forestry specialists can be reached through your county Extension agent or by contacting the Cooperative Extension Service at the land-grant universities and colleges listed below:

ALABAMA

Auburn University
Extension Forestry
Alabama Cooperative Extension Service
Auburn, AL 36849-5418
205/844-1007

Alabama A&M
P.O. Box 628
Normal, AL 35762
205/851-5417

Tuskegee University
School of Agriculture & Home Economics
Tuskegee University, AL 36088
205/727-8327

ARKANSAS

University of Arkansas
P.O. Box 391
Little Rock, AR 72202
501/671-2186

University of Arkansas-Pine Bluff
P. 0. Box 82
Pine Bluff, AR 71601
501/541-6860 or 6576

FLORIDA

University of Florida
118 Newins-Ziegler Hall
Gainesville, FL 32611-0303
904/392-5420

Florida A&M University
P.O. Box 338
Tallahassee, FL 32307
905/599-3550

GEORGIA

University of Georgia
Extension Forest Resources
University of Georgia
Athens, GA 30602
706/542-3446

Fort Valley State College
P.O. Box 4061
Fort Valley, GA 31030
912/825-6451

KENTUCKY
University of Kentucky
Lexington, KY 40546-0073
606/257-2906

Kentucky State University
Atwood Research Facility
Frankfort, KY 40601
502/227-6738

LOUISIANA

Louisiana State University
Extension Forestry
265 Knapp Hall
Baton Rouge, LA 70803-1900
504/388-4087

Southern Univ. A&M College
P.O. Box 75044
Baton Rouge, LA 70874-5044
504/771-5704 or 3660

MISSISSIPPI
Mississippi State University
P.O. Box 5446
Mississippi State, MS 39762
601/325-3150

Alcorn A&M University
P.O. Box 1323
Lorman, MS 39096
601/877-3849

NORTH CAROLINA

North Carolina State University
Extension Forest Resources
Box 8003
Raleigh, NC 27695-8003
919/737-5578

North Carolina A&T State University
1601 E. Market Street
Greensboro, NC 27411
919/334-7709

OKLAHOMA

Oklahoma State University
239 Ag. Hall
Stillwater, OK 74078
405/744-6432

Langston University
P.O. Box 846
Langston, OK 73050
405/466-2231, Ext. 340

SOUTH CAROLINA
Clemson University
272 Lehotsky Hall
Clemson, SC 29634-1003
803/656-2480

South Carolina State College
P. 0. Box 1892
Orangeburg, SC 29116-1892
803/536-8397

TENNESSEE

The University of Tennessee
P.O. Box 1071
Knoxville, TN 37901-1071
615/974-7346

Tennessee State University
P. 0. Box 522
Nashville, TN 37209
615/320-3337

TEXAS

Texas A&M University
Extension Forestry
Room 302 Hort/Forestry Bldg.
College Station, TX
77843-2135
409/845-1351

Prairie View A&M University
P.O. Box B
Prairie View, TX 77446
409/857-2517

VIRGINIA

Virginia Tech
100 Cheatham Hall
Blacksburg, VA 24061-0321
703/231-8844

Virginia State University
Box 540
Petersburg, VA 23803
804/524-5959

2. State Forest Services -- Each State in the South has a State forestry agency responsible for many activities important to forestry. Although responsibilities may vary slightly from State to State, most have as a portion of their work the production and sale of seedlings, fire prevention and suppression, preparation of management prescriptions for landowners, administration of State and Federal cost-share programs, enforcement of forestry practices and laws, and information programs. Each State forestry agency has county or regional offices where professional advice is available to landowners. Offices are listed in your telephone directory or the State forester's office can be contacted. State Foresters' offices in the South are:

Alabama Forestry Commission
513 Madison Avenue
Montgomery, AL 36130-0601
205/240-9300

Arkansas Forestry Commission
P.O. Box 4523 Asher Station
3821 W. Roosevelt Road
Little Rock, AR 72214
501/664-2531

Florida Division of Forestry
Florida Dept. of Agriculture
3125 Conner Boulevard
Tallahassee, FL 32399-1650
904/488-4274

Georgia Forestry Commission
P.O. Box 819
Macon, GA 21398-4599
912/751-3521

Kentucky Division of Forestry
627 Commanche Trail
Frankfort, KY 40601-1798
502/564-4496

Louisiana Office of Forestry
Louisiana Dept. of Agriculture
P.O. Box 1628
5150 Florida boulevard
Baton Rouge, LA 70821
504/925-4500

Mississippi Forestry Commission
301 N. Lamar Street, Suite 300
Jackson, NO 39201
601/359-1386

North Carolina Division of Forest
Resources
Box 27687
512 N. Salisbury Street
Raleigh, NC 27611
919/733-2162

Oklahoma Forestry Division
Oklahoma Dept. of Agriculture
2800 N. Lincoln Boulevard
Oklahoma City, OK 73105
405/521-3864

South Carolina Commision of Forestry
P.O. Box 21707
Columbia, SC 29221
803/737-8800

Tennessee Division of Forestry
Department of Conservation
Box 40627
Nashville, TN 37204-4062
615/360-0720

Texas Forest Service
Texas A&M University
College Station, TX
77843-2136
409/845-2641

Virginia Department of Forestry
P.O. Box 3758
McCormick and Alderman Roads
Charlottesville, VA 22903-0758
804/977-6555

3. Consulting Foresters -- Consultants throughout the South offer complete forestry services from site preparation and stand establishment through timber harvesting and marketing. Consultants can be found in the yellow pages of your telephone directory. Directories listing consultants can be obtained from your county Extension agent, Extension forester or State forestry agency.

4. Forest Farmers Association -- Organized in 1941 to give private landowners a greater voice in matters affecting their interests. The membership includes private landowners, representatives from wood products industries, professional foresters, manufacturers, and leaders in related fields. Costs are minimal and include a magazine subscription. The address is: Forest Farmers Association, P.O. Box 95385, Atlanta, GA 30347-0385.

5. Forest Industry -- Many wood-using industries offer assistance to landowners in the form of technical advice, management planning, site preparation and planting services. Local wood-using industries can be contacted to determine the extent of services available in your area.

6. State Forestry Associations -- membership in State associations is open to all groups and individuals. They sponsor many types of informational, educational, and service functions forlandowners and the public.

Alabama Forestry Association
555 Alabama Street
Montgomery, AL 36104

Arkansas Forestry Association
410 S. Cross St.
Little Rock, AR 72201-3014

Florida Forestry Association
P.O. Box 1696
Tallahassee, FL 32302

Georgia Forestry Association
500 Pinnacle Ct. Suite 505
Norcross, GA 30071-3634

Kentucky Forestry Industries Association
310 Kings Daughters Drive, #7
Frankfort, KY 40601

Louisiana Forestry Association
P.O. Drawer 5067
Alexandria, LA 71307

Mississippi Forestry Association
201 Realtors Building
620 N. State Street
Jackson, MS 39202-3398

North Carolina Forestry Association
1600 Glenwood Drive, Suite I
Raleigh, NC 27608

Oklahoma Forestry Association
13 North Central
Idabel, OK 74745

South Carolina Forestry Association
P. 0. Box 21303
Columbia, SC 29221

Tennessee Forestry Association
P. 0. Box 290693
Nashville, TN 37229

Texas Forestry Association
P.O. Box 1488
Lufkin, TX 75902-1488

Virginia Forestry Association
1205 East Main Street
Richmond, VA 23219

7. American Forest Council, Southern Region -- A nonprofit State organization that is supported by the forest products industry to encourage the full development of the forest resources. Its programs include news and information services for media, group conferences, conservation communications training, Project Learning Tree and the American Tree Farm Program. AFC manages the Tree Farm Program through State tree farm committees. Its address is: American Forest Council - Southern Region, 2900 Chamblee-Tucker Road, Building #5, Atlanta, GA 30341.

8. Agricultural Stabilization and Conservation Service -- ASCS county offices distribute funds to private nonindustrial landowners for woodland conservation practices. An ASCS office is located in most counties in the South.

9. USDA Forest Service – An agency of the U.S. Department of Agriculture, the Forest Service manages our national forest lands in the South. In addition, the Forest Service conducts research applicable to management of privately-owned lands and publishes information that is available from the Southeastern Forest Experiment Station, Box 2680, Asheville, NC 28802, and the Southern Forest Experiment Station, U.S. Postal Service Building, 701 Loyola Avenue, New Orleans, LA 70113. The State and Private Forestry branch of the Forest Service's Southern Region assists State forestry agencies, industry, and individual landowners through publications, consultation, and other types of assistance. Headquarters for the agency's Southern Region is: USDA Forest Service, 1720 Peachtree Road, N.W., Atlanta, GA 30367-9102.

Appendix

Checklist of Common and Scientific Tree Names[1]

Common Name	**Scientific Name**
Apple, southern crab	*Malus angustifolia*
Ash	
green	*Fraxinus pennsylvanica* Marsh.
pumpkin	*F. profunda* (Bush) Bush
white	*F. americana*
Basswood, American	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Birch	
river	*Betula nigra* L.
sweet	*B. lenta* L.
Boxelder	*Acer negundo* L.
Buttonbush, common	*Cephalanthus* occidentails L.
Casuarina	*Casuarina* species
Chestnut	*Castanea spp.*
Cherry	
black	*Prunus serotina* Ehrh.
pin	P. *pensylvanica* L.
Cottonwood	
black	Populus *trichocarpa* Torr. & Gray
eastern	P. *deltoides* Bartr. ex Marsh. var. *deltoides*
swamp	P. *heterophylla* L.
Cypress	
baldcypress	*Taxodium distichum* (L.) Rich. var. *distichum*
pondcypress	T. *distichum* var. *nutans* (Ait.) Sweet

'Adapted from references at end of appendix.

Dogwood	*Cornus florida*
Elm	
American	*Ulmus americana L.*
cedar	U *crassifolia* Nutt.
red	U *rubra*
winged	*U alata* Michx.
Eucalyptus	*Eucalyptus* species
Hackberry, common	*Celtis occidentalis L.*
sugarberry	C *laevigata Willd.*
Hickory	
bitternut	*Carya cordiformis* (Wangenh.) K. Koch
mockernut	C *tomentosa* (Poir.) Nutt.
nutmeg	C *myristicaeformis*
pignut	C *glabra* (MR.) Sweet
shagbark	C *ovata (AM.)* K. Koch
shellbark	C *laciniosa* (Michx F.) L*ud.
water	C *aquatica* (Michx f) Nutt.
Holly, American	Ilex *opaca*
Honeylocust	*Gleditsia triacanthos* L.
Hophornbeam, easUrn	*Ostrya virginiana* L.
Hornbeam, American	*Carpinus caroliniana* Walt.
India rosewood	*Dalbergia sissoo*
Locust	*Robinia* species
Magnolia	
cucumbertree	*Magnolia acuminata* L.
southern	M. *grandiflora* L.
sweetbay	M. *virginiana*
Mahoe	*Hibiscustiliaceus*
Mangrove	*Rizophora species*
Maple	
black	*Acer nigrum* Michx. f
red	*A. rubrum* L.
silver	A. *saccharinum* L.
sugar	k *saccharum* Marsh.
Mulberry, red	*Morus rubra* L.

Oak	
black	*Quercus velutina* Lam.
blackjack	*Q. marilandica* Muenchh.
bur	*Q. macrocarpa* Michx.
cherrybark	*Q. falcata* var. *pagodifolia Ell.*
chestnut	*Q. prinus L.*
chinkapin	*Q. muehlenbergii* Engelm.
laurel	*Q. laurifolia* Michx.
live	*Q. virginiana Mill.*
northern red	*Q. rubra L.*
Nuttall	*Q. nuttalli* Palmer
overcup	*Q. lyrata* Walt.
pin	*Q. palustris* Muenchh.
post	*Q. stellata* Wangenh.
scarlet	*Q. coccinea* Muenchh.
Shumard	*Q. shumardii* Buckl.
southern red	*Q. falcata* Michx. var. *falcata*
swamp chestnut	*Q. michauxii* Nutt.
swamp white	*Q. bicolor* Willd.
water	*Q. nigra L.*
white	*Q. alba L.*
willow	*Q. phellos L.*
Palmetto cabbage	*Sabal palmetto*
Pawpaw	*Asimina* species
Pear	*Pyrus communis L.*
Pecan	*Carya illinoensis* (Wangenh.) K. Koch
Persimmon, common	*Diospyros virginiana L.*
Pine	
loblolly	*Pinus taeda* L.
shortleaf	P. *echinata*
Virginia	*P. virginiana*
Roughbark lignumvitae	*Guaiacum sanctum*
Sassafras	*Sassafras albidum* (Nutt.) Nees
Sweetgum	*Liquidambar styraciflua* L.
Sycamore	*Platanus occidentalis* L.
Tupelo	
black (blackgum)	*Nyssa sylvatica* Marsh. var. *sylvatica*
water	*N. aquatica* L.

Walnut	
black	Juglans *nigra L.*
white (butternut)	J *cinerea L.*
West Indies mahogany	*Swietenia mahogani*
Willow, black	*Salix nigra* Marsh.
Yellow-poplar	*Liriodendron tulipifera L.*

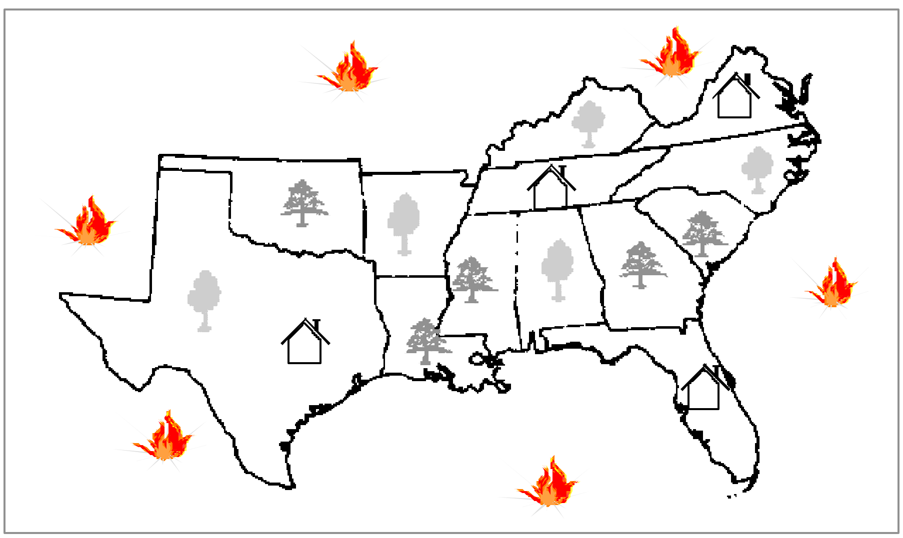
References

Barrett, John W. ed. 1980. Regional silviculture of the United States. 2nd ed. New York: John Wiley & Sons, Inc. 651 p.

Burns, Russell M.; Honkala, Barbara H., tech. coords. 1990. Silvics of North America. Vol. 2, Hardwoods. Agric. Handb. 654. Washington: U.S. Department of Agriculture. 877 p.

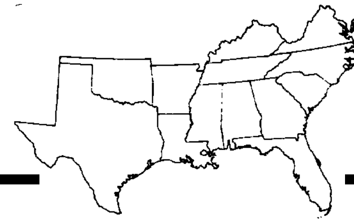
When The Forest Becomes A Community

A Forester's Handbook for the Wildland/Urban Interface



Southern Group of State Foresters

Southern Forest/Urban Interface Council Members



ALABAMA
Forestry Commission
513 Madison Avenue
Mongomery, AL 36130
(334) 240-9304; FAX 240-9390

ARKANSAS
Forestry Commission
3821 West Roosevelt Road
Little Rock, AR 72204-6396
(501) 296-1940; FAX 296-1949

FLORIDA
Division of Forestry
3125 Conner Boulevard
Tallahassee, FL 32399-1650
(904) 488-4274; FAX 488-0863
Homepage: http://thunder.met.
fsu.edu/forestry

GEORGIA
Forestry Commission
P.O. Box 819
Macon, GA 31298-4599
(912) 751-3480; FAX 751-3465
Homepage: http://www.state.
ga.us/GFC

KENTUCKY
Division of Forestry
627 Comanche Trail
Frankford, KY 40601
(502) 564-4496; FAX 564-6553

LOUISIANA
Office of Forestry
P.O. Box 1628
Baton Rouge, LA 70821
(504) 925-4500; FAX 922-1356
Homepage:http://ldaf.state.la.us/
forestry/forestry.htm

MISSISSIPPI
Forestry Commission
Suite 300, 301 Building
Jackson, MS 39201
(601) 359-1386; FAX 359-1349
Homepage: http://www.mfc.state.ms.us

May 1998

NORTH CAROLINA
Division of Forest Resources
P.O. Box 29581
Raleigh, NC 27626-0581
(919) 733-2162; FAX 715-4350
Homepage: http://www.ehnr.state.
nc.us/EANR/DFR

OKLAHOMA
Department of Agriculture
Forestry Services
2800 North Lincoln Boulevard
Oklamhoma City, OK 73105
(405) 521-3864; FAX 522-4583
Homepage:http://www.oklaosf.state.
ok.us/~okag/forhome.html

SOUTH CAROLINA
Forestry Commission
P.O. Box 21707
Columbia, SC 29221
(803) 896-8800; FAX 798-8097
Homepage: http://www.state.sc.
us/forest

TENNESSEE
Department of Agriculture
Division of Forestry
P.O. Box 40627
Melrose Station
Nashville, TN 37204
(615) 360-0722; FAX 360-0756

TEXAS
Forest Service
College Station, TX 77843-2136
(409) 845-2601; FAX 845-5764
Homepage: http://agcomwww.tamu.
edu/agcom/news/tfshome/tfs.html

VIRGINIA
Department of Forestry

P.O. Box 3758
Charlottesville, VA 22903
(804) 977-6555; FAX 977-7749
Homepage: http://www.state.va.us/~dof/dof.htm

USDA FOREST SERVICE

Region 8 Office
1720 Peachtree Road, NW
Atlanta, GA 30367-9102
(404)347-4243; FAX 347-3270

Table of Contents

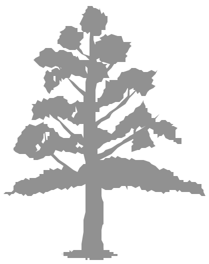
Purpose

State forestry agencies are responsible for providing many forestry related services in *forest/urban interface* areas. Services include fire management, urban forestry assistance, forest management, insect and disease advice, and assistance with the aftermath of natural disasters.

This handbook was written by members of the Southern Forest/Urban Interface Council and other contributors to provide State forestry personnel with ideas about the importance of the interface, and ways to deal with some of the problems that may arise.

Introduction

The *wildland/urban interface* is a term that came into existence in the late 1980's to describe the area where the city environment meets the rural environment. No one definition of the wildland/urban interface (or forest/urban interface) has been universally accepted. A few definitions include:



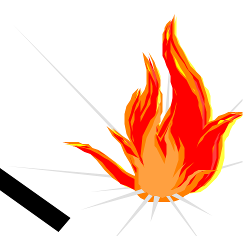
A zone where man made improvements intermix with the wildland fuels.
(S 205, Fire Operations in the Urban Interface)

An area where improved property and wildland fuels meet at a well defined boundary.
(National Fire Protection Association (NFPA) 299, Standard for Protection of Life and Property from Wildfire, 1997 edition)

"...three types of interface. The <u>classic</u> interface occurs when city boundaries and suburbs press against wildland vegetation as in the subdivision on the outskirts of town. The <u>mixed</u> interface is where homes and other structures are intermixed with wildland vegetation similar to the conifer forests growing throughout mountain communities. The occluded interface is when islands of wildland vegetation occur inside a metropolitan area like undeveloped pockets of wildland preserved within a large developed urban area."
(Charles W. Philpot, U.S. Forest Service)

The general zone where significant penetration of people has occurred or is occurring but where there remains significant acreage of forest.
(Land Use and Forest Resources in a Changing Environment, The Urban/Forest Interface: Summary Observations and Research Needs, Marion Clawson, pp.199)

Any area where potentially dangerous combustible wildland fuels are found adjacent to combustible homes and other structures.
(Fire Protection in the Wildland/Urban Interface: Everyone's Responsibility, National Wildland/Urban Interface Fire Protection Program, pp.3)



No matter what definition of the *forest/urban interface* is used, they all refer to a geographical area where two diverse systems - forest and urban - meet and interact, giving rise to conflicts concerning management of natural resources.

It is important to remember that life in the country is different from life in the city. County governments are not able to provide the same level of service that city governments provide.

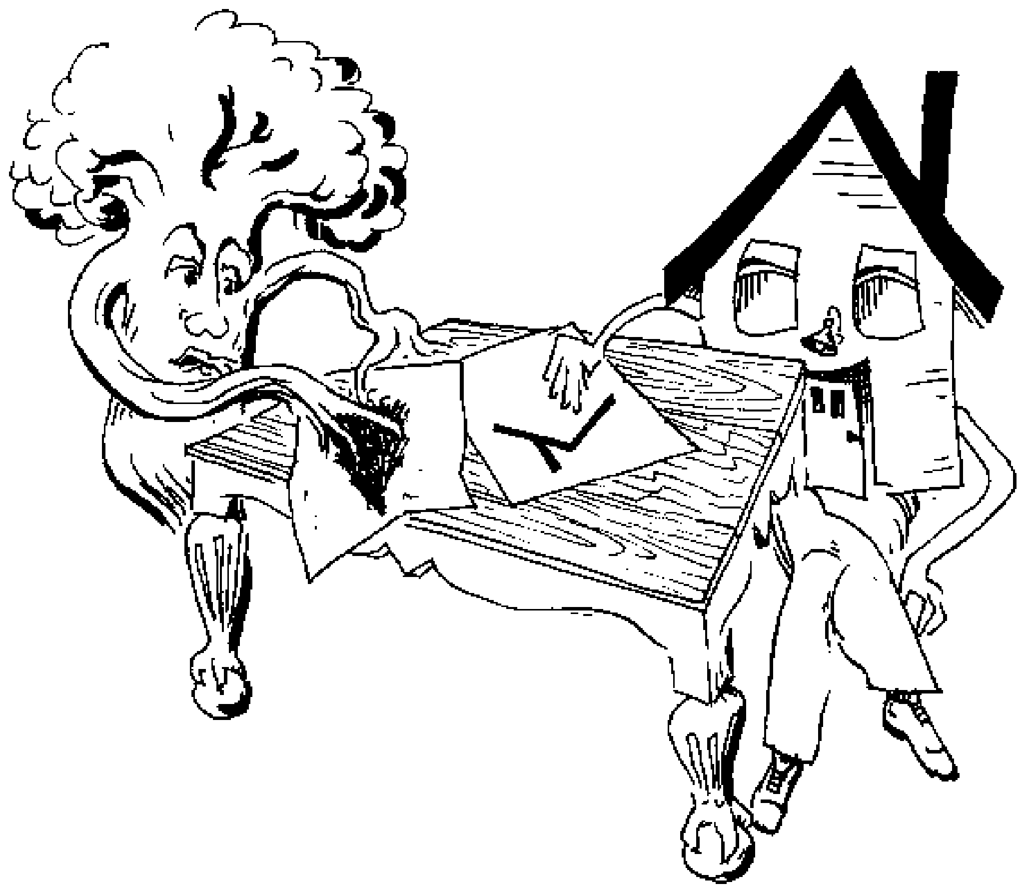
The **stresses** of today's high pressure work environment, the degradation of urban areas, better transportation systems, and the development of new technologies, such as computer commuting, are causing many people to move into rural areas. When they move, the new residents bring with them expectations of receiving the same level of public services they had in the city.

They may also bring **misconceptions** and a lack of understanding about the forest resource they are moving into. These two perceptions can lead to problems for the natural resource manager. As people with little or no exposure to resource management move into forested areas, conflicts arise over the use of traditional forestry techniques such as prescribed burning and timber harvesting.

It is critical that foresters develop **new approaches** to solving land use and forest management problems created in the forest/urban interface. Programs must be designed to help citizens understand forestry issues and form proper and informed opinions. However, information must be provided to the public in an honest and unbiased manner. Education to one group may be propaganda to another.

Conflicts in interface areas frequently arise at property boundaries. These disputes often reflect the interaction of people, forest landowners and users, with increasingly dissimilar values and expectations. For the forest resource manager, these interactions promise to be a continuing source of opportunity. State Foresters are resolved to provide the leadership and develop partnerships to provide appropriate management practices and protection services wherever interface issues are found.

Incorporating Planning
in the Forest/Urban Interface



The first requirement to ensure that planners understand the vital need to incorporate interface issues into the planning process is **to be present at the table when the plans are being developed.**

Foresters must be at the table when plans are being formed.

Recently a planning official told a group of southern foresters, "We simply aren't aware of every issue and do not have the background and expertise to deal with some issues." The planning official, from a rapidly growing area experiencing a bewildering array of interface problems, further explained that very few planners would invite foresters to a planning session, "but most planners would be glad to have you there for a better understanding of the issues."

Demeanor of the forester in this strained environment should **NOT** be one of overbearing expertise, but that of a caring and knowledgeable natural resource expert willing to listen and share. To sustain such a channel of communication, it is essential that the forester become well aquainted with city and planning officials, and offer assistance with resource data and specific recommendations. As these interactive relationships continue, emphasize the importance of maintaining contact with foresters and forestry interests. Always project the image that you, as a forester, represent the collective interests of all people involved.

Foresters should be a part of any interface planning team or committee.

The spectrum of people you will be working with will be varied and at times potentially volatile. So it is necessary that you have the knowledge and negotiating skills to sell yourself as a competent professional focused on collective interests. Professional appearances is very important, so always dress professionally.

Other professionals that you can expect to encounter and should work closely with include: wildlife officials, land developers, water quality experts, soil scientists, county extension agents, local natural resource regulators, fire officials, home builder associations, neighborhood coalitions, garden clubs, civic clubs, environmental preservation groups, real estate associations, and representatives from the various media. Often these individuals will have strong interests as well.

Again, the important thing is to maintain your presence at the forest/urban interface planning table as a knowledgeable professional who assumes leadership when the opportunity is available.

BECOMING INVOLVED

The following list of suggestions represent ways that foresters can become involved in the county planning process:

- Send a letter to each county director of planning offering your services. Express interest in becoming a part of the planning process. Send a copy of the letter to the county administrator.
- Get on any mailing lists dealing with committee meeting agendas.
- Get to know the county planning commission members and their backgrounds. Find out who feels strongly about certain forestry related issues.
- Offer to present a brief slide or video program to the county planning commission on forestry considerations for county planning. While a program tailored to specific counties would be preferable, a good generic program for the state may be far more realistic. The program can also be used for regional planning district commissions or similar groups.
- Find out when the next **Comprehensive Plan** review will be, and if the county has a committee that deals with the rural, agricultural, forestry and forest/urban interface aspects of the comprehensive plan. Try to become a part of this committee or suggest the development of one. As a minimum, provide input on the value of the forest resource during the review process.

- After becoming involved, the forester should set up **tours** for the planning commission members and county officials to explain the complexities of the forest/urban interface.
- Foresters should continually identify issues to take a position on and present them during the county review process.
- Encourage county governments to establish a county **Technical Review Team**, to meet and review site plans and subdivision plans in the preliminary stages of a project. During these "design" meetings, various agencies will be able to comment on the project and advise developers of the requirements of their agencies as well as schedules for submission and approval. The goal is to get agencies involved up front. This will improve communications, let developers and builders know what is needed and expected, reduce problems and save time.

Fire Management

in the Forest/Urban Interface

INTRODUCTION

There are many things to consider when dealing with wild or prescribed fire in the *forest/urban interface*. There is a vast diversity of lifestyles and personal conceptions of what is acceptable. The people in the interface range from those who were the original rural residents, accustomed to the presence of fire in their environment, to those who have recently moved from urban areas and have no concept of the hazards and benefits of fire behavior, and would prefer to have a fire and smoke-free environment. The clash of these two cultures can sometimes be quite volatile.

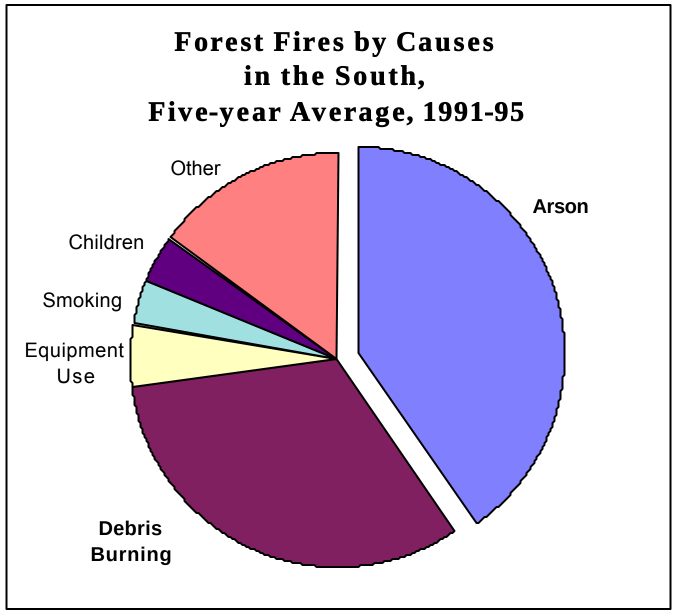
Many new residents build expensive homes and bring with them a "back to nature" philosophy that harbors a desire to leave their property and all of the property around them as undisturbed as possible. This philosophy often leads to insufficient access roads and hazardous fuel conditions very near structures. The new residents also may have the misconception that all issues can and should be resolved with ordinances or by levying new taxes. The long-time residents generally maintain older ideals and may resent the influx of these city dwellers.

It is our duty as land managers to adopt an operational role in the forest/urban interface that includes wildland firefighting, hazardous fuels reduction, cooperative fire prevention and education, and technical assistance.

FIRE PROTECTION

Fire Prevention

Fire prevention by the most recent definition is "All the activities concerned with minimizing the incidence of fires". To effectively reduce the two main causes of fire ignitions in the South, arson and debris burning, everyone will need to participate in the prevention process. Opportunities abound to address other interface issues including urban forestry and forest management through prevention contacts and partnerships with other agencies and organizations.



Successful fire prevention programs in the interface may include the following:

- Develop **partnerships** among fire services, community groups, local officials, forest industry, developers, and the insurance industry.
    - Organize **advisory groups** or planning teams within the partnerships to develop and guide woodland home fire protection programs. No single agency can solve this problem.
    - Select a coordinator for woodland home fire protection programs.
- Recommend and stress the importance of firewise construction, firewise landscaping, and alternative disposal of vegetative debris, such as wildlife brush piles and chipping. Homeowners associations can purchase neighborhood chippers to reduce brush and debris around homes.
- Provide **education programs** for adults and children that will have a positive effect in reducing interface ignitions. As new residents with children move into

the interface, state forestry agencies need to maintain strong educational programs aimed at keeping children-caused fires at low levels.

- **Tools for successful awareness programs include:**
  - Prepare materials that can be direct mailed to high risk areas, hung on doors or passed out at programs or events.
  - School and community programs.
  - Landowner workshops in larger developments, such as spring and fall clean-up days.
  - Personal contacts and presentations.
  - Media contacts and news coverage.
  - Fire prevention hazard inspections and fire safety checklists for individual homes.
  - Forest fire danger and prevention signs, featuring woodland home fire prevention messages.
  - Special events or conferences.
- A positive, proactive **law enforcement program** including:
  - The consistent enforcement of fire laws.
  - A permit system.
  - Hazard inspections.
  - Warning tickets.
  - Community watch groups in arson areas.

Legal

Voluntary compliance to fire prevention measures has in many cases proven not to be successful or unsuccessful.

The most desirable alternative to many fire problems associated with the interface is voluntary compliance to fire prevention measures. In many cases this has proven not to be successful or to be unsuccessful, therefore, some legal measures should be considered:

- Ordinances/building codes.
  - A model fire code for the forest/urban interface is available from the International Fire Code Institute, 5360 Workman Mill Road, Whittier, CA 90601-2298.
- Burning bans in high risk areas.
- Permit systems.

- Fire protection/mutual aid agreements.
  - *"Developing a Cooperative Approach to Wildfire Protection"* is a publication and companion video developed by the National Wildland/Urban Interface Advisory Group. It is available from the National Interagency Fire Center (see address on next page).

Pre-suppression

Pre-suppression is all activities taken prior to an emergency that will reduce property loss.

- Homeowners and protection agencies share the responsibility for reducing the threat of wildfire. Homeowners should be made aware of this responsibility.
- Work with **insurance companies** to develop short courses for insurance industry continuing education programs. Insurance companies should also be encouraged to start education programs for employees and clients about forest fire risk to woodland homes and offer rate reductions for those homeowners who comply with established fire protection and safety standards.
- In woodland developments, fire agencies need to understand the potential for homes to ignite from forest fires. A **Hazard Assessment** or **Risk Analysis** will help to determine this and help communities when planning for fire safety measures involving structures and surrounding lands.
  - The National Fire Protection Association (NFPA) has a *"Standard for Protection of Life and Property from Wildfire (NFPA 299)"* that will help you develop a numerical risk rating. It is available from NFPA, P.O. Box 9101, Quincy, MA 02269-9101.
  - A *"Wildland/Urban Interface Fire Hazard Methodology"* handbook was developed by the National Wildfire Coordinating Group's Wildland/Urban Interface Advisory Group. It is available from the National Interagency Fire Center.
- **Forest Fire Response Plans** for woodland communities identify the anticipated problems and appropriate responses for fighting a fire in or near the c... ade a...

A risk analysis will help determine the potential for an interface fire to occur.

A number of wildfire prevention publications and videos are available for fire protection agencies and organizations from:
National Interagency Fire Center
Great Basin Supply Center
3833 S. Development Avenue
Boise, Idaho 83705
Mail or Fax your order for a Publications Catalog (NFES #3362) Fax-(208) 387-5573/5548

Firewise Subdivision Design

Firewise subdivision design can spell the difference between disaster and success in dealing with interface fires. County governments should be encouraged to provide adequate access and roads by using state road specifications, and developers should work closely with fire agencies to design firesafe communities.

Firesafe Community Recommendations:

Clearly mark all addresses.

- Build at least two **entrances** to the development.
- Provide a **traveled way** of not less than 24 feet wide, providing for simultaneous access for emergency vehicles and the evacuation of residents. Improved gravel **shoulders** shall be a minimum of four feet wide on each side. Construct road **curves** with at least a 100 foot radius. Avoid road **grades** of more than 12 percent.
- Make **cul-de-sacs** large enough (at least a 50 foot radius) to allow large vehicles to turn around without having to back up. Make "Hammerhead T's" at least 40 feet long.
- Minimize the number of **dead end streets**. If a street must dead end, it should be well signed and have adequate room for vehicles to turn around at the end. Looped road networks are preferred with unobstructed traffic circulation.
- Construct **driveways** wide enough and straight enough to accommodate emergency vehicles.
  - 12 foot traffic lanes with a 15 foot vertical clearance of tree branches.
  - Provide turnouts every 400 feet, or at the midpoint if it is between 150 and 800 feet in length. Can emergency vehicles turn around once they reach the house?

Standardize all hydrant connections.

- Clearly mark all **addresses**.
- Construct **bridges** at least as wide as the road and capable of handling at least 20,000 pounds per vehicle axle. Build bridges of non-combustible materials.
- Make a minimum spacing between buildings of 60 feet with a 30 foot property line setback. This will allow room to maintain a minimum safety zone around each home.

- Install a reliable water source, preferably hydrants on at least 6 inch lines. Dry hydrants or fill pipes are acceptable if pressurized hydrants are not available. **Standardize** all hydrant connections.
- Place electric power underground if possible. Keep overhead power lines trimmed free of intruding vegetation.
- Leave green spaces or natural barriers intact. Large developments need safety zones.

Firewise Home Design

Firewise home design can significantly increase the chances a home will survive a forest fire. The design should include a safe location for the house and the use of less combustible building materials.

Build with fire resistant materials.

Firewise home designs include:

- Building on the most level portion of the land, set back at least 30 feet from the edge of a ridge for a single story house.
- Using fire resistant **roof** materials.
  - The number one cause of home losses in wildland areas is from untreated wood shake shingles on roofs.
  - Wooden roofs are highly vulnerable to **firebrands** or embers that can travel by wind a mile or more ahead of a forest fire. Even non-flammable roofs need to be checked for gaps that can allow firebrand to collect on wood subroofing.
  - **Roof sprinklers** are not always the answer because water pressure may be low or the electricity needed to pump water may fail.
  - Keep roofs, roof valleys, and gutters clean of flammable material such as leaves and pine straw. Place and maintain spark arresters (screens) on chimneys.
- **Walls** clad with fire resistant materials.
  - Materials, such as stucco, masonry (stone, brick or block), metal, and log, stand up better under heat and exposure. Vinyl can melt, exposing inner wall components to heat and embers. Wood is generally assumed to be highly flammable, and not the best option.
  - The edges of flammable wall material will ignite before flat surfaces. Trim materials are usually the first to catch fire.
- **Windows** made of fire resistant material. Windows broken during a fire can offer a direct path for flames into the structure.

- **Single pane** windows can break very easily from the heat of a fire.
- **Double and multiple pane** windows offer only slightly better protection.
- **Tempered glass** is the best choice. There is a significant difference in the amount of heat it will withstand compared to single pane glass. Tempered glass is expensive, so use it for the largest and most vulnerable picture windows. Sliding glass doors are required to be made from tempered glass.
- Minimize the number and size of windows on any side of the house that is most likely to be exposed to a forest fire. The use of several smaller (two foot wide or less) individually framed windows placed together is more resistance to breakage than one large non-tempered picture window. Windows should not face flammable trees or shrubs that are closer than 30 feet.
- Non-flammable shutters for windows and skylights can also help.

Exterior additions to homes should be constructed of fire resistive materials.

- Fire resistive **vents and soffits**:
  - Cover exterior attic and underfloor vents with wire mesh no larger than 1/8 inch to prevent firebrands and sparks from entering the house. All roof joist openings should also be fireblocked.
  - Undereave soffit vents should be closer to the roof line, rather than the wall, to prevent heat or flames from becoming entrapped.
  - Eaves should be boxed or designed with minimal overhang.
    - Enclosing or boxing an eave, or making it a soffit, reduces the surface area and opening available to a fire. Boxing an eave with appropriate materials also slows a fire's entrance into the attic and sub-floor areas adjacent to the eaves and overhangs.

The arrangement spacing and density of vegetation can be more crucial than what is planted.

- Fire resistive **decks, porches and fences**.
  - Consider terraces instead of elevated decks, or use less flammable material for decks. Screen or box in decks and porches whenever possible to keep out sparks and flames.
  - Examine your yard for areas where leaves collect. Those are the same places the wind will carry burning embers.
  - Wooden fences attached to homes can act as fuses or fuel bridges that lead a fire to the home. If a fence must be attached to the house, construct it with less flammable materials.

Firewise Landscape Design and Maintenance

A home in a woodland setting is surrounded by flammable vegetation. Firewise landscaping can help create a defensible space or safety zone around a home. This not only helps keep fire from approaching a home, but it provides a safe space for firefighters to work.

The goal is to "break the chain" of fuel between homes and natural vegetation, eliminating things that can catch fire and carry themit to the house. Remember that proper landscaping is important, but the type of building materials used for the house is still the most important element of survival.

Remove highly flammable species

Firewise Landscape Recommendations:

- There are no fire-proof plants, but some are more fire resistant than others.
- Choose plants and trees with:
    - A high moisture content.
    - A low oil or resin content.
    - Minimal litter and accumulated debris.
    - Limited foliage and few dead branches.
    - A lower overall height.
    - An open, loose branching habit.
    - Easy maintenance and pruning.
    - Drought resistance.
- Location of plants and trees in a yard should be carefully planned. The arrangement, spacing and density can be more crucial than what is planted.
    - Proper **maintenance** is also vital to remove excess debris and help plants retain their fire resistive properties. Pruning and shaping can increase a plant's fire resistance. Lack of maintenance can make it more flammable.

Keep vegetation from making a fire ladder.

- Reduce the amount of material that a fire can use as fuel for a distance of at least 30 feet around the home (75 feet if in a pine forest). As the slope of the lot increases, additional clearance of up to 100 feet may be necessary. Steep slopes can be terraced to slow down forest fires.
    - Remove highly flammable species, such as juniper, cedar and pines.

- Have nothing flammable next to the house. The most critical area is the zone within 5 feet. Keep this clean and clear of trees, brush, tall grass and other burnables.
- Maintain a well-kept lawn. Use raised beds, rock gardens, stone walkways, walls and patios to create visual interest while maintaining a fuel break.
- Occasional trees and shrubs should be kept small and be at least 10 feet from the house. Space trees 10 to 15 feet between tree crowns and prune 10 to 15 feet up from the ground.
- Avoid fire ladders where fire can climb from the ground into tree branches. Do this by pruning trees, spacing tall trees away from medium-sized trees, and by using ground covers and small plants under tall trees.
- Stack firewood at least 15 feet from the home.
- Remove limbs overhanging chimneys and the roof.
- Keep flammable liquids stored away from the home in out-buildings.
- Burn trash in a safe trash burner (if trash burning is allowed).

Rapid Fire Detection and Location are Key to Successful Control

- Conduct woodland home hazard inspections. Use information from the inspections to teach homeowners how to improve fire safety around their homes.

Additional forest fire protection information is available from:

- **Firewise Homepage at http://www.firewise.org** - The web site is sponsored by the National Wildland/Urban Interface Fire Protection Program.
- Firewise landscaping demonstration projects have been planted in some states, giving homeowners and fire officials a chance to see an appropriately designed safety zone. Lists of suggested plants and trees can also be made available for homeowners.

Detection and Communication

To rapidly detect a fire and to provide the proper fire agency with the location of the fire, are two keys to the successful control of any wildfire. This is very essential in interface areas because of lives and property at risk.

Since most fires are reported by the general public, neighborhood watch groups, local constables, police, or local fire personnel on routine patrol, the following should be considered:

- Have one place to report fires.

- Train emergency operators to obtain enough information to determine the exact location and size of the fire, the type of equipment necessary for suppressing the fire, which agency should respond to the fire, and the number of homes threatened.
- Establish mutual aid agreements which specify the dispatch authority (chain of command) for each agency's resources.
- Establish and use radio systems that allow various agencies to communicate with each other.

Suppression Activities

The operational activities for the forest/urban interface can be divided into three parts:

- The Incident Command System (ICS).
- Cross training.
- Strategy and tactics.

Prescribed fire can be a useful tool for training and fuel reduction.

The Incident Command System is an orderly, easy to use system which allows the building of a command structure small enough or large enough to handle any size incident. Forest/urban interface firefighter training is necessary for both structural and forest firefighters. Strategy and tactics courses can be used to cross train firefighters. Cooperating fire protection agencies should become familiar with each others suppression equipment and tactics for safety and efficiency.

Firefighters in the forest/urban interface should:

- Think safety first.
- Use tactics that meet the particular fire situation.
- Use tactics that are aimed at a successful initial attack.
- Look at the big picture, beyond just the first few houses.
- Adjust tactics to meet changing fire situations. Fires can change suddenly from mostly wildland, to mostly structural, to a combination of both.
- Use tactics which take into account the presence of civilians in the area and the potential need for evacuation.
- Combine standard tactics with environmentally and aesthetically sensitive suppression methods.
- Use natural barriers or pre-constructed firebreaks wherever possible.

Cross Train Firefighters

Prescribed Fire

Prescribed fire is a useful means of reducing the accumulation of hazardous fuels in forested areas adjacent to homes. Removing fuels by mechanical or hand labor is the safest method of disposal. The use of prescribed burning is an alternative to mechanical or hand labor, but smoke and escaped fires must be considered when fuels are reduced using this method.

Permanent firebreaks should be wide enough to allow access by wildland fire suppression apparatus and they should be maintained. Local fire departments should have the location of these firebreaks on their maps.

Due to the close proximity of homes occupied by residents who may have no concept of fire behavior, citizens living in interface areas must be educated about the beneficial uses of fire.

Prescribed Fire Types Recommendations:

- Use a prescribed fire as a tool for training firefighters and an opportunity for educating local residents.
- Explain to residents how prescribed fires are used as a tool to reduce the fuel hazard near woodland homes before forest fires occur.
- Make local residents aware that smoke and ash from a prescribed fire may make the area unsightly for a month or so every two to three years, but the reduction in fuel will provide protection from a wildfire.
- Identify and assess the risks involved prior to any prescribed burn.
- Develop, adhere to, and share with adjacent homeowners a detailed burn plan if the prescribed burning program is to remain credible.
- Use natural barriers wherever possible.
- Use environmentally sensitive methods when firebreak construction is necessary.
- To limit smoke problems, make sure the burn is complete before the evening inversion takes place. Proper smoke management is essential in the interface.
- Notify local fire departments and/or 911 dispatchers of plans to conduct a prescribed burn in an interface area.
- Ensure that adequate suppression resources are staged to not only meet management needs, but to also provide "peace of mind" for local residents.
- Be absolutely sure the prescribed burn is controlled before leaving the area.
- Use other techniques to reduce fuel where fire cannot be used, including: bush-hogging, mowing, chipping, pre-commercial thinning in young pine stands,

commercial thinning in marketable pine stands, and grazing animals such as goats.

Smoke Management

Prescribed fires produce varying quantities of smoke, an elusive by-product which can be a major concern. Therefore smoke management must be considered in every prescribed burn plan. Awareness of smoke production, meteorological conditions and transport characteristics will enable you to refine existing smoke management prescriptions. Three basic objectives of smoke management are to identify and avoid smoke sensitive areas, to reduce emissions, and to disperse and dilute smoke before it reaches smoke sensitive areas.

Public relations are also an essential part of prescribed burning. Fire managers should feel obligated to minimize effects on nearby residents and be prepared to "sell" his or her job to the general public. Attitude, experience, and attention to appearance are all very important to creating a positive public image.

Insects and Diseases

in the Forest/Urban Interface

INTRODUCTION

Management of pests in the *forest/urban interface* is a challenge to land managers because of tree problems associated with development activities and the wide range in values between urban and rural trees. Generally, trees in the interface are more valuable than trees in the rural forest, and the high cost of treating individual trees is more easily justified.

In addition to problems caused by forest pests, trees in the interface are affected by the activities of people. Prevention, through careful planning, management, and maintenance, is the most practical and effective way of protecting trees against pest problems in the interface.

Microorganisms, insects and predisposing stress factors are the three major influences to consider. Important groups of microbes include fungi, viruses, bacteria and phytoplasmas. Bark beetles, borers, defoliators, and scales are the most damaging insect groups. Soil compaction, grade changes, and injuries are the greatest sources of predisposing stress.

PREVENTING PESTS

Following are guidelines for preventing or mitigating the effects of pest organisms:

- Plan development to protect specimen trees and remove trees at risk.
- Promote diversity of tree species, sizes, and ages.
- Plant only trees that are appropriate for the site.
- Choose species and varieties that are resistant to pest problems.
- Maintain plenty of space for each tree. Remove some if necessary.
- Maintain tree vigor through appropriate mulching, fertilizing and watering.
- Water high value vegetation during severe drought.
- Remove fallen trees and diseased leaves and branches.
- Protect trees against disturbance and injury.

The most common stress factors that cause initial decline are drought, storm damage, construction injury to roots and stems, misuse of chemicals by people, and attacks by certain kinds of pests. Once a tree is weakened by disturbance or other unfavorable conditions, pests can become established more easily and cause the tree to decline further. Healthy trees tend to resist pests and recover from disturbance more quickly.

PREVENTING TREE STRESS

Following are guidelines for preventing or mitigating the effects of stress on trees:

Healthy trees tend to resist pests.

- Plan site developments to minimize soil compaction and grade change near residual trees.
- Aerate compacted soils.
- Maintain about three inches of mulch for at least a three foot radius around trees, particularly where soil compaction or dry conditions are likely.
- Leave the forest floor undisturbed where possible, while still maintaining a firesafe zone around the home.
- Avoid changes in soil drainage patterns.
- Direct construction activities and excavation away from trees to be retained, or remove trees where significant damage will be unavoidable.
- Remove unnecessary objects and debris that provide shelter for pests in yards.
- Avoid misapplication of insecticides, herbicides, fertilizers, and other chemicals. Read the entire label before applying.
- Use pest-free, high quality planting stock and proper planting practices.
- Avoid mechanical injuries to trees from lawnmowers, string trimmers, and other equipment.
- Remove diseased plants and other sources of pest organisms.

- Maintain tree vigor through appropriate fertilization and watering.
- Search for pest organisms or disease symptoms frequently and treat them before they cause damage.

PUBLIC EDUCATION

It is important to keep people in the interface informed about the potential impact of pests and of ways to minimize this impact. There are many ways to communicate with interface residents, landowners, agencies, and organizations including:

Keep the public informed about the potential impact of pests.

- Public meetings.
- Media coverage.
- Informational booths at malls, fairs and expos.
- Insect hotlines (designated phone lines).
- Electronically posted information.
- Developing technical advisory committees and volunteer programs, such as Master Gardeners and Tree Stewards.
- Publication and distribution of leaflets and brochures.
- Direct mailings.
- Demonstration and training programs.
- The declaration of a "Tree Emergency".
- On-site visits by trained, unbiased professionals.
- Homeowner associations and civic organizations.
- High school clubs.
- Community college, vocational, and continuing education courses.

Natural Disasters

in the Forest/Urban Interface

INTRODUCTION

Every year floods, ice storms, hurricanes, torna-does, and wind cause a tremendous amount of damage to trees in the *forest/urban interface*. Without proper care before and after these disasters, trees can pose a danger to lives and property. Many tree-related problems can be reduced or eliminated through proper planning and care. Communities and homeowners need to have a plan detailing proper tree care before a disaster strikes, and a recovery plan to restore trees after a disaster occurs.

PLANNING

A community natural disaster mitigation plan for trees would include:

- Tree care before the disaster.
- Repairing and saving damaged trees.
- Proper disaster response and cleanup.
- Regulations for vegetative debris pick-up and disposal for private pro-perty.
- Replanting and recovery of trees.
- A community urban forestry master plan for tree planting and care of the community's trees.

DISASTER TEAMS

Develop a disaster team to manage activities and make all decisions. The team should include representatives from:

- Utility companies and police, fire, and public works departments.

- The news media.
- Private arboriculture firms and nurseries.
- State forestry departments.
- The weather service.

Be sure to coordinate the natural disaster mitigation plan for trees with disaster recovery plans made by other agencies. The plan should be updated annually. It is important that training is provided to everyone involved so each person knows their role when a disaster occurs.

PUBLIC EDUCATION

It is also important to have information available to the general public before and after a disaster occurs. This can be in the form of videos, handouts, and/or public service announcements.

Public education topics may include:

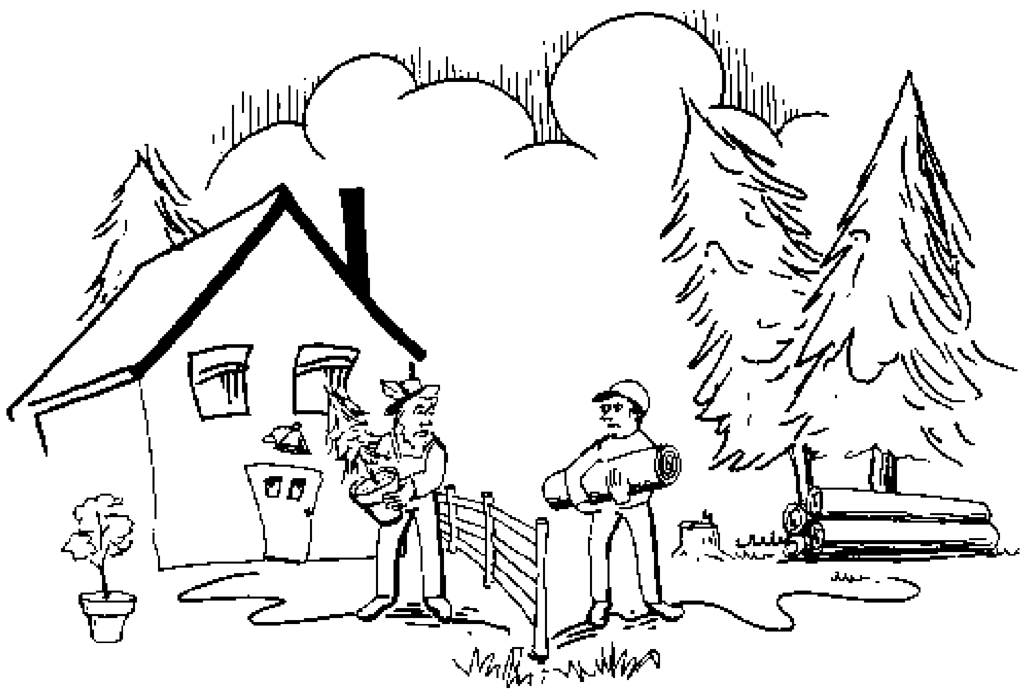
- How to prune or repair damaged trees.
- How to identify trees worth saving.
- How to hire a professional arborist.
- How to select quality nursery stock.
- How to determine fair vendor prices.
- Proper debris disposal.
- Safety when clearing debris.
- Chain saw safety.
- How to hire a forestry consultant.
- Tree salvage operations after a disaster.
- The benefits of trees and the advantages of a safe and healthy urban forest.

Make information available before and after a disaster occurs.

This is just an overview of what can and should be done before and after disasters. For good detailed information dealing with natural disasters, please consult "Storms Over the Urban Forest". It is available from: USDA Forest Service, Northeastern Area, 1992 Folwell Avenue, St. Paul, MN 55108, (612) 649-5243.

Forest Management

in the Forest/Urban Interface



INTRODUCTION

Forest/urban interface areas pose new problems and challenges for foresters and forest land owners in managing the forest resource. The Southern Forest Based Economic Council estimates that 92 percent of the ownership units are less than 100 acres, and as small as 24 acres in some states. The overall average size of a Southern private forest ownership is only 38 acres.

The average size of a southern private forest ownership is 38 acres.

Problems and issues that may be encountered in the interface include:

- Fragmented tracts of land under different forest management. Landowners that are neither farmers nor forest industry have increased by nearly 50 percent in the south. Many of the five million private owners of forestland in the South have smaller holdings than in the past.
- Close proximity of homeowners with differing opinions towards forest management.
- Forested tracts at the urban fringe are usually in transition to residential and commercial real estate.

- **Taxes** on agricultural and forest lands in interface areas are often assessed on the basis of development or market value rather than present use, which encourages development of the land for uses other than forestry.
- Local **ordinances**, such as buffer requirements and mandatory burning bans, may increase the difficulty and costs of forest management. Some states have "Right to Practice Forestry" laws to restrict county governments from passing ordinances to prevent forestry.
- Harvest **restrictions** may result in timber values lower than timber in rural areas.
- Timber markets may be limited. Need to be more creative with marketing operations.
- The size of treatment areas is generally much smaller than in rural areas.
- The visual impacts of forest management may be unacceptable to local governments and residents.
- Smaller tracts cost forestry agencies more to service than larger tracts in rural areas.
- The use of prescribed burning and broadcast application of herbicides are often eliminated as management tools due to the proximity of homes and other sensitive areas.
- Mud on roads, dust, smoke, noise, and site disturbances may be unacceptable to residents in the interface.
- The need for protection from timber theft, off-road vehicles, trash dumping, and other trespass is often greater in interface areas.
- Unscrupulous timber buyers can be a problem for landowners who are not familiar with timber marketing practices and procedures.

Complications and impediments to forest management in the interface may seem insurmountable.

Although the complications and impediments to forest management in the interface may seem insurmountable, increased contact with the public presents new opportunities for the forestry community to fairly solve conflicts involving forest management before they occur.

Every opportunity should be taken to discuss forestry issues, enhance public understanding and knowledge about forest management, the forestry profession, and improve the management of forest resources in interface areas. Improved communication with environmental groups and participation in land use planning is also necessary to enhance understanding of forestry and interface issues. Even though most landowners in the interface may not be interested in plantation style, intensive forestry, many are interested in managing for multiple benefits and practicing sound stewardship of their forest lands.

Since a growing number of people and a considerable amount of forest land in the South are situated in interface areas, state forestry agencies must be prepared to furnish more creative forest management assistance to landowners in interface areas.

Foresters should identify and establish positive relationships with planning agencies, conservation groups, decision makers, and opinion leaders. Foresters should also become familiar with local ordinances and regulations that affect timber harvesting, water and air quality protection, threatened and endangered species, public hunting and fishing, and garbage and hazardous waste disposal. When possible, foresters should take advantage of opportunities to improve their awareness and understanding of conditions, problems, issues, laws, and processes unique to interface areas. Foresters should also be prepared to act as subject matter experts with local planning and zoning commissions and be involved in the development of regulations.

It is important that foresters enjoy a positive working relationship with, and possess a good knowledge about the mission and role of other natural resource agencies that also serve the interface area, as well as with forest industry representatives and private consultants. Organization of multi-resource management teams may be helpful.

Foresters must be familiar with information concerning the forest resource, including factors that affect forest management in interface areas.

These factors may include the following:

- Planned or potential **use** of forested areas for residential and commercial development.
- Local officials' and opinion leaders **attitudes** toward forestry issues.
- Landowners reasons for owning their lands.
- Landowners interest in non-timber values of land.
- The **condition** of forest health in the interface area.
- Specific forest pests that threaten forest health.
- Volumes, species, stocking, and quality of timber.
- Current markets for timber grown in interface areas.
- The availability of service vendors in the interface area.
- Sources of planting stock and other materials needed by landowners.
- Reforestation cost-share and tax incentive programs.
- Suitable harvesting methods.
- Coordination of forestry activities with local agencies and organizations.
- Educational opportunities for landowners and the general public.

The following sections are partial checklists of items that should be considered by foresters when working with landowners and planning forest resource management in interface areas.

SILVICULTURE

While forest management in the interface may involve some modifications to existing practices and techniques, it probably will not bring about many totally new practices. What will be different will be the need to communicate the linkages between goals and practices to all parties involved. Since the interface is more populated, there are more stakeholders in every resource management decision. To reduce conflict, the forest manager will need to become skilled in salesmanship and communications.

General Considerations

A forester should plan and guide management operations.

- A forester should make sound management plans and guide management operations.
- Work with county officials to promote silvicultural exemptions from local ordinances in agriculturally zoned areas.
- Coordinate forest management activities with local agencies and organizations.
- Advise landowners about tax incentive laws designed to maintain forests or open space.
- Identify landowner objectives for forest management.
- Identify and mark property boundaries.
- Develop appropriate timber harvesting guidelines for interface areas.
- Assess forest health.
- Identify special resources management needs (archaeological, historical, geological, cultural).
- Identify sensitive aesthetic features.
- Manage noise sources.
- Exclude livestock from forested areas.
- Determine wildfire protection needs and plan for those needs.
- Control exotic species which could escape into the wild and become a nuisance or wildfire hazard.
- Protect water quality through use of best management practices (BMP's).
- Restore and protect wetland areas where possible.

Silvicultural Systems

Silvicultural systems will need to be adapted to manage resources at a smaller scale. Systems that are practical, desirable and economically efficient in rural forests may not produce desirable results in the interface. Silvicultural systems that are too labor intensive for rural forests may be more practical for interface areas. Also, silvicultural systems for the interface will be more aesthetically focused and less affected by economies of scale.

- Develop alternative silvicultural systems that will accomodate landowner objectives.
- Assess the suitability of even-age versus uneven-age forest management systems.
- Determine an appropriate and manageable stand size.
- Identify conflicts and compatibility of timber harvesting with recreational use of land in the interface.
- Manage forests for tree and wildlife species diversity.
- Determine the need for natural or artificial regeneration.
- Assess the ability of interface forests to produce high quality forest products on small (5-10 acre) tracts. Promote this idea to appropriate landowners.

Always use Best Management Practices.

Artificial Regeneration

Regeneration options in the interface will naturally be impacted by soil and site conditions, just as they are in rural forests. However, there is one significant difference. Interface property owners are more concerned about temporary aesthetic conditions than rural forest owners. This concern will result in some unique challenges for artificial regeneration. Neat and orderly plantations in rural areas may suggest production or plantation management to an interface landowner. To compound matters, after-planting treatments may also need to be adapted to conform to landowner and community aesthetic standards.

Interface regeneration options:

- Match tree species to site.
- Recommend genetically improved planting stock.
- Recommend compatible mixes of tree species.
- Plan regeneration to benefit wildlife, both game and non-game species.
- Determine appropriate and acceptable methods of mechanical and chemical site preparation.

- Prescribe best management practices for mechanical and chemical site preparation.
- Determine the need for tree shelters and animal repellents.
- Determine the availability of seedlings of desirable native species.
- Recommend post-planting cultural practices, including weed control and fertilization.

Intermediate Stand Management Practices

Intermediate stand management practices are more likely to be readily accepted by interface landowners. Few modifications will be needed for thinnings, limited vine control and chemical use. The intermediate practice most likely to need modification is prescribed fire. In addition to concerns about escaped fire, smoke management and air quality are very real and serious concerns in the interface.

- Determine the need for pre-commercial/commercial thinnings or timber stand improvements. Consider non-traditional reasons for applying forest management practices to achieve specific results. For example, thinnings are done in some areas to reduce fire risk prior to development.

Protect visual quality in interface areas.

- Determine the need for timber stand improvement (cull tree removal, crop tree crown release) measures.
- Determine the need for herbicide use.
- Recommend fuel wood utilization as a timber stand improvement practice.
- Apply landscape management principles to protect visual quality in interface areas.
- Determine the need for hardwood control in pine stands, depending on the long-term management strategies.
- Determine the need for pruning.
- Determine the need for vine control, especially in hardwoods.
- Plan prescribed burning operations and manage smoke in sensitive areas.

Timber Harvesting

Timber harvesting has the most potential of all forest management activities to meet opposition and resistance in interface areas. While harvesting remains a necessary and needed part of forest management, greater attention will need to be paid to managing the aesthetics and off-site impacts of the harvest. The potential for property rights disputes is greatly enhanced in these areas. Further, smaller harvest volumes and non-traditional market schemes <u>may</u> result in lower prices than for rural sales.

Timber harvesting recommendations:

- Pre-plan harvesting operations.
- Identify and mark harvest area boundary lines.
- To avoid or mitigate complaints, inform adjacent landowners of planned forestry activities.
- Develop cooperative management and marketing ventures among landowners in the interface. Educate homeowner and subdivision groups in timber marketing procedures.
- Assess forest pest occurrence and plan forest practices to reduce pest occurrence. Forest health concerns usually provide an acceptable rationale for harvesting timber in interface areas.
- Salvage timber promptly following natural disasters and pest outbreaks.
- Identify appropriate forest regeneration systems.
- Identify long-range timing of intermediate and final harvests.
- Plan harvests for multi-products.
- Determine minimum operable volumes.
- Prescribe, use, and enforce BMP's to protect water quality.
- Locate, lay out, and designate forest roads, log landings, major skid trails, stream crossings, and stream side management zones.
- Survey for and provide protection for special resources (historical, archaeological, geological, and threatened and endangered species).
- Use loggers who have received BMP training and certification.
- Use special harvesting equipment and procedures, such as planks, mats, and portable bridges to minimize site disturbance. Support the development of equipment to meet new needs.
- Encourage forest industry to support loggers who can specialize in small areas and operate on small tracts, using smaller equipment such as forwarders and pre-haulers.
- Develop incentives for the very best loggers.
- Develop logging guidelines for interface areas.
- Keep hard surface roads free from mud and debris.
- Protect residual trees from logging damage.
- Protect property improvements.

Rehabilitate.

Stabilize.

Regenerate.

- Determine the locations of power and telephone lines, pipelines, roads, and other infrastructure facilities and protect them.
- Reduce dust and excessively loud logging noise.
- Monitor logging operations.
- Dispose of slash to reduce forest fire hazard and visual impacts. Chipping and firewood cutting can be done to eliminate some logging debris.
- Rehabilitate and stabilize areas disturbed by logging operations. Restore visual disturbances.
- Plan for stand regeneration before harvesting. Have a plan up front.

Watershed Management

Special provisions will be needed to protect water quality in the interface. Small variances in Best Management Practices (BMP) use, that would be acceptable in less sensitive rural areas, can become critical issues in the interface. Side issues such as mud that is tracked onto paved county roads and streets can become significant safety hazards for interface residents. The higher number of people present in the interface results in more opportunities for conflicts over water quality.

Watershed management recommendations:

- Determine watershed management objectives.
- Coordinate watershed management activities with local agencies and organizations.
- Properly dispose of garbage and waste. Prevent petroleum product spills.
- Coordinate monitoring operations with loggers.
- Locate, lay out, and designate roads, log landings, major skid trails, stream crossings, and stream side management zones.
- Suspend logging operations during wet weather.
- Encourage landowners to monitor BMP's during logging operations prior to harvesting.
- Rehabilitate and stabilize disturbed areas promptly.
- Keep downed trees and logging debris out of streams and other water sources.
- Manage beaver ponds.

Establish and maintain visual buffers.

Aesthetics and Visual Quality

Most resource management conflicts in the interface will occur when traditional forest management activities impact aesthetics or visual resources. Temporary visual impacts are much less acceptable in the interface. Many other issues may actually be surrogates for these visual impacts.

To avoid resource management complete:

- Coordinate management activities with local agencies and organizations and adjoining landowners.
- Provide forestry input when local ordinances are being developed.
- Plan and maintain visual quality.
- Mitigate dust, mud, and noise during logging operations.
- Train loggers to be sensitive to landowners' concerns for aesthetics.
- Assess the proximity and view of management activities from other properties, developments, and highways.
- Consider using alternative silvicultural and cultural practices.
- Consider the aesthetics of stand size and configuration. Design is important.
- Determine and establish visual buffers.
- Modify harvesting and site preparation operations to provide better visual quality.
- Avoid unnecessary damage to roads, residual trees, understory vegetation, recreation trails, vistas, and other resources.
- Protect unique areas, unique features, and special resources.
- Insure safe access to public roads.
- Locate roads, log landings, and skid trails to minimize visual impact.
- Rehabilitate and stabilize disturbed areas promptly.
- Dispose of trash properly and cleanup every site.
- Protect flowering trees and plants which provide autumn color or spring flowers.

Plan for wildlife.

Wildlife Management

Wildlife management opportunities will be more limited for some species of wildlife than in less fragmented rural areas. However, wildlife habitat enhancement is a common goal of many interface landowners. Species that are tolerant of people and prefer edge communities should do well, while others may struggle. Also, undesirable or non-target species are usually attracted to an improved habitat.

Interface wildlife management recommendations:

- Identify the species of wildlife the landowner wants to feature.
- Create age and class diversity in timber stands.
- Use native species.
- Provide forage and browse.
- Provide hard and soft mast.
- Leave and protect den trees.
- Leave and protect vine patches.
- Leave and protect perch trees.
- Construct and install artificial nests whenever possible or practical.
- Create permanent wildlife openings and annual food plots.
- Create wildlife corridors and water sources.
- Protect and manage threatened and endangered species.
- Plant and protect trees and shrubs for wildlife food.
- Protect, restore, and manage wetlands habitat.
- Manage beaver ponds.
- Identify wildlife habitat needs for game and non-game species.
- Control destructive or excessively large wildlife populations.

Living with Wildlife

in the Forest/Urban Interface

INTRODUCTION

When people build homes in the forest they interact with more than trees. Homeowners need to realize that the site of their "dream home" was once the territory of a host of animals that don't recognize property deeds or no trespassing signs. The opportunity to view and interact with wildlife is often one reason people move to the woods, and many individuals take steps to make their property more attractive to wildlife. However, problems may arise when people don't understand animal behavior, or the homeowner's interests conflict with the lifestyles of a particular species.

ANIMAL DAMAGE

Is The Problem Real?

Often a situation involving wildlife is a problem only because the homeowner perceives it as one. Educational programs which explain the behavior and beneficial aspects of wildlife may convince people that they can tolerate the damage in return for the benefits of having a particular species on their property. Consult local wildlife officials or county extension agents for information on specific problems.

CULTURAL TECHNIQUES

The best time to minimize damage is before it starts. Once animals have developed a pattern of use, it can be difficult to change. The following suggestions may be incorporated into local ordinances or homeowners association regulations:

- Remove food sources that may attract unwanted animals. Be sure that garbage and pet and livestock foods are securely stored. Use sturdy metal or tough plastic garbage cans with tight lids. Secure cans so they can't be knocked over. Don't leave bowls of pet food outside overnight.
- Remove cover that may attract unwanted animals. A forest fire safety zone also helps prevent animal damage.
  - Removal of trash, brush piles, and thick vegetation around the home greatly reduces its appeal to undesirable animals such as rodents and skunks.
  - Trim vegetation to prevent it from covering foundation walls. Allow two feet between the vegetation and the building.
  - Wooden shingles and siding, which increase the risk from forest fire, are highly susceptible to damage from woodpeckers as well as various gnawing rodents such as groundhogs.

Wildlife lives in the interface too!

- Exclude animals from areas such as gardens by using wire or electric fencing. Extend the fence 1-1/2 feet underground or bend it outward at ground level for 18 inches to keep out digging animals such as groundhogs.
- Beaver damage to trees may be prevented by wrapping the bottom part of the tree in hardware cloth.
- Rodents and snakes can be denied access to homes by sealing openings in foundations and points where plumbing and wiring enter the building by using 1/4 inch mesh, wire screen on vents.

- Before screening or blocking exterior accesses, ensure that all animals, especially the young, have left. Do a visual check with a flashlight.
- Fill in holes around the foundation.
- Trim tree limbs away from the roof to deter access onto the building. Install a chimney cap.
- Screening vents and structural openings with wire screen can also help prevent sparks and firebrands from entering during a forest fire.

REMOVING THE ANIMAL

If necessary, the animal causing a problem may have to be removed or destroyed. Before this step is taken, the local game warden should be consulted to see if any restrictions apply. Wildlife agencies and county extension agents can offer advice on the trapping and removal of nuisance animals, and local trappers can often be hired to perform this task. However, live trapping and relocation are only a temporary solution to wildlife problems. Unless preventative measures are taken, other animals may move back in.

WILDLIFE AND PETS

Pets should be confined, if possible, in woodland communities. Free roaming dogs and cats can be very destructive to wildlife, especially in the spring and early summer when many animals are nesting or rearing young. In addition, the higher probability of contact between wild animals and pets means a greater risk from disease, such as rabies. All dogs and cats should be vaccinated for rabies and given booster shots as required.

While animals, such as geese, raccoon and deer will respond to feeding, be aware of the potential damage it can cause.

ATTRACTING WILDLIFE

Landscaping for Wildlife

The selection and placement of trees, shrubs, and ground covers used in landscaping can play a major role in encouraging the use of property by wildlife. Excellent information is available through the National Wildlife Federation's Backyard Wildlife Habitat Program.

Feeding

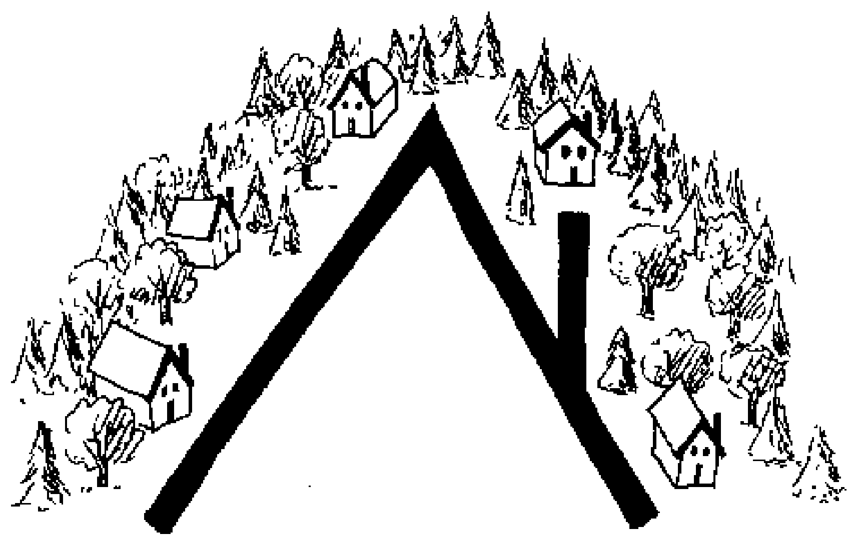
The creation of artificial feeding sites is a good way to attract wildlife to a particular area. The most common example of this is the use of bird feeders. Information on types of feeders, feed mixes and placement is available through the Audubon Society, local bird clubs, wildlife agencies and local libraries.

While larger animals, such as raccoon, deer and bear, will respond to artificial feeding, landowners should be aware of the potential for damage created by this practice. After finishing a meal offered by the homeowner, these large animals may proceed to devour or destroy other items that are not on the menu.

Urban and Community Forestry

in the Forest/Urban Interface

When people move to forested areas, their very presence changes those areas. They are no longer the wildlands that they once were. A woodland development is filled with trees that have a tremendous psychological, aesthetic and environmental value to homeowners. Trees in these "urban" forests provide shade, privacy, a home for wildlife, and scenic beauty. Urban forests also require care to maintain their health, and to maintain a fire-safe environment.



CHANGING LAND USE - CHANGING VALUES

What do people value most when they move to the woods? We know that trees and forests are the most important part of this lifestyle. Therefore, woodland residents usually act to protect the forested character of their communities, often coming in conflict with traditional uses of the land. Different groups of people expect different things from the forest based on their background and their experience, or lack of experience, in the natural world. At times they cannot see how their actions permanently change the environment they want to preserve.

Southern forests are changing as greater demands are made of them. As our values and expectations change, more diverse issues will impact the smaller and more fragmented forests of the future.

COMMUNITY PLANNING

Everyone has to work together to preserve trees and anticipate tree problems in growing areas. Woodland developments can affect soil and water quality, soil erosion, land available for wildlife populations, demands on recreation areas, the availability of forest products, forest fire occurrence and natural scenic beauty. Sensitivity to the conservation of natural resources should be a major component of any community planning, especially in the forest/urban interface, balancing what we want with the limits to the resource. This applies not only to expanding rural communities, but also to highly developed areas that are seeing a restoration of forests and trees.

Community planning may involve actions, such as giving county planners advice and ideas, or establishing a public participation process. Foresters should take a leading role in determining a vision for the community forest and help to resolve conflicts for land use.

Think about how rural areas may change in the future. Rural forestry practices may conflict with urban expansion.

Foresters must also keep in mind how rural areas may change in the future. For example, in rapidly growing areas, some kinds of reforestation may have to be thought out. If you know an area planted in pine will probably become a development in ten years, are you adding to the fire problems of the future? Sometimes rural forestry practices come in conflict with urban expansion, and these concerns must be pointed out to landowners.

Opportunities and strategies for planning can include:

- Planning for proper tree planting and maintenance before urban growth starts.
- Identifying sensitive lands before development starts. Work with conservation groups such as The Nature Conservancy.
- Developing conservation easements. Work with local outdoor foundations and urban forestry councils.
    - An open space or conservation easement is a legal agreement between a landowner and a public body or conservation group. The parties agree to protect the open space and natural resource values of the land. The easement is recorded with the land in the local court house.
    - Easements allow land to remain in the private sector and on the tax rolls. Open space easements preserve farm land, forest land, natural areas and recreational areas by restricting intensive uses, such as developing and mining, which would alter the conservation values of the land.
- Transfer of property development rights.
- Zoning bonuses.

- Conversion of land uses.
- Providing tax incentives for land in forest and agricultural uses.
- Developing and using GIS/GPS technology.
- Adopting tree and green space ordinances.
    - Be aware of covenants that limit tree removal in fire-prone woodland developments and resorts. This should be presented as a problem to the homeowner's association and solutions should be given.
- Developing educational programs dealing with tree preservation and protection.

LANDSCAPE PLANNING

- Proper planning before development can help maximize the benefits that existing and future trees can provide to a site. Avoid retaining existing trees that may become hazard trees after the development is complete.
- Planting the right tree in the right place can prevent future conflicts between trees and people.
    - Lists of appropriate species for planting near powerlines are available from most electrical companies.
    - Less flammable and smaller species should be planted near the homes in forest fire risk areas.
- Proper planting techniques can help insure survival and growth of new trees.
- Proper care and maintenance such as mulching, watering, pruning and fertilization can promote good health of newly planted and existing trees.
    - Tree pruning attitudes in rural areas can be hard to change, especially after severe storm damage. People tend to top all of their trees so they won't fall on their houses, which causes a weaker and more diseased tree in the long run.
    - Information about tree care, species selection, and certified arborists is available from the International Society of Arboriculture, P.O. Box 908, Urbana, IL 61801, or The National Arbor Day Foundation, 100 Arbor Avenue, Nebraska City, NE 68410, (217) 355-9411.

TREE CARE

Selecting and Planting Trees

Woodland homeowners have two choices when selecting yard trees and plants. They can work with the plants and trees native to the site, using the patterns found in nature, or they can introduce new ones. Most homeowners do both. When choosing new species, homeowners should consider hardiness zones, planting site quality, fire resistance if within 30 feet of the house and the benefits to wildlife.

Other things to consider are:

- Pick the right tree for the right **purpose**. What is the trees purpose?
  - If for shade, the tree should be large and sturdy.
  - For aesthetics, the tree should feature a graceful form and showy foliage or flowers.
  - For wildlife, berry-producing shrubs may be best.
- Avoid fast-growing, weak-wooded species, such as lombardy poplar or silver maple.
- Pick the right tree for the available **space**.
  - Avoid planting large trees in confined or limited space.
  - Avoid planting trees too close to buildings, other trees, septic drain fields, sidewalks, driveways, or where future views will be obstructed.
- Pick the right tree for the environmental **conditions**.
- Plant at the right time. Early fall is usually best.
- Plant the tree properly.
  - Dig a hole large enough to accommodate all of the roots. Be sure to remove all circling roots.
  - Use natural soil to fill the planting hole.
  - Use no more than two inches of mulch to establish a “tree well” around the newly planted tree.

Tree Health

Environmental stress is the main cause of most tree health problems. Too much or too little water, light, nutrients or optimum temperatures can cause stress. A host of insects and diseases also threaten forest trees every year. Trees are also very susceptible to mechanical damage during home construction, and their survival depends on careful planning. Trees that are structurally weakened may pose a threat to people and property.

Trees with the following symptoms may be hazard trees:

- Dead or dying branches.
- Old wounds and obvious signs of decay.
- Yellowing, reddening, or thinning foliage.
- Shortened height growth or a sudden large crop of seed.
- Signs of root damage.

Tree topping is not tree pruning!

Pruning

Regular pruning of trees and shrubs is an important part of woodland home landscape maintenance. Trees are pruned to control growth, to enhance tree appearance, to open a view, and to remove branches that pose a safety hazard to people or property. Pruning may also invigorate trees by removing weak, dead or damaged wood that can harbor insects or disease. Proper pruning also improves a home's forest fire safety zone by reducing the amount of flammable vegetation and by breaking the chain of fuels in a yard. "Fire ladders" where fires can climb from the ground into tree branches, can be eliminated by pruning trees 10 to 15 feet up from the ground.

Some things to remember are:

- Tree topping is not pruning.
- Make pruning cuts at intersections not in mid-branch.
- Make your cut at the branch collar.
- Use proper pruning tools.
- For large limbs, make cuts in three stages to prevent tearing the bark.
- Prune at the right time.
- Remove the right amount of branches. Don't over prune.

NATURAL AREAS AND GREENWAYS

Leaving areas in natural tree cover can provide:

- Better aesthetic qualities.
- Recreational areas.
- Wildlife habitat.
- Emergency evacuation routes.

RIPARIAN AREAS

Riparian areas are forests adjacent to streams, rivers, bays and lakes. They serve as a transition or buffer zone between the land and water environments, playing a key role in defining water quality.

Restoring them is a major concern in urban areas. The goal in interface areas is to identify riparian areas at risk and maintain them, preventing their eventual degradation. Foresters should recommend that at least 35 feet of forest buffer be left on each side of streams as recommended by the Natural Resource Conservation Service standard.

Leaving riparian areas can:

- Stabilize stream banks and systems.
- Provide shade and lower stream temperatures. Elevated temperatures reduce the amount of oxygen in the stream, adversely affecting biological communities.
- Provide wildlife food, cover, and thermal protection, corridors for migration, linkages for other forest systems, and in some cases a unique or critical wildlife habitat. Over half of all birds and animal species depend on riparian areas for some part of their life cycle.
- Provide streamside trees that are essential to the aquatic food web. Most aquatic insects like mayflies, on which fish and other species depend on to live, rely primarily on leaf detritus as food.
- Reduce or slow down storm water runoff and flooding. Proper placement of trees can reduce storm water runoff by allowing water to soak into soils and holding soil in place.
- Protect water quality by trapping, filtering and transforming upland sources of pollution such as sediments, nutrients and chemicals.
- Provide some of the same benefits of greenways.

- Think forest! Not just planted trees with a lawn underneath. A riparian area needs the forest floor litter layer to function. A natural roughness slows down the velocity of the water, and an uneven forest floor provides multiple small settling basins for water and sediments.

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Thinning Southern Bottomland Stands: Insect and Disease Considerations

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THINNING SOUTHERN BOTTOMLAND HARDWOOD STANDS: INSECT AND DISEASE CONSIDERATIONS

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Abstract: The effects of thinning on insects and diseases have not been thoroughly examined in southern bottomland hardwood forests. To address this issue, a study was initiated at sites in Mississippi and Alabama. These study sites allowed us to make observations concerning insect and disease activity 1-5 years following thinning. On all sites there was an unthinned control and 1 or more thinned areas. Mississippi study sites received only 1 type of thinning treatment, whereas sites in Alabama were subjected to 3 different thinning treatments: (1) light thinning to 70-75% residual stocking, (2) heavy thinning to 50-55% of residual stocking, and (3) B-line thinning to a desirable residual stocking for bottomland hardwoods (Putnam et al. 1960). Study sites in Mississippi were surveyed for insects and diseases before and after thinning operations. Woodboring beetles (Coleoptera: Buprestidae, Cerambycidae, Scolytidae, and Platypodidae) were of primary interest as some species are associated with tree mortality and wood-degrade. Signs and symptoms of pathogens associated with rot and/or decay were tabulated. Potential effects of insects and diseases should be of interest and concern to resource managers. We report here on the numbers of insects and diseases recorded during individual tree surveys, as well as on the results of insect sampling conducted in thinned and unthinned stands. Observations on tree wounding, as a result of thinning, are reported. Conclusions and hypotheses will be drawn and stated as to the management and ecological significance of these findings. Directions for future investigations also will be recommended.

Keywords: disease, pathogens, thinning, tree wounding, woodboring beetles.

Management of hardwood forests in the southern USA is intensifying, as economic opportunities increase. Conversely, forest management activities are, at the same time, becoming less intense in other areas as societal values are considered. In particular, interests in ecosystem management, forest health, and habitat restoration are increasing. There also is considerable interest in the sustainability of southern forests for purposes of producing fuel, fiber, lumber products, and chemicals. As a result of these latter interests, and in connection with broader ecological interests, the effects of harvesting, periodic flooding (including greentree reservoirs), and fire are of concern (Nebeker et al. 1998). In each case, insects and disease-causing organisms have increased or decreased opportunities to affect a residual stand as various physiological stresses are added to or removed from the system. Consequently, there is a growing demand to understand these complex relationships.

The relationship between silvicultural practices, (e.g., thinning, and pest organisms including insects and diseases) has been investigated extensively in pine forests but to a lesser degree in hardwood forests. Thinning guidelines, with pest management recommendations, have been developed for pine stands (Nebeker et al. 1985). Similar information regarding the broader effects that silvicultural practices have on assemblages of pest species populations within southern bottomland hardwoods is lacking.

Our objective was to investigate the potential positive and negative aspects of thinning southern bottomland hardwood stands in relation to insect and pathogen populations. Of critical interest were the effects on the residual stand resulting from insect damage and diseases that develop as a consequence of thinning practices. This is especially important with the increasing economic opportunities now developing in southern forests. The effect of stand modification practices on current or potential pest problems will be discussed with respect to current and past research concerning insects and diseases. Management approaches will be suggested that will help minimize losses from insects and diseases.

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STUDY AREAS

This study was conducted in 4 bottomland hardwood stands located in northeastern and southwestern Mississippi and western Alabama. Two study sites were established in Mississippi; 1 within the Delta National Forest (Sharkey County) and a second on a privately owned bottomland hardwood stand in Monroe County. Thinning treatments at both sites were performed in 1997. In Alabama, 2 study sites were established in bottomland hardwood stands on land owned by Gulf States Paper Corporation. The Alabama sites were located near Aliceville in Pickens County and Demopolis in Marengo County. Thinning at the Aliceville site took place September 1994, while thinning treatments near Demopolis were performed September 1995.

METHODS

Plot Design and Thinning Treatments

At the Delta National Forest, 2 rectangular 0.96-ha treatment areas were established in Compartment 38. Treatments consisted of an unthinned control and a commercial thinning. Both treatment areas were divided into four 0.24-ha measurement subplots and surrounded by a 19.8 m buffer strip. Measurement subplots were further subdivided into 6 square 0.04-ha sectors for ease of measurement. Corners of all sectors and of the measurement subplot were permanently marked with PVC pipe driven into the ground. All 48 sectors were established and inventoried prior to the commercial thinning. The second Mississippi study site in Monroe County had been thinned in 1997, with the remainder left unthinned (control). No measurement plots were established at this site and stands were simply identified as unthinned or thinned.

At each of the 2 study sites in Alabama, 12 rectangular 0.8-ha treatment plots were established as previously described by Meadows and Goelz (1998). One 0.24-ha measurement subplot was established in the interior of each treatment plot and was surrounded by a 19.8 m wide buffer strip. Each measurement subplot was divided into 6 0.04-ha^2 sectors for ease of measurement. All corners were permanently marked with PVC pipe driven into the ground. Thinning intensity was defined by 3 levels of residual stocking, based on the stocking guide for southern bottomland hardwoods developed by Goelz (1995). The study consisted of an unthinned control and 3 treatments: (1) light thinning to 70-75% of residual stocking; (2) heavy thinning to 50-55% of residual stocking; and (3) B-line thinning to a desirable residual stocking following partial cutting in well-managed, even-aged southern bottomland hardwoods, as recommended by Putnam et al. (1960). The thinning operation (Meadows and Goelz 1998) consisted of a combination low thinning and improvement cutting in which the objective was to remove most of the pulpwood-sized trees as well as sawtimber-sized trees that were damaged, diseased, of poor bole quality, or of an undesirable species. Hardwood tree classes, as originally defined by Putnam et al. (1960) and modified by Meadows (1996), formed the cutting priority for each treatment. Trees were removed from the cutting stock and cull stock classes first and then from the reserved growing stock class, if necessary, until the target residual stocking was met.

Pre-thinning Inventory

Pre-thinning inventory determined tree species composition, initial stand density, insect activity, and numbers of diseases. The following variables were measured on all trees greater than, or equal to, 13.75 cm diameter at breast height (dbh): species, dbh, crown class, tree class, vigor classes, number of epicormic branches, length and grade of sawlogs, and number of insect and disease signs and symptoms. Locations of sample trees within their respective plots were recorded using an x-y coordinate system. An individual number was painted on each tree at about breast height (bh), and a tag was nailed to the base of each tree. A dot also was painted on each tree at bh to assure consistency in measuring dbh. Primary tree species in the areas are sweetgum (*Liquidambar styraciflua*), willow oak (*Quercus phellos*), Nuttall oak (*Q. nuttallii*), cherrybark oak (*Q. pagoda*), southern red oak (*Q. falcata*), Shumard oak (*Q. shumardii*), shagbark hickory (*Carya ovata*), mockernut hickory (*C. tomentosa*), sugarberry (*Celtis laevigata),* and various elms (*Ulmus spp.).* Other species scattered throughout the stands included white oak (*Q. alba*), swamp chestnut oak (*Q. michauxii*), overcup oak (*Q. lyrata*), and green ash (*Fraxinus pennsylvanica*).

Post-thinning Inventory

Post-thinning inventory was conducted in the same manner as the pre-thinning inventory except that additional data were collected concerning thinning related wounding to the canopy, upper-bole (above bh), lower-bole (below bh but above the root collar zone), root collar, and roots. Commonly

Table 1. Percentages of total numbers of trees, insect borer wounds, and disease indicators (signs and symptoms), by tree species, resulting from the summer 1997 pre-treatment survey of the unthinned plot and the plot designated to be thinned in Compartment 38 of the Delta National Forest, Mississippi, 1997.

Tree Species	Percent of total trees	Percent of total borer indicators	Percent of total disease indicators
Unthinned plot			
Sweetgum	51.7	1.3	24.4
Willow oak	28.3	59.9	46.3
Nuttall oak	9.2	28.3	14.6
Sugarberry	5.4	0	9.8
Other	5.4	10.4	4.9
Plot designated to be thinned			
Sweetgum	47.4	8.7	10.7
Willow oak	29.4	39.1	71.4
Nuttall oak	6.6	39.4	7.1
Sugarberry	5.4	0	0
Other	11.4	12.8	10.7

encountered insect signs and symptoms consisted of: insects themselves in various life stages, frass, bore holes, boring dust, scarring (resulting from callus tissue growing over entrance or exit holes), and galleries. Disease signs and symptoms commonly seen included slime flux (weeping or oozing indicative of bacterial wetwood), stained wood, fruiting bodies such as conks and mushrooms, cankers, and fungal mats.

Insect Sampling and Analysis

Townes-style Malaise traps were installed in unthinned and thinned stands at both the Delta National Forest and Monroe County sites, with 1 trap per stand. Malaise traps are tent-like structures that passively trap flying insects and funnel them up into a collecting head filled with a killing agent/preservative. Malaise trap were chosen due to their efficiency in collecting low-flying beetles (Hutcheson 1990), and their ability to provide characteristic beetle samples of specific sites (Hutcheson and Jones 1999). Woodboring beetles were sampled at the Delta National Forest from 20 August to 9 October 1997 shortly following thinning. Sampling at the Monroe County site was conducted from 1 April to 31 October 1998, 1 year following thinning. The collecting heads of all Malaise traps were filled with 70% ethanol as a killing agent/preservative. Traps at both sites were serviced at 1-2 week intervals. Black-light traps also were utilized and were run 1 night a month from August to October 1997 at the Delta National Forest only. Insects collected from both sites were sorted and stored in vials containing 70% ethanol. Specimens belonging to specific woodboring beetle families were removed from the samples and identified to species. Families of interest included the Cerambycidae (longhorned beetles), Buprestidae (metallic woodborers), Scolytidae (bark beetles), and Platypodidae (ambrosia beetles).

Diversity indices were calculated to characterize the assemblages of woodboring beetles collected from the unthinned and thinned stands at both study sites. Indices applied were the Shannon-Weiner index (designated as H'; Magurran 1988) and evenness (designated as J'; Pielou 1966). Statistical differences between the 2 stands in terms of the diversity indices were tested following Hutcheson (1970) and procedures from Zar (1996). The coefficient of community (Pielou 1974) was calculated to compare species assemblages between unthinned and thinned stands. Percent similarity also was calculated to compare species abundance between unthinned and thinned stands. Larval host preferences were determined for the collected woodboring beetles species from Yanega (1996), Solomon (1995), MacRae (1991), and Wood (1982).

Table 2. Comparison of pathogens evident 1 year before (pre) and after (post) thinning in stands designated as unthinned and thinned in Compartment 38 of the Delta National Forest, Mississippi, 1998.

Disease type and species	Unthinned		Thinned	
	Pre	Post	Pre	Post
Canker decay, heartwood decay				
Inonotus hispidus	3	2	3	0
Root and butt decay	1	0	0	0
Ganoderma lucidum	0	0	0	1
Inonotus spp.	0	0	0	1
Unidentified pathogen	3	5	10	2
Heartwood decay				
Schizophyllum commune	0	0	0	2
Stereum gausapatum	0	0	0	2
Dead wood decay				
Trichaptum biforme	0	0	0	1
Stereum hirsutum	0	0	0	4
Wetwood				
Various anaerobic bacteria	1	4	0	1
Total disease types	3	3	2	4
Total individuals	8	11	13	14

Table 3. Post-treatment tree species composition and distribution of insect and disease signs and symptoms, along with proportions of individuals affected within each tree species, in parentheses, in control and thinned plots in Compartment 38 of the Delta National Forest, Mississippi, 1998.

	% total of trees		% total of insect borer indicators		% total of disease indicators	
Tree Species	Control	Thinned	Control	Thinned	Control	Thinned
Sweetgum	51.7	34.0	4.7(8.1)	3.5(6.7)	18.2(0.8)	7.1(3.3)
Nuttall oak	9.2	8.0	37.0(72.7)	45.2(71.4)	18.2(9.1)	35.7(42.3)
Willow oak	28.3	46.6	42.6(45.6)	47.8(46.3)	36.4(2.9)	57.2(12.2)
Sugarberry	5.4	3.4	5.3(7.7)	0	9.0(7.7)	0
Other[a]	5.4	8.0	10.4(15.4)	3.5(14.3)	18.2(7.7)	0
Total	240	88	319	115	11	14

[a]Eastern cottonwood, common persimmon, green ash, honeylocust, overcup oak, American elm

RESULTS

Pre-thinning Inventory

A survey of the study area on the Delta National Forest prior to thinning revealed no differences in total numbers of trees, insect signs and symptoms, or disease signs and symptoms between the unthinned and thinned areas. A total of 469 trees were inventoried and numbered. Sweetgum, willow oak, Nuttall oak, and sugarberry were the dominant species in the study area (Table 1). Insect signs and symptoms totaled 742 with 374 borer holes on 240 trees in the unthinned plot and 368 borer holes on 228 trees in the thinned plot. Disease signs and symptoms totaled 69, with 59% being associated with the trees in the control treatment. Two well-developed decay diseases (caused by *Ganoderma lucidum* and *Inonotus hispidus*) and bacterial wetwood infections were in the stand prior to thinning. Willow and Nuttall oaks made up about 36% of the stands on each plot type but had 61% to 88% of the insect and disease indicators (Table 1). By comparison, sweetgum occupied approximately 50% of each type of plot yet sustained less than 25% of the insect and disease indicators.

Post-thinning Inventory

Wounding.—Wounding to the residual trees may occur during any entry into a stand. Generally, this occurs when a harvested tree falls into a residual tree, or when logging equipment causes damage to the residual stems. The scraping and removal of bark exposing xylem is typical of logging damage.

A "turn tree" (residual tree around the base of which a log is dragged) is a good example of typical basal wounding. The wounds provide places for insects to enter and serve as infection courts for pathogens.

Extensive wounding resulted from the thinning operation in the Delta National Forest. In the thinned plots, 84% of the residual stems were damaged in some way. Of the total wounds, 53% were on the lower-bole (basal wounding), followed by root damage (28%), root collar wounding (16%), upper-bole wounding (2%), and branch wounding or breakage (1%). Wounding of the roots, root collar, and lower bole was generally caused by logging equipment or was the result of tree removal (e.g., "turn trees"). Wounding to the upper-boles and branches occurred as cut trees fell into residual trees. During subsequent surveys of these study sites, wounds will be monitored for additional insect and disease activity.

Thinning related damage to the sites in Alabama was less, totaling 44 and 61 harvest related wounds at the Aliceville and Demopolis sites, respectively. At the Aliceville site, 43.2% of the wounds were in the light thinning treatment and 27.3% and 29.5%, respectively, in the Putnam and heavy thinning treatments. The greatest harvesting damage at the Demopolis site was in the heavy thinning treatment where 41% of harvesting related wounds were observed, followed by 31.1% in the Putnam treatment, and 27.9% in the light thinning treatment.

Insect and Disease Survey.— All numbered trees in the unthinned and thinned plots were examined in November 1998 on the Delta National Forest, March 1998 at Demopolis, and March 1999 at Aliceville for signs of insects and diseases. One year after thinning on the Delta National Forest,

Table 4. Tree species composition of control and thinned plots at the Aliceville (1999) and Demopolis (1998), Alabama sites.

	% total of trees - Aliceville				% total of trees - Demopolis			
Tree species	Control	Light	Putnam	Heavy	Control	Light	Putnam	Heavy
Sweetgum	23.7	12.0	6.0	13.2	25.2	25.2	19.2	22.1
Green ash	13.1	4.0	10.4	3.3	4.7	10.2	3.8	10.5
Mockernut hickory	13.1	38.0	8.5	26.4	4.3	3.1	6.7	1.2
Shagbark hickory	6.7	9.3	12.0	9.9	2.4	6.3	7.7	1.2
Cherrybark oak	13.7	13.3	36.7	15.3	4.7	9.4	16.3	16.3
Swamp chestnut oak	0	0	0	0	13.8	9.5	10.6	9.3
Water oak	3.6	3.4	12.8	4.4	5.5	9.5	9.6	10.5
Willow oak	2.4	4.0	2.5	12.1	20.5	8.7	17.3	12.8
Other[a]	23.7	16.0	11.1	15.4	18.9	18.1	8.8	16.1
Total trees	329.0	150.0	117.0	91.0	254.0	127.0	104.0	86.0

[a]American elm, blackgum, flowering dogwood, ironwood, red maple, red mulberry, sassafras, laurel oak, overcup oak, southern red oak.

logging wounds on some trees showed evidence of incipient pathogen activity (Table 2), and some had entrance holes caused by woodborers, most notably by ambrosia beetles (*Platypus spp.).* There were 11 occurrences of *G. lucidum, I.* spp., *Schizophyllum commune, Stereum gausapatum, S. hirsutum*, or *Trichaptum biforme* on year-old logging wounds. *Stereum hirsutum* and *T. biforme*, unlike the other 4 fungi, are saprophytic on dead wood. Many of the logging wounds at tree bases varied in size from 1000 cm^2 or larger and had exposed, dead wood.

Ratio of disease indicators per total number of sample trees was 4.6% (11/240) on the unthinned plot and 15.9% (14/88) on the thinned plot. New infections accounted for the difference in the number of disease types between the unthinned (3) and thinned (4) plots, as well as the difference in percentages of individual disease indicators between plot types (Table 2).

The increased number of infection courts resulted from logging damage incurred the previous year. Of the 25 disease indicators recorded on the Delta National Forest in the unthinned and thinned plots, 76% (19/25) occurred on willow or Nuttall oaks (Table 3). A similar finding (68%; 47/69) was noted in the pre-treatment data (Table 1).

Data in Table 2 also show the effect thinning had on controlling disease. Three *I. hispidus* infections were removed from the thinned plots, and 2 of the 10 unidentified rots (basal rots with no apparent fruiting bodies), also were eliminated. The use of thinning to control hispidus cankers from the larger forest compartment surrounding the study plots is the subject of a related study (Meadows et al. 2002).

Of the 434 borer holes caused by insects, 319 were recorded on 87 trees in the unthinned plot and 115 were noted on 27 trees in the thinned plot (Table 3). Even though the number of total borer holes was less in the thinned plot, the number of borer holes per sample tree increased from 3.7 in the unthinned plot to 4.3 in the thinned plot. This is an indication of the number of new insect borer attacks on logging wounds. Bacterial wetwood in oaks can often be diagnosed because of the slime flux oozing from wood borer attacks. New borer attacks are either not of the type usually associated with wetwood, or have not advanced to the point where the infections begin to ooze out of the holes.

The tree species composition following thinning treatments is presented in Table 4 for the study sites in western Alabama near Demopolis and Aliceville. These sites provide an excellent opportunity to examine insect and pathogen activity 3 and 5 years, respectively, after thinning treatments. Disease

Table 5. Post-treatment survey of insect and disease signs and symptoms at the Demopolis, Alabama site, 1998.

Treatment	% total of insect borer indicators	Number	% total of disease indicators	Number
Control	59.0	924	46.7	14
Light	17.0	267	10.0	3
Putnam	11.6	181	26.6	8
Heavy	12.4	195	16.7	5
Total		1567		30

Table 6. Post-treatment survey of insect and disease signs and symptoms at the Aliceville, Alabama site, 1999.

Treatment	% total of insect borer indicators	Number	% total of disease indicators	Number
Control	43.3	324	65.6	21
Light	15.8	118	15.6	5
Putnam	25.0	187	6.3	2
Heavy	15.9	119	12.5	4
Total		748		32

Table 7. Post-treatment distribution of insect and disease signs and symptoms, along with the proportion of individuals affected within each tree species, in parentheses, in control and thinned plots at the Aliceville, Alabama site, 1998.

	Insect signs and symptoms				Disease signs and symptoms			
Tree species	Control	Light	Putnam	Heavy	Control	Light	Putnam	Heavy
Sweetgum	0	5.9(11.1)	0	0.8(8.3)	20.0(5.1)	25.0(11.1)		0
Green ash	2.5(11.6)	0	3.7(57.1)	0	20.0(9.3)	0	0	20.0(33.3)
Mockernut hickory	2.2(16.3)	13.6(10.5)	2.7(57.1)	0.8(4.2)	10.0(4.7)	25.0(10.5)	0	20.0(4.2)
Shagbark hickory	0	1.7(7.1)	4.7(21.4)	1.7(11.1)	0	0	0	0
Cherrybark oak	55.8(71.1)	51.7(75.0)	44.4(60.5)	17.6(42.9)	5.0(2.2)	25.0(75.0)	0	0
Water oak	25.6(83.3)	14.4(40.0)	34.8(80.0)	21.8(100.0)	0	0	100.0(40.0)	0
Willow oak	9.3(62.5)	3.4(42.9)	2.7(66.7)	44.6(81.8)	5.0(12.5)	0	0	20.0(9.1)
Other[a]	4.6(19.6)	9.3(23.6)	7.0(50.0)	12.7(63.6)	40.0(16.3)	25.0(23.5)	0	40.0(18.2)

[a]Blackgum, flowering dogwood, ironwood, red maple, overcup oak, red mulberry, sassafras, southern red oak, white oak.

Table 8. Post-treatment distribution of insect and disease signs and symptoms, along with the proportion of individuals affected within each tree species, in parentheses, in control and thinned plots at the Demopolis, Alabama site, 1999.

	Insect signs and symptoms				Disease signs and symptoms			
Tree species	Control	Light	Putnam	Heavy	Control	Light	Putnam	Heavy
Sweetgum	0.5(7.8)	1.1(6.3)	0.6(5.0)	0	20.0(3.1)	0	12.5(14.3)	0
Green ash	0.1(8.3)	1.1(15.4)	0	1.0(11.1)	0	33.3(7.7)	0	0
Mockernut hickory	0.3(27.3)	0.8(25.0)	1.7(28.6)	0	10.0(18.2)	0	12.5(14.3)	0
Shagbark Hickory	0.1(16.7)	0	0	0	10.0(16.7)	0	12.5(12.5)	0
Cherrybark oak	4.0(41.7)	13.9(66.7)	13.8(23.5)	9.2(35.7)	20.0(16.7)	0	12.5(5.9)	20.0(7.1)
Swamp chestnut oak	18.5(74.3)	9.8(50.0)	12.7(45.5)	12.4(50.0)	10.0(2.9)	0	12.5(9.1)	0
Water oak	22.8(100.0)	33.1(91.7)	33.6(66.7)	56.4(77.8)	0	33.3(8.3)	37.5(30.0)	20.0(11.1)
Willow oak	44.8(78.8)	27.1(100.0)	34.8(50.0)	16.9(72.7)	10.0(1.9)	0	0	60.0(9.1)
Other[a]	8.9(3.0)	13.1(42.9)	2.8(60.0)	4.1(50.0)	20.0(7.0)	33.3(4.8)	0	0

[a]American elm, blackgum, ironwood, red maple, laurel oak, overcup oak, red mulberry, sassafras, white oak.

indicators were greatest in the control plots (Tables 5 and 6). During the thinning operation most of the diseased trees were removed, and with the limited logging damage, subsequent pathogen activity has been minimal. Insect borer indicators follow a similar trend (Tables 5 and 6) with the greatest activity in the control plots. Nearly twice as many borer indicators were observed at the Demopolis site compared to the Aliceville site, this being attributed primarily to tree species composition. The greater incidence of borer indicators was observed on the oak component of the stands (Tables 7 and 8).

Insect Trapping

At the Delta National Forest, a total of 1,371 individuals representing 21 species were collected from the thinned stand, and a total of 172 individuals representing 14 species were collected from the unthinned stand (Table 9). Cerambycids dominated Malaise trap samples of woodboring beetles. From the Monroe County site, a total of 536 individuals representing 56 species were collected from the thinned stand, and a total of 144 individuals representing 33 species were collected from the unthinned stand (Table 10).

Table 9. Woodboring beetles collected from 20 August to 9 October 1997 in control and thinned plots in Compartment 38 of the Delta National Forest, Mississippi.

Family and species	Control	Thinned
Cerambycidae		
Ataxia crypta	0	1
Distenia undata	1	4
Ecyrus dasycerus	1	7
Elaphidion mucronatum	0	6
Enaphalodes atomarius	0	12
Leptostylus aperatus	0	8
L. transversus	0	6
Leptura emarginata	1	0
Neoclytus acuminatus	12	27
N. mucronatus	1	28
N. scutellaris	2	22
Styloleptus biustis	1	9
Urographis fasciatus	2	35
Xylotrechus colonus	8	55
Scolytidae		
Dryocotes betulae	11	97
Hylocurus binodatus	0	8
Monartum mali	4	34
Xyleborus ferrugineus	47	353
Xylosandrus crassiusculus	21	36
Platypodidae		
Platypus compositus	60	621
P. flavicornis	0	1
P. quadridentatus	0	1
Total species	14	21
Total individuals	172	1371

At the Delta National Forest (Table 9), *Urographis fasciatus* and *Xylotrechus colonus* comprised 62% of the total Malaise trap catch of cerambycids in the thinned stand. In the unthinned stand, these 2 species accounted for 35% of collected cerambycids. Of those woodboring beetles examined, cerambycid species were the most frequently collected in Malaise traps from unthinned and thinned stands. Based on black-light trap samples, the most abundant woodboring beetle species collected in the 2 stands was the platypodid, *Platypus compositus*, accounting for 35% of all specimens from the unthinned stand and 45% of all specimens in the thinned stand. The scolytid, *Xyleborus ferrugineus*, also was common in black-light trap samples, accounting for 27% of the total catch from the control and 26% from the thinned stand.

For the 3 beetle families collected at the Delta National Forest, species richness and abundance were higher in the thinned stand (Table 11). There was no difference in species diversity between the thinned

Table 10. Woodboring beetles collected from 1 April to 31 October 1998 in control and thinned stands in Monroe County, Mississippi.

Family and species	Control	Thinned
Cerambycidae		
Aegomorphus modestus	2	0
A. quadrigibbus	1	0
Analeptura lineola	0	3
Anelaphus parallelus	1	3
A. villosus	2	2
Asemum striatum	0	1
Astylidus parvus	1	0
Astylopsis sexguttata	0	1
Ataxia crypta	0	1
Brachyleptura circumdata	0	1
Curius dentatus	6	5
Cyrtophorus verrucosus	0	1
Distenia undata	1	4
Doraschema cinereum	1	0
Elaphidion mucronatum	7	24
Enaphalodes atomarius	2	16
Euberia quadrigeminata	0	2
Euderces pini	0	1
Eupogonius pauper	0	1
Gaurotes thoracica	1	1
Hyperplatys maculata	1	0
Knullinana cicta	0	3
Liopinus alpha	0	1
Microgoes oculatus	1	0
Monochamus carolinensis	0	2
Neoclytus acuminatus	15	48
N. mucronatus	5	18
N. scutellaris	13	95
Oberea praelonga	0	1
O. tripunctata	1	0
Obrium maculatum	0	1
Orthosoma brunneum	12	7
Paralaphidion aspersum	0	2
Psyrassa pertenius	0	1
P. unicolor	0	1
Saperda discoidea	4	1
S. lateralis	2	3
Stenosphenus notatus	0	10
Strangalia bicolor	4	12
S. luteicornis	4	25
S. solitaria	0	7
Styloleptus biustis	1	0
Typocerus acuticauda	0	1
T. lugubris	1	1
T. lunulatus	0	10
T. velutinus	5	30
T. zebra	0	34
Urographis fasciatus	2	7
Xylotrechus colonus	22	45
X. sagittatus	0	2
Buprestidae		
Acmaedera tubulus	0	3
Agrilus arcnatustorquatus	0	1
A. bilineatus	14	27
A. obsoletoguttatus	5	6
Buprestis rufipes	2	0
B. lineata	0	1
Chalcophora virginiensis	0	2
Chrysobotrhis femorata	0	52
C. scitula	0	1
C. sexsignata	1	2
Dicerca obscura	0	1
Texania campestris	0	1
Scolytidae		
Monartum mali	3	2
Orthomicus caelatus	0	1
Xyleborus fuscatus	1	1
Total species	33	56
Total individuals	144	536

Table 11. Species richness and standardized abundance of wood boring beetles collected 20 August to 9 October 1997 from control and thinned hardwood stands in Compartment 38 of the Delta National Forest, Mississippi.

	Number of species		Number of individuals/trap/day	
Treatment	Control	Thinned	Control	Thinned
Cerambycidae	9	13	0.57	2.96
Scolytidae	4	5	22.75	63.25
Platypodidae	1	3	0.75	90.37
Total	14	21	24.07	156.58

Table 12. Species richness and standardized abundance of wood boring beetles collected 1 April to 31 October 1998 from control and thinned hardwood stands in Monroe County, Mississippi.

	Number of species		Number of individuals/trap/day	
Treatment	Control	Thinned	Control	Thinned
Cerambycidae	27	42	0.61	2.26
Buprestidae	4	11	0.14	0.51
Scolytidae	2	3	0.06	0.02
Total	33	56	0.81	2.79

(H' = 1.99) and control (H' = 1.83) stands. Evenness was slightly higher for the unthinned (J' = 0.69) than the thinned stand (J'=0.64), reflecting a more equitable distribution of numbers among collected species. This is understandable as nearly half of the insects trapped in the thinned stand were of a single platypodid species, *P. compositus*. The coefficient of community between the control and thinned stand was 74.3, indicating relatively similar species assemblages. Percent similarity was low at 24.7, indicating little similarity in species abundances between the 2 stands. A difference primarily due to the larger number of individuals collected per species in the thinned stand, especially *P. compositus*.

At the Monroe County site, cerambycids dominated Malaise trap samples of wood-boring beetles, accounting for 75% of the species and 83% of the individuals taken in the thinned stand. In the unthinned stand, cerambycids represented 79% of the species collected and 94% of the individuals. The most commonly collected cerambycids in the thinned stand were *Neoclytus acuminatus, N. scutellaris,* and *X. colonus* comprising 43% of the specimens taken. These 3 species accounted for 42% of the cerambycids collected in the unthinned stand. *Chrysobotrhis femorata* was the most frequently trapped buprestid in the thinned stand, but the species was absent from the unthinned stand.

Although larger numbers of species and individuals were collected from the thinned stand (Table 12), there was no significant difference between the unthinned and thinned stands in terms of species diversity (H' = 3.03 and 3.07, respectively). Evenness was slightly higher for the control (J' = 1.97) than in the thinned stand (J '= 1.75). The coefficient of community for the control and thinned stands at this study site was 55.6, indicating a lower degree of similarity between species assemblages. In particular, the thinned stand contained more species overall than the unthinned stand, and of all species encountered, 55% only were collected in the thinned stand. Percent similarity was 31.8 indicating a low level of similarity in terms of species abundance between the 2 stands. Again, much of the difference is tied to the thinned stand where larger numbers of individuals were collected for certain species.

Woodboring beetles play a number of important roles in forest ecosystems, from the decomposition of dead woody material (Harmon et al. 1986) to affecting the vigor and mortality of forest trees (Drooz 1985). To examine the ecological role of woodboring beetles in the context of forest health, larval host preferences and standardized abundances were determined for the most frequently trapped genera from both the Delta National Forest and Monroe County sites. From the Delta National Forest, 3 cerambycid, 1 platypodid, and 4 scolytid genera were examined (Table 13). Seven cerambycid and 2 buprestid genera were examined from the Monroe County site (Table 14).

For both sites, hardwood tree species represent the primary larval hosts for all examined genera. Most species within these genera prefer weakened, stressed, or dying host trees, as well as freshly felled and dead wood. The cerambycids (*N. acuminatus, N. scutellaris, U. fasciatus,* and *X. colonus)*, typically prefer weakened trees or downed woody material as larval hosts (Solomon 1995). *Platypus compositus* does not feed on wood directly, but rather burrows into severely weakened and freshly felled hardwood trees and cultivates fungi upon which adults and larvae feed. The buprestid, (*C. femorata*) often attacks trees stressed by disease, drought, other insects, or whose bark has been damaged (Solomon 1995).

DISCUSSION

The magnitude of logging damage is dependent upon the principal variables as follows: (1) silvicultural system, (2) type of equipment and configuration, (3) tree species, (4) spacing (density), (5) size class (age), (6) season of harvest (soil moisture conditions), and (7) operator carelessness (Nebeker et al. 1998). Types of damage encountered include limb breakage and wounding, bole wounding (upper and lower bole), root wounding, and root breakage.

Table 13. Standardized abundance and larval host preference of the most frequently collected woodboring beetles from control and thinned stands in Compartment 38 of the Delta National Forest, Mississippi.

Family and genus	Number of individuals/trap/day: Control	Thinned	Larval host preference[a]
Cerambycidae			
Neoclytus	0.30	0.71	W/SH, DH
Urographis	0.01	0.07	W/SH, DH
Xylotrechus	0.15	0.75	W/SH, DH
Scolytidae			
Dryocoetes	0	0.05	W/SH, DH
Monartum	0.04	0.21	W/SH, DH
XYleborus	0.03	0.36	W/SH, DH
Xylosandrus	0.10	0.22	HH, W/SH
Platypodidae			
Platypus	0.09	0.16	W/SH, DH

[a]Larval host preferences: HH = healthy hardwoods, W/SH = weakened/stressed hardwoods, DH = dead hardwoods.

Table 14. Standardized abundance and larval host preference of the most frequently collected woodboring beetles from control and thinned stands in Monroe County, Mississippi.

Family and genus	Number of individuals/trap/day: Control	Thinned	Larval host preference[a]
Cerambycidae			
Elaphidion	0.06	0.11	DH
Enaphalodes	0.01	0.07	DH
Neoclytus	0.15	0.75	W/SH, DH
Stenosphenus	0	0.05	DH
Strangalia	0.04	0.21	HU
Typocerus	0.03	0.36	DH, P
Xylotrechus	0.10	0.22	W/SH, DH
Buprestidae			
Agrilus	0.09	0.16	W/SH, DH
Chrysobothris	0	0.26	W/SH, DH

[a]Larval host preferences: W/SH = weakened/stressed hardwoods, DH = dead hardwoods, HU = hardwood of unknown condition, P = pine.

Other reports indicate considerable logging damage is a common occurrence in thinning operations. Logging wounds occurred on 62% of the residual stems following a thinning operation in a riverfront hardwood stand in Mississippi (Meadows 1993). The most common types of damage included: (1) broken branches in the residual canopy, (2) upper and lower bole wounding, and (3) exposure and breakage of roots. Such wounding serves as an infection court for disease organisms and as attraction points for various insects that degrade or cause potential mortality of the residual stems. In addition, disease propagules such as fungal spores, bacteria, and viruses may be introduced into trees through wounds created by insects, birds, mammals, or by the equipment used to harvest trees. The subsequent reduced vigor of individual trees also may reduce the overall health of the residual stand, making it susceptible to further attacks by insects and pathogens.

Abundances of pathogens and insects were higher in thinned stands at both the Delta National Forest and Monroe County study sites. Higher abundances in the thinned stands is understandable as large amounts of logging slash, in the form of branches and harvest tops, can be left in the wake of thinning operations. In the context of forest health, beetles that feed on dead wood represent a vital component in the initial breakdown and fragmentation of woody material. Higher abundance of woodboring beetles in the thinned stands also may be a result of insect attraction to damaged or injured host trees. During thinning operations, damage to the residual stand may result. Wounds that occur during stand entry and logging operations may cause stressed trees to release volatile compounds that attract some woodboring beetles (Dunn et al. 1986, Kimmerer and Kozlowski 1982).

The final effects resulting from insects and diseases are unknown. Stands must be monitored for a number of years to document overall changes over time. It is anticipated that these initial decays will be more advanced when examined during future surveys, and that more new infections will have occurred on other logging wounds in the thinned plot. Also, more sites must be monitored to determine if unique situations exist that warrant consideration. Alongside silvicultural practices, effects of other management strategies (greentree reservoirs) applied to bottomland hardwood systems need to be investigated in light of insect and pathogen activity. If prescribed burns are introduced into the southern bottomland landscape, what will be the response of insects and pathogens to this changing landscape?

MANAGEMENT IMPLICATIONS

It is our intent to produce a pest management guide for southern bottomland hardwoods similar to one produced by Nebeker et al. (1985) for southern pines. They state that although the principal goal of thinning is improving the growth and value of stands, other benefits are obtained, such as hazard reduction for insect infestations, disease epidemics, and damage due to abiotic agents. The mechanics by which thinning reduces these hazards is not completely understood. However, observations indicate that thinning can result in positive and/or negative effects, depending on how, where, when, and why it is conducted.

The presence of more than one kind of hazard (e.g., insects and diseases) in a particular area at a given time poses some problems in designing an optimal thinning strategy. Other factors that complicate the situation are the forest type (species composition), stage of stand development, site quality, growth rate, live crown ratio, equipment used, machine operator experience, anticipated direct damage to residual stems, and ultimately the cost effectiveness of the operation. Soil compaction, soil improvement, water quality issues, wildlife habitat enhancement, weed problems, aesthetics, and the like, cannot be ignored if all aspects of thinning are to be taken into account. This is certainly true of the bottomland hardwood landscape.

Clearly, logging damage is one of the most detrimental actions that can occur to a bottomland hardwoods residual stand. The amount of injury and rot caused by insects and diseases during the time before the next thinning, or final harvest, is directly proportional to the percentage of trees damaged during the initial thinning. In general, conducting a partial thinning in an average, healthy bottomland hardwood stand, and causing little logging damage in the process will result in increased tree growth and added stand volumes before the next treatment. Furthermore, opening up a stand (in terms of available sunlight) with adequate, healthy advanced regeneration in the understory will accelerate development of the next stand.

However, a high percentage of logging wounds of sufficient size to become infected and develop severe decay, or be attacked by insects, will decrease the merchantable volume of the next harvest. A vigorously growing tree may be able to produce callus tissue over a small wound (e.g., 100 cm^2, or less) in 1 or 2 growing seasons. This growth walls off incipient infections and prevents the development of severe infections, and/or prevents significant insect damage. A larger wound may never heal and would most likely develop a severe decay or insect problem. Wound dimensions and locations (i.e., azimuths) were recorded for each tree in the Delta National Forest study. Several years from now we plan to report the relationships of wound size and numbers to the further development of insects and disease damage in the Delta National Forest stand.

The high percentage (84%) of logging wounds in the thinned stand was caused by an inexperienced equipment operator (Bellsaw harvester) who made too many entries and re-entries in the plot to remove marked trees. Therefore, we think there is value in educating loggers and forest managers about the importance of preventing disease and insect damage in residual stands by minimizing the number of wounds during thinning.

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Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

A Survey of Allelopathic and Other Chemical Interactions of Oaks (Quercus sp.)

A Survey of Allelopathic and Other Chemical Interactions of Oaks *(Quercus* sp.)

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ABSTRACT
Oak trees *(Quercus* sp.) have been proposed to express allelopathy on other plant and herbivore species. Different species of oaks, various parts of the trees, litter, soil under the trees, leachates, and chemicals extracted from the trees and soil have been tested on other tree species, local herbaceous plants and grasses, crops, and insect herbivores. An allelopathic effect from the oaks has been repeatedly demonstrated, although it seems to be species specific with reference to the oak and the "receptor" species in question, and is sometimes temporally dependent. In some cases, positive or no effects were observed and allelopathic effects were confounded by other interactions from biotic and abiotic factors. This paper will examine research on possible allelopathic and other chemical effects of oaks in natural systems, laboratory analyses including bioassays and chemical constituents, and the effects exerted by other species on oak establishment and development. Additional research is needed to understand the exact role of oak allelochemicals in natural systems, the mechanisms controlling production and release of allelochemicals, and the separation of allelopathy from other ecological processes such as competition. Practical applications include future use of allelochemical research in agricultural and soil science, weed and pest management, and plant growth regulation.

INTRODUCTION
Oak trees *(Quercus* sp.), significant species in deciduous and mixed forests, have been proposed to express allelopathy towards other plant and herbivore species. By utilizing different species of oaks, various parts of the tree, and chemicals isolated from extractions of the trees and soil, researchers have tested the biochemical influence of *Quercus* sp. on other trees, woodland plants, crops, and insect herbivores. An allelopathic effect from the oaks has been repeatedly demonstrated, although it seems to be species specific with reference to the oak and the "receptor" species in question. In some cases, positive or no effects were observed, and a few instances of chemical defense by different species towards the oak will be mentioned. This paper will examine research on possible allelopathic and other chemical effects of oaks in natural systems, laboratory analyses including bioassays and chemical constituents, and the chemical effects exerted by other species on oak establishment and development.

Oaks and Man
Oak trees *(Quercus* sp.) are distributed around the world and are common in natural ecosystems in the Western World. There are 80 species of oak in the United States and greater than 55 species in Central America (Walker 1990). Oaks are also found in Europe, Russia, China, Korea, Japan, and the Himalayan Mountains of India. Please see Appendix for a list of the oak species mentioned in this paper.

Very early in history man recognized the significance of oaks and included this tree in his religious, language, numbering, and chronology systems (Graves 1966). Native Americans also included the oak in their mythology (e.g., Buhner 1996) and in medicine as astringents, tonics, hemostatics, and antiseptics (Hutchens 1991).

Modern man has used the oak for a variety of purposes. Pioneers feed acorns to their livestock and ground the seed to make a coffee substitute. Besides firewood, oaks have been employed in many ways for housing, transportation, furniture, containment, industry, and entertainment (Walker 1990). A list of the uses of oak is found in Table 1.

Table 1. Man's uses for oak, besides firewood (developed from Walker 1990).

Use	Part and type of tree
Tannin acid for leather industry	Bark of chestnut oak
Fencing	Heartwood of post oak
Cork	Bark of Mediterranean county cork oak
Yellow dye	Inner bark of black oak
Roofing	Wood of shingle oak
Barrels for liquid, furniture	Wood of white oak
Wagon axles, boats	Wood of live oak
Saddles, oxbows, plows, baskets & buckets, tool handles, guitars, telephone poles, oil tanks	Wood of Oregon white oak
Railroad ties, mine shafts, barrels for solids, furniture, caskets, tool handles, bridges, fences, pallets, BBQ charcoal, chemical industry	Wood of red oak

Definition and Brief History of Allelopathy

It has been suggested *Quercus* sp. may exert an allelopathic effect on forest ecosystems. Molisch (1937) first used the term "allelopathy" to represent biochemical interactions between all plants including microorganisms. These interactions include inhibition and stimulation. Rice, in his second edition of Allelopathy (1984), returns to Molisch's definition of allelopathy and discusses the importance of separating allelopathy (involving the addition of a chemical to the environment) from competition (the reduction or elimination of a resource as water, light, food, or minerals from the environment required by neighboring plants). Rice also mentions the effects of the chemical released can be direct or indirect. Rice uses Muller's (1969) suggestion that the term "interference" includes both allelopathy and competition, as it is difficult to separate them in scientific studies, even today (Rice 1984, p. 1-2). In the strictest definition of allelopathy only plant-to-plant or plant-to-microorganism interactions are considered. A few studies on oak-to-insect relations will be included in this paper.

Allelopathy has been observed as early as 300 BC by Theophrastus as the effect of chickpea (*Cicer arietinum*) crops on soil and weeds (cited by Rice 1984, p. 2). In more modern times the first scientist to note the possible cause of allelopathy as crop exudates was DeCandolle in 1832.

He suggested a plausible solution of crop rotation. An in-depth history of the observation and early study of allelopathy can be found in Rice (1984).

Controversy about Allelopathy
There exists in the scientific community a debate as to whether allelopathy is a real (and testable) phenomenon or is an artifact resulting from the interaction of biotic and abiotic factors. Rice in his Preface to first edition of Allelopathy (1974) states, "The wide acceptance by ecologists of allelopathy as an important ecological phenomenon has occurred only within the past ten years." However, Harborne (1993) summarizes the debate on the existence of allelopathy as a distinct ecological process by citing Harper (1977) with the view allelopathy cannot be separated from other interactions such as competition (Harborne 1993, p. 245). Harborne continues by stating in consideration of the wide variety of toxic plant chemicals known today, it would be surprising if the chemical effect of allelopathy did not exist. Einhellig (1989, 1999) accepts the existence of allelochemicals but presents multiple chemicals, acting in an environment with abiotic (moisture, heat, light, nutrient deficiencies, soil organics) and biotic (disease, herbivores, competition, pollution) factors, can have an integrated effect greater than one chemical alone.

A second controversy in the scientific community involves whether allelochemicals in soils could exist at concentrations effective against other plants. Schmidt and Ley (1999) present the view that microorganisms degrade most allelochemicals before phytotoxic levels are reached. Soil complexing and sorption, combined with slow diffusion rates, also aid in deactivating allelochemicals. Kholdebarin and Oertli (1992a, 1992b) conducted a pair of studies using seed powder from *Quercus borealis*, *Q. robur,* and *Q. petraea* to investigate allelopathy on nitrogen transformations. From their results they concluded low nitrification rates were related to chemical nitrogen fixation and microbial immobilization, not biological inhibition by allelopathic chemicals from the oaks. Nitrite oxidation was also attributed to non-allelopathic causes. Many other scientists have shown direct or indirect proof of allelochemical reactions (for reviews see Rice 1984, Harborne 1993), and those involved with oaks will be presented here.

Practical Applications of Allelopathy Research
In some cases, allelopathy is an incorrect label for other complex interactions, but in instances where it is proven real, allelopathy may be used to further soil and plant science. Practical applications for allelopathic research include soil fertility and weed management, insect pest and nematode management, and plant growth regulation (Narwal 2000, Putnam and Weston 1986). Soil fertility and weed management science investigates crop rotation, biological nitrogen fixation, intercropping, cover crops and natural herbicides, use of organic waste as mulch, reforestation/revegetation, and tree farming and tree litter. Insect pest and nematode management include crop rotation, intercropping, insect resistance, insecticide allelochemicals, disease management, and plant material and oil nematocides. Plant growth regulation research covers growth retardation, nutrient absorption, flower induction, premature aging or senescence, delayed seed decay, and increase germination and biomass.

Oaks and the Study of Ecology
Early in ecological thought, oaks were acknowledged as a climax species in succession (Ricklefs 1976). Currently, climax theory is challenged and the concept of a continuum of species changes

in communities is being evaluated. However, oaks play an important part in changing natural systems and the development of ecological theory, particularly in the fields of succession and allelopathy.

A study of nitrogen cycling by Smith and coworkers (1968) began with the hypothesis as ecological succession advances in old field and forest systems, nitrification is inhibited. The ecosystems studied included a tall grass prairie, an oak-pine forest (*Quercus stellata-Pinus echinata*), and a post oak-blackjack oak forest (*Q. stellata-Q. marilandica*). Nine sites were chosen to represent the first stage of succession (1-2 years after abandonment from cultivation), the second stage (6-25 years after abandonment), and the climax stage. Soil samples were analyzed for ammonium and nitrate. Ammonium was the lowest in the first succession stage, intermediate in the second stage, and highest in the climax stage. The reverse trend was true for nitrate. The highest nitrate levels were measured in the first stage of succession, intermediate concentrations in the second stage, and lowest amounts in the climax stage. These trends were generally consistent for each of the three ecosystems studied. Bacteria involved in the nitrogen cycle by converting ammonium to nitrate were counted. Populations of two nitrifying bacteria, *Nitrosomonas* and *Nitrobacter*, were highest in the first stage, intermediate in the second stage, and lowest in the climax stage of succession. These results lead to the concept that some factor or combination of factors were diminishing the nitrifying bacteria population as succession progressed, thus slowing the conversion rate of ammonium to nitrate.

Research continued at the site. Soil texture, pH, and organic carbon resources were shown not to be factors influencing the decaying nitrification rate with succession (Rice and Pancholy 1972). The species in the climax forests were oaks and pines, both types of trees that repress nitrification. As the oak and pine densities increased, there was a corresponding nitrification decrease. The next research by Rice and Pancholy (1973) investigated the presence of tannins and their decomposition by-products of the topsoil of the second and climax stage sites. Condensed tannins were found in the upper 15 cm of the soil, with the highest concentrations in the climax sites. Compounds produced from the degradation of hydrolyzable tannins were also detected (gallic and ellagic acids). In bioassays with *Nitrosomonas*, condensed tannins, hydrolyzable tannins, ellagic acid, gallic acid, digallic acid, and commercial tannic acid all inhibited nitrification. The inhibition occurred at lower concentrations than those found in the topsoil. From the studies presented here, the original hypothesis was supported. As ecological succession advances in old field and forest systems, nitrification is inhibited. The source of the inhibition is chemical compounds produced by the oak and pine trees. Hydrolyzable tannins found in *Quercus marilandica, Q. stellata*, and *Q. velutina* reduced nitrification by soil microorganisms. Further research by Rice and Pancholy (1974) discovered the three aforementioned species of oak produced scopolin and in tests, scopolin inhibits nitrifying bacteria.

After examining resource availability, light, minerals, acidity, and moisture were excluded as causes for the lack of vegetation under four species of trees in a Missouri bottomland forest (Lodhi 1976). The four types of trees were *Quercus alba* (white oak), *Q. borealis* (northern red oak), *Platanus occidentalis* (sycamore), and *Celtis occidentalis* (rough-leaved hackberry). Bioassays were performed using leaf leachates, decaying leaves, and soil collected from under the four trees. Significant reductions in seed germination and radicle and seedling growth of local understory species were recorded. Digallic, ellagic, and gallic acids, and scopolin were detected in the soil beneath the oaks in January and April. Lodhi (1978) related the concentrations of toxins in the soil directly to litter biomass and decay rate. Toxicity pertained to the chemical nature of the compounds (free or bound), and solubility in water. Red oak leaf toxins exist in free form, easily leached into the soil, and were more inhibitory in January than in April (Lodhi 1978). Oak trees lose their leaves in autumn, approximately November, in southern Missouri (R.A. Wilson, personal communication). White oak leaves have bound toxins, and had greater detrimental effects in April than in January. Bound toxins required hydrolysis in the laboratory or degradation in the field before release into the local environment. The toxins were implicated in the allelopathic effect of the oaks on the understory plants (Lodhi 1978).

From these few examples briefly explained here, one can see the significance of oaks and allelopathy in natural systems and ecological thought. A summary of allelochemical cycling, complete with diagrams, can be found in Reigosa et al. (2000). Additional research is needed to gain a clear understanding of the exact role of allelochemicals in ecology (Attiwill and Adams 1993, Seigler 1996). A survey of allelopathic and other chemical effects of *Quercus* sp. in different ecosystems and in laboratory experiments with bioassays and chemical analyses, and allelopathy exerted by other plants on oak germination and growth will be reviewed in this paper.

OAK ALLELOPATHY

Numerous scientific studies have been completed on oak allelopathy in which the oak trees produce one or more chemicals detrimental to the germination and growth of other species. Tree components, litter, soil under the trees, leachates, and extractions have been tested on different tree species, local herbaceous plants and grasses, and crops in this research. In a few instances, a negative effect was not observed, or was confounded by other interactions from biotic and abiotic factors. Chemicals isolated from oak species were investigated with bioassay testing to determine their role in allelopathy. All of this research combined increases our understanding of allelopathy by oaks.

Oak Allelopathy on Endemic Species

An early study of oak allelopathy was conducted by Hook and Stubbs (1967). In a sparsely wooded, bottomland hardwood forest little understory vegetation grows under three species of oak, *Quercus falcata* var. *pagodaefolia* (cherrybark oak), *Q. michauxii* (swamp chestnut oak), and *Q. shumardii* (Shumard oak). Sunlight and water limitations were eliminated as possible causes for the vegetation deficiencies. Sparse plant densities were more prevalent in low, wet areas. An allelopathic effect from the oaks was proposed as the reason for the minimal understory plant density.

In a germination and growth study, *Quercus falcata* var. *pagodaefolia* (cherrybark oak) and *Liquidambar styraciflua* (sweetgum) were sprouted in soil taken from under the oak. Both seed germination and seedling growth were inhibited. In the next part of the study fresh, whole leaves of the oak were rinsed with water. Sweetgum seedling growth was reduced in the presence of the leaf leachate water. The rinsing of the oak leaves with water mimicked the rain on the leaves in the forest, and it was postulated a toxic leachate from the leaves (salicylic acid) was reducing the understory growth (DeBell 1971).

Frei and Dodson (1972) examined the relationship between five species of oaks and epiphyte orchids in a Mexican cloud forest. There were no orchids growing on *Quercus magnoliafolia*, and few orchids on *Q. penuncularis* and *Q. scytophylla*. However, on *Q. vicentensis* and *Q. castanea* the orchids were quite common. Frei and Dodson discovered the bark of the first three oak species was toxic or inhibitory to orchid seed germination and growth. Chemical analyses of the bark of the five species revealed ellagic acid and possibly other gallic acid derivatives in *Q. magnoliafolia,* and condensed tannins in the bark of the other four species. Combinations of gallic and tannic acids, or ellagic and tannic acids proved to be toxic to the orchids. The orchids only grew on oak species producing few toxins.

In the upland forests of central Oklahoma two species of oak are common, *Quercus stellata* (post oak) and *Q. marilandica* (blackjack oak). McPherson and Thompson (1972) investigated the suppression of the understory in this forest type with a set of field experiments on litter removal, root exclusion, post-burn herb growth, soil moisture, and bioassays. The seeds tested in the bioassays were from local weeds, herbaceous understory plants, and lettuce. In their findings McPherson and Thompson stated suppression is real, competition for light is inconsequential, and competition for moisture during spring was minimal. Litter had a mechanical effect on the seedlings rather than an allelopathic one. They separated the effects of intact roots from those of litter and suggested oak roots have an allelopathic influence on the seedlings. The green leaf leachate was surmised to have allelochemicals as it reduced seedling growth, but not seed germination. McPherson and Thompson mentioned the effects of allelopathic chemicals depend on the specific species of oaks and understory plants, and vary in time and space with the influence of litter and the competition factors of light and moisture.

Kolesnichenko (1976), as cited by Roshchina and Roshchina (1999), examined volatile and water-soluble allelochemicals from oak tree roots, and conducted growth studies of the effects on photosynthesis and phosphorus assimilation. Kolesnichenko tested *Quercus robur* (common oak) on other trees and woody plants, and composed the following list of species negatively affected by the oak: *Fraxinus pubescens, Pinus sylvestris, Cotinus coggygri, Populus tremula, Populus deltoides, Robinia pseudoacacia, Ulmus* sp., and *Acer negundo.*

A series of laboratory and greenhouse experiments by Harrington (1987) demonstrated the presence of allelopathic chemicals from *Quercus gambelii* (Gambel oak). These substances did not stop germination of *Pinus ponderosa* (Ponderosa pine) seeds, but delayed germination and slowed radicle growth. Harrington addressed the differences between laboratory and field conditions, and the influence of temperature, rainfall, leachate concentration, canopy coverage, and soil conditions on the severity of the allelopathic reactions. He also briefly discusses the interaction of competition and allelopathic substances.

The Himalayan Mountains of India have oaks. In a summary of his work since 1979, Melkania (1992) chose six allelopathic species including two oaks, *Quercus leucotrichophora* and *Q. floribunda*, and examined plant undergrowth, soil and light characteristics, and allelopathic agents of leachates from plant parts and soil. Bioassays were tested with *Lepidium virginicum* and *Lolium perenne*. Of the six species considered, *Q. floribunda* had the highest understory species richness (39), and the highest soil pH. *Q. leucotrichophora* had the second-to-last species richness (20). Although the six species examined had 12 understory plants in common, the biomass of each of the understory species was different under each tree species. This was true even between the two oaks. When bioassayed on *Lepidium virginicum* both oaks had the most inhibitory reactions from leaf litter, wood litter, and soil. In tests with *Lolium perenne*, *Q. leucotrichophora* showed the most inhibition from leaf and wood litter and soil. However, *Q. floribunda* expressed the highest inhibition with extracts from leaf litter, soil, and young developing leaves. Melkania mentions litter was more inhibitory than soil, young leaves, old leaves, and drip water (simulated rain dripping from the leaves). Young leaves were more toxic than old leaves, attributed to the degradation and dilution of allelochemicals. There was a difference of effects on the two bioassay species and Melkania suggested this was an example of selective allelopathic effects.

Oak Allelopathy on Crop and Forage Species

Rizvi et al. (1999) noted in the business of agroforestry (the science of growing agricultural crops with forest species), most of the woody species have allelopathic effects on the food and fodder crops. More research is needed to understand and develop compatible companion crops with built-in pest control, better yields and nutrition, and sustainability. In this section, examples of oak allelopathy on crops and forage will be presented.

In Costa Rica, *Quercus eugeniaefolia* grows in pure stands with very few understory plants. However, the resources of water, light, minerals, open space, and bare soil are plentiful and other parts of the forest are densely vegetated. By testing aqueous extracts of green and freshly fallen leaves of the oak, Gliessman (1978) observed a toxic effect on cucumber seedlings. He determined the toxin was produced in the green leaves and was most effective during the dry season. Analytical research identified phenolics in the top 5 cm of the soil beneath the oaks. Allelopathy was suggested as the cause of oak dominance in stands.

Matizha and Dahl (1991) performed a laboratory study using leaf litter from *Quercus harvardii* Rydb. (sand shinnery oak) on a forage species, *Eragrostis curvula* (weeping lovegrass). The forage grass is an imported species planted in native shinnery oak range in western Texas to feed cattle. Extracts from oak leaf residue reduced shoot root length by 92%, but did not affect germination or shoot growth. Phytotoxic plant residues were implicated. It was recommended specific soil preparation will be needed to grow weeping lovegrass in shinnery oak range. An early study by Murphy and Crampton (1964) investigated oak effects on forage species in California. Growth of forage increased with the removal of *Quercus douglasii* (blue oak) and it was concluded the oaks had a negative effect on forage productivity.

Using the powdered leaves of five oak species, Kil (1999) tested the germination and growth of lettuce in petri dishes. The five species are *Quercus serrata* Thunb., *Q. mongolica* Fisch., *Q. aliena* Bl., *Q. variabilis* Bl., and *Q. acutissima* Carruth. In the results, lettuce seed germination was significantly reduced at the application level of 20 g leaf powder per dish by all species of oak, and at 10 g leaf powder per dish was significantly decreased by *Q. acutissima* Carruth. In the seedling growth study, only *Q. aliena* Bl. significantly reduced the seedling weight, and only at the 20 g leaf powder concentration.

Mitzutani (1999) noted wild grasses did not grow under single species stands or mixed forests of *Quercus mongolica* Fisch. var. *grosseserrata* and *Q. serrata* Murr. in Hokkaido, Japan. Allelopathy was suspected. Lettuce, green amaranth, wheat, and timothy grass were cultured for 30 days in soil taken from under the oaks. Growth was inhibited by 50-90% as compared to controls. A second set of soil samples was extracted and bioassayed with the four test species, resulting in similar seed germination and seedling growth inhibition. Mitzutani identified nine allelochemicals.

Aqueous extracts of dried fresh leaves, leaf liner, and flaked bark from *Quercus glauca* Thunb, and *Q. leucotrichophora* A. Camus was bioassayed on the three crops of wheat, mustard, and lentils (Bhatt and Chauhan 2000). Oak leaf litter and bark was added to soil with crop seeds. Germination and growth of crop seedlings was recorded. Soil from beneath the oaks in the forest was tested on the seedlings, and pigment and biomass was measured. In all situations, germination, growth, biomass, and pigment concentration were reduced.

An alley cropping system was used to examine the growth of maize in between rows of *Juglans nigra* (black walnut) and *Quercus rubra* (red oak) in a series of studies by Gillespie et al. (2000a, 2000b) and Jose et al. (2000). The main focus of the research was competition between the maize and the trees. Although allelopathic root exudes were noted for black walnut, the researchers concluded the levels of the allelochemicals in the soil were too low to have an effect. However, the scientists did not pursue an analogous study with the oaks, and summarized their results in terms of competition only. Two other studies examining *Quercus robur* (common oak) effects on soil also omitted considering allelopathic chemicals (Andersson 1991, Schottelndreier and Falkengren-Grerup 1999). Although pH, rhizosphere chemistry, and vegetation patterns were researched in the studies, oak leaf and bark leachates and root exudates were not included as possible influences in the soil.

Oak Allelopathy on Insect Species

Although the exact definition of allelopathy includes only plant-to-plant or plant-to-microorganism relationships, chemicals produced by oaks have negative effects on insects, ranging from feeding deterrents to death. In a few cases changes in post-damage biochemicals produced by the oaks were originally suspected to reduce herbivory have been shown ineffective in diminishing herbivore consumption.

Butterflies and moths in Britain feed on *Quercus robur* leaves in the spring, with high densities in May. This corresponds to the time when total tannins are low and condensed tannins are almost nonexistent in the leaves. Tannin concentrations increase from April to September as the leaves grow and age (Feeny and Bostock 1968). In mid-June, Lepidoptera stop feeding on the oaks, corresponding to the time when condensed tannins increase in the leaves. Tannins are feeding deterrents due to taste and toxicity (Feeny 1976). Other feeding deterrents are flavonoids. Flavonoids in *Quercus macrocarpa* (bur oak) restrict feeding by elm bark beetle (Norris 1977).

West (1985) studied the phenomenon of *Phyllonorycter* spp. larval death in the mines of *Quercus robur* leaves. After 25% of the leaf area covered by mines was removed, larval deaths reached 50-100% greater than controls. A strong negative correlation between damage and larval survival was revealed. As leaf damage increased, larval death increased also. West proposed damage-induced changes in the leaves affect herbivore population dynamics.

Tannins of *Quercus petraea* diffuse into the soil from the main lateral roots and tree trunk bark below the soil surface. Negative effects in the soil from the tannins were observed in the biological activity, especially among earthworms (Deschaseaux and Ponge 2001).

By removing some of the leaves from *Quercus emoryi* (Emory oak) and measuring the tannin and protein content of the primary and secondary leaves over time, Faeth (1992) examined biochemical changes induced by herbivory. It was believed that after herbivore defoliation, secondary leaves would express chemical changes to reduce the potential of further herbivore attack. Faeth revealed the secondary leaves had 2.5 times greater hydrolyzable tannins, lower condensed tannins, and higher protein concentrations than primary leaves, thus making the secondary leaves more palatable to herbivores. Similar results were found by Glyphis and Puttick (1989). Increased polyphenol levels in leaves of *Quercus coccifera* were not correlated with decreased herbivory by insects.

Oak Facilitation

In a few instances, oaks promote the germination and growth of vegetation in contrast to allelopathic effects discussed previously. In the California grassland, *Quercus agrifolia* (live oak) increased nutrient concentrations, organic matter, and soil infiltration rates beneath the canopy compared to the grassland (Parker and Muller 1982). An extensive study was conducted by Callaway et al. (1991) on facilitation and interference of *Quercus douglasii* (blue oak) on the productivity of understory species. Facilitation was noted for individual trees (positive trees) and was attributed to a canopy-mediated increase in soil nutrients by litterfall and throughfall. However, high biomass of lateral roots reduced facilitation, possibly by allelopathic root exudates. Dominance by each factor was observed in different locations. Kolesnichenko (1976), as cited by Roshchina and Roshchina (1999), examined volatile and water-soluble allelochemicals from oak tree roots, and conducted growth studies on their effects on photosynthesis and phosphorus assimilation. Kolesnichenko tested different trees and woody plants with *Quercus robur* (common oak) and found a few species expressing positive effects by growth with the oak: *Acer tataricum, Acer platanoides, Tilia cordata, Corylus avellana, Gleditchia* sp., and *Lonicera* sp. Oak-dominated forest litter generally improved understory vegetation productivity, although the effect was species specific and some allelopathic effects were observed (Monk and Gabrielson 1985)

A small number of studies found no effect, positive or negative, of oaks on bioassay organisms. *Quercus robur* (common oak) had no toxicity in trials with proteolytic microorganisms (Souto et al. 2001). Soil was amended with air-dried and ground *Quercus rubra* (red oak) leaves and no allelopathic inhibition on the nodulation or N-2-fixation of soybeans was observed (Heckman and Kluchinski 1995). Kolesnichenko (1976), as cited by Roshchina and Roshchina (1999), examined volatile and water-soluble allelochemicals from oak tree roots, and conducted growth studies on photosynthesis and phosphorus assimilation. Kolesnichenko tested different trees with *Quercus robur* (common oak) and found a few species expressing neutral effects when exposed to oak: *Acer compestre, Juglans regia,* and *Picea excelsa.*

Non-Allelopathic Effects and Interactions of Oaks

A few scientists searched for evidence of allelopathy of oaks and credited the results to factors other than allelopathy. Alternatively, an interaction of one or more components with allelopathy has been suggested in a different set of studies.

Kholdebarin and Oertli (1992a) focused their efforts on determining whether polyphenolic substances in seed powder from *Quercus borealis, Q. robur,* and *Q. petraea* act as allelopathic agents. In the system they studied, the decreased nitrification rate was attributed to chemical nitrogen fixation and microbial immobilization, not biological inhibition by allelopathy. The corresponding research on nitrite oxidation with *Q. robur* delivered similar results of non-allelopathic effects (Kholdebarin and Oertli 1992b). Abiotic processes of fixation or volatilization were implicated in the rapid conversion of nitrite to nitrate.

Allelopathy can be but one component in an ecological system and the interactions with other physical and chemical resources may be difficult to separate. In a review paper by Vila and Sardans (1999), allelopathy is treated as a factor affecting plant competition. Both *Pinus halepensis* and *Quercus ilex* emit terpenes, although oaks release terpenes at lower rates or concentrations than pines. In the presence of the pine oak growth was reduced, but Penuelas and Llusia (1998) could not conclude the reason was an allelopathic effect of the terpenes, or competition or interference. Reigosa et al. (2000) combine the phytotoxicity of *Quercus robur* with pH and relative humidity to explain the effects on soil microbial populations. In Barritt and Facelli's work (2001), the physical properties of oak-Eucalyptus (*Q. agrifolia-Eucalyptus obliqua*) litter together with their allelochemicals significantly affected the emergence of an introduced annual forb and a native grass. Melkania (1992) concluded the allelopathic effects of *Q. leucotrichophora* and *Q. floribunda* could not be separated from effects of litter biomass and light.

CHEMISTRY OF OAK ALLELOPATHY

A variety of chemicals isolated from oaks have been implicated as allelopathic agents (see Table 2). Tannins are some of the most important compounds. Allelopathic chemicals found in oak have a variety of structures ranging from phenolics, coumarins, salicylic acid, and even volatile organic compounds. Some of these chemicals have been mentioned previously. Therefore a short survey of allelopathic agents and their origins will be presented in this section.

In the flavonoid group of plant-produced chemicals are the tannins. Two types of tannins are present in oaks. Hydrolyzable tannins have a chemical structure consisting of a glucose molecule attached to a simple phenolic acid. Condensed tannins are more complex, with two or more hydroxyflavanol units bonded together. Tannins are astringent, and are thought to be feeding deterrents to herbivores (Harborne 1993, p. 142).

Table 2. A partial list of allelopathic chemicals in oaks.

3,4,5-trimethoxybenzoic acid	kaempferol
3,4-dihydrobenzoic acid	methanol
3,4-dimethoxybenzoic acid	monoterpenes
acetaldehyde	p-coumaric acid
acetic acid	p-hydroxybenzaldehyde
acetone	p-hydroxybenzoic acid
benzoic acid	pentagalloylglucose
C-10-benzenes	procyanidin
digallic acid	salicylic acid
ellagic acid	scopolin
ethanol	tannic acid, same as gallic acid
ferulic acid	tannins (hydrolyzable and condensed)
hexahydroxydiphenic acid	toluene
isoprene	vanillic acid

By trenching a clear-cut area and sealing the trench from roots with plastic sheeting in a *Quercus stellata*-*Q. marilandica* forest, Moleski (1976, as cited by Rice 1984) determined condensed tannins originated from oak roots and not from throughfall, stemflow, or leaching and decay of leaf litter. He also measured nitrate concentration and *Nitrosomonas* and *Nitrobacter* populations, and all were higher in the cleared area than in the surrounding forest. He supported the hypothesis of reduced nitrate amounts in the soil were a response of nitrification inhibition likely due to condensed tannins, plant uptake of nitrate, or both, and not from microclimate changes. Soil nitrate levels decreased during succession for two reasons: plant uptake and nitrification rate deceleration.

Szabo and Kevey (1997, as quoted by Kazinczi 1999), studied tannins from two species of oak, *Quercus cerris* and *Q. petraea*. Tannins were present in the leaves in concentrations of 94.5 mg g^{-1} and 47.9 mg g^{-1}, respectively, and contaminated the soil during leaf fall and decomposition. Szabo and Kevey determined tannin content depends on species of tree, season, location, and leaf age.

The next set of paper cited briefly show the broad range of chemicals, locations, and influences. Condensed tannins were located in the root cap, epidermal layer, and endodermis of oak. After exposure to ectomycorrhizal microorganisms the tannin concentration decreased in the root cap and epidermal layer. The microbes were unable to colonize because of the suberin in the outer cortex and endodermis. In the laboratory ectomycorrhizal fungi could use tannins and other polyphenolic chemicals (Tam and Griffiths 1993). Fisher (1980) identified coumarins and phenolics from oaks as the inhibiting factors of herbs and grasses, and Kuiters and Denneman (1987) isolated phenolic acids from soils, specifically benzoic acid from soil under *Quercus* sp. In the search for allelopathic agents, Mitzutani (1999) identified nine allelochemicals in soil under *Quercus mongolica* Fisch. var. *grosseserrata* and *Q. serrata* Murr.: 3,4-dihydrobenzoic acid; p-hydrobenzoic acid; 3,4,5-trimethoxybenzoic acid; 3,4-dimethoxybenzoic acid; vanillic acid; p-coumaric acid; ferulic acid; p-hydroxybenzaldehyde; and kaempferol. Three phenolic compounds from oaks were bioassayed for allelopathic effects on radish, lettuce, alfalfa, and komatsuna (Ohira and Yatagai 1994). Inhibition was recorded for coumarin, cinnamic acid, and benzoic acid for all tested species. The type of inhibition varied with the crop, another example of species specificity. Water dripping off of leaves of *Quercus falcata* in South Carolina was noted to restrict growth of groundcover under the trees. Salicylic acid was discovered in the leaf runoff, and in bioassay studies was determined to be toxic (Muller and Chou 1972). Holzinger et al. (2000) distinguished nine volatile organic compound types from *Quercus ilex* leaves during photosynthesis. They are methanol, acetaldehyde, ethanol, acetone, acetic acid, isoprene, monoterpenes, toluene, and C-10-benzenes.

ALLELOPATHY BY OTHER SPECIES ON OAKS

Oaks are one of many species exhibiting allelopathy. There are numerous studies of allelopathic chemicals from other species and the reactions of oaks to the chemicals. A short discussion of some of this research will be presented in this section.

Kolesnichenko (1976, as cited by Roshchina and Roshchina 1999), recorded *Pinus sylvestris* had a negative effect on *Quercus robur*, but *Larix decidua* had a positive effect. In a different study *Q. robur* was inhibited by the ash *Fraxinus excelsior* (Kolesnichenko and Aleikina 1976, as cited by Rice 1984). In the presence of ash roots, the soil minerals were not absorbed as efficiently by the oak roots than if the oak roots were grown with the same oak species. A laboratory study of mineral uptake revealed oak roots were inhibited by chemicals from the ash roots. The second effect of the ash roots on the oak roots was the effective reduction in the rate of protein synthesis by the oak roots. A second laboratory study showed oak root protein synthesis decreased in the presence of chemicals from ash roots.

Two studies with different fern species recognized an allelopathic effect from the ferns on *Quercus rubra* seedlings (Hanson and Dixon 1987, Smith and Vankat 1991). An indirect allelopathic effect by a grass on *Q. rubra* was presented by Timbal et al. (1990). The effect involved the change in the micorhhizal population of the oak roots. Goldenrod is allelopathic to red and white oak (Patel and Larson 1987).

Neutral and positive effects on oaks from other species have been recorded. In the Appalachian Mountains, *Rhododendron maximum* is known to be detrimental to tree seedling germination and survival. However in a field study, *Quercus rubra* suffered no significant negative effects when grown beneath *R. maximum* (Nilsen et al. 1999). Depending on the substrate in which the bacteria is grown, *Azospirillum brasilense* Cd. can have no effect or a positive effect on *Quercus ithaburansis* Decaisne. Fructose-grown bacteria have a neutral effect, and malate-grown bacteria improves oak seedling development (Zaady et al. 1993).

CONCLUSIONS

This review paper has summarized allelopathic effects of *Quercus* sp. (oaks) on other species of trees, plants, and insects. Researchers have used numerous tools and methods in the field and laboratory to investigate whether the phenomenon of oak allelopathy is real, the severity of the effects, and any modifications to the effects by physical, chemical, biological, and temporal factors. In this paper, evidence for the allelopathy of oaks has been presented. Allelopathy seems to be species specific for both the oak and the receptor species, and is seasonally dependent in a few cases. Additional research is needed to understand the exact role of oak allelochemicals in natural systems, the mechanisms controlling production and release of allelochemicals, and the separation of allelopathy from other processes such as competition. Practical applications include future use of allelochemical research in agricultural and soil science, weed and pest management, and plant growth regulation.

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Appendix. List of scientific names of oak species cited in this paper.

Quercus sp.
Q. acutissima Carruth.
Q. agrifolia
Q. alba
Q. aliena Bl.
Q. borealis
Q. castanea
Q. cerris
Q. coccifera
Q. douglasii
Q. emoryi
Q. eugeniaefolia
Q. falcata
Q. falcata var. *pagodaefolia*
Q. floribunda
Q. gambelii
Q. harvardii Rydb.
Q. ilex
Q. ithaburansis Decaisne
Q. leucotrichophora
Q. macrocarpa
Q. magnoliafolia
Q. marilandica
Q. michauxii
Q. mongolica Fisch.
Q. penuncularis
Q. petraea (Mattus.) Liebl.
Q. robur
Q. rubra
Q. scytophylla
Q. serrata Thunb.
Q. shumardii
Q. stellata
Q. suber
Q. variabilis Bl.
Q. velutina
Q. vicentensis
Q. virginiana

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Flood-Tolerant Trees

Flood-Tolerant Trees

Some trees are able to withstand flooding, recover, and resume normal functioning. This trait is of special concern to managers of recreation areas subject to flooding and land adjacent to multipurpose reservoirs, where water levels fluctuate. Native trees in river flood plains prove their adaptation, but trees around recently constructed flood-control reservoirs may not be capable of withstanding intermittent flooding. The flood-tolerant trait should be considered when selecting trees to save or to plant on such areas.

Flood tolerance varies with species. Investigators in different locations or using different study conditions may disagree on the days of flooding a species may survive, but they generally agree on the relative flood tolerance of a species. Black willow, green ash, and silver maple are considered to be relatively flood tolerant. Black cherry, blackjack oak, and post oak—species injured by considerably less flooding—are said to be intolerant.

Flood injuries also vary. Early symptoms include leaf-tip and stem twisting, red coloration, chlorosis, and leaf wilting. Dieback of roots and twigs and the formation of dead spots in the bark may follow, and if flooding continues the entire tree eventually dies. Some trees may not follow this pattern; leaf wilting can be followed directly by the death of the tree.

Recovery is relative. A logger who seeks a long, straight trunk with no lower branches or defects may find that a flood has destroyed a young tree's potential for producing quality lumber. A few inches of dieback to terminal leaders may result in vigorous growth of lateral branches and subsequent poor form. A park manager, however, may consider such a tree as being only slightly injured. A wildlife manager may consider the loss of a mast crop to be a serious loss, but the logger may see it as a minor one.

Trees often recover rapidly from slight injuries, such as twig dieback. With more severe injuries, recovery may take a year or longer. Reduction of vigor may render a tree unusually susceptible to adverse environmental con-

Which species are best suited for flood plains and reservoir areas?

By William L. Loucks

ditions. Until vigor is restored, such a tree is especially susceptible to insect and disease attacks, drought, and additional flooding.

Physiological responses and tolerance mechanisms of trees to flooding were studied extensively from the 1940s through the mid-1970s. These studies helped foresters understand the impact of flooding on trees and suggested future investigations, but the state of the art has not developed sufficiently to issue a precise statement on the adaptability of a species to a specific flooding situation. In fact, conclusions are often at variance.

Brunk and his coworkers (1975) reported that on two sites silver maple had considerable mortality after having been flooded for 120 days. In contrast, Bell and Johnson (1974) reported that silver maple showed no ill effects after a 189-day flood. Such apparent discrepancies are caused by the physiological responses of the tree as it interacts with environmental conditions. Since these interactions are not well understood, predictions of flood tolerance must be in general terms. A look at tree and flood characteristics indicates the complexity of interactions.

Trees

Various characteristics of a tree affect its flood tolerance.

Height—Tree height as compared to water depth is the most obvious. Investigators (Hall and Smith 1955, Hosner 1960) have shown that injury increases as water covers foliage. Some species that survive months standing in several feet of water may succumb in less than a month when foliage is completely covered. Few species can tolerate complete submersion during the growing season for as long as one month.

Vigor—The vigor of a tree at the time of flooding influences tolerance. Flood tolerance generally increases with the

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These trees survived a month with water over the soil surface.

Photographs by William L. Loucks

Recreation managers need to consider flood tolerance when selecting trees for flood-prone areas.

age of the tree, until it begins to lose vigor with overmaturity. Yeager (1949) observed that healthy, vigorous trees show the greatest resistance to flooding and saturated soil. Both the very small and the overmature classes show the greatest susceptibility. Insect and disease attacks and adverse soil conditions also affect vigor, as do excessively wet or dry soils or soils with poor permeability.

Roots—Survival and growth of flooded roots are indicative of a species' ability to adjust to long periods of floods. Some species maintain normal roots in an active or dormant condition. Others rely upon new secondary and adventitious roots that may form from the root collar or on the trunk near the water surface. Species unable to maintain normal roots or to grow new ones quickly die.

Recovery—Rate of recovery following drainage is a factor in tolerance. Trees need to build up food reserves for future stress conditions—flood, drought, insects, diseases—and young trees must produce height growth to get their foliage above flood levels. Environmental conditions often limit recovery. If the soil drains rapidly, and soil moisture is maintained near field capacity, the surviving root system will initiate new growth and recovery will be rapid. However, if the soil remains saturated, the root system may deteriorate. At the opposite extreme, if soils dry quickly because of drought conditions, adventitious roots may be of little benefit. The tree is then dependent upon survival of the secondary root system.

Variations—Little is known about tolerance variations within a species. Flood tolerance may well be an inherited trait that could explain the discrepancies in reports on survival.

Floods

Determining flood tolerance is complicated by the diverse characteristics of floods.

Season—Tolerance varies with the season. Deciduous trees suffer few adverse physiological effects in dormant season flooding. However, saplings may be injured by mechanical damage from ice. Such damage is usually limited, unless the water level changes. A higher water level may cause floating ice to scrape the bark. The author observed several acres of two- to four-inch-diameter saplings sheared off or uprooted by ice that became suspended on the trees when water receded.

Trees are most susceptible to flooding in late spring just after the first flush of growth. At that time food reserves have been so lowered that the trees are at a critical stage of development. New foliage must quickly replenish the food reserves. The timing of a spring flood influences species differently. Because silver maple flushes earlier than green ash, an early flood might be more injurious to silver maple and a later flood more injurious to green ash. After this critical period, tolerance increases with the season.

In some situations massive injury can result from fall flooding. In the fall of 1973, a flood at Tuttle Creek Lake in Manhattan, KS, completely submerged numerous trees for an extended period. Some of these species had survived floods of similar duration in early spring and summer yet suffered extensive damage from the fall flood. The injury pattern differed from that of the earlier floods. Twig mortality normally

"Some trees tolerate continuous flooding longer than they can intermittent."

starts at the tip and progresses towards the trunk. Normal twig dieback occurred but, in addition, dead spots the size of a quarter appeared on the larger branches and trunks. The spots rapidly increased in size until all of the tissue above ground was dead. Apparently the flood had interfered with the normal hardening process, and since the temperature was below freezing when the water receded, the nonhardened tissue was killed.

Duration—The longer trees are exposed to flooding, the greater the injury. Few woody species can tolerate continuous flooding. Some may survive for a decade or longer with several feet of water over the root system, but most trees can withstand only 1-4 months with water over the soil surface.

Short periods of flooding during the growing season do not result in serious injury to most trees, even though the total length equals one continuous lethal period. Alternately flooding and draining an area may increase the growth of some species. However, if the flooding is frequent enough to keep the soil saturated or to prevent recovery from previous flooding, the injuries will accumulate and serious damage may occur.

Frequent floods of even short duration may prevent establishment of regeneration. New seedlings often are demanding of conditions for establishment; many have low tolerance to flooding.

Some trees tolerate continuous flooding longer than they can intermittent. Yeager found no significant damage to eastern cottonwood in the first year of continuous flooding. Most trees died in the second year, and some survived until the fifth year. In studying the effect of intermittent flooding at Kentucky Reservoir in Springville, TN, Hall and Smith found that the lowest healthy cottonwood occurred at an elevation flooded only 35 percent of the growing season over an eight-year period.

During continuous flooding, adventitious roots develop near the water line and assume, at least partially, the role of the original root system. Some species, supported by adventitious roots, function for an extended period. When the water recedes, adventitious roots are left above the soil level, dry out, and die. If the original roots have been injured, the tree may be left without an adequate root system. When selecting trees to be planted on flood plains, land managers should pay special attention to studies of tolerance to intermittent flooding. The results of these studies will be more indicative of what may be expected.

Water level—The depth of water influences flood tolerance. Three water levels are critical: saturated soil with the soil surface wet but not covered by water; water covering the soil surface but not the foliage of a tree; and water covering the foliage. The mortality rate is less for trees in saturated soils than for those with water covering the soil. After water covers the soil, the depth has little significance until the lower foliage is covered. Although growth usually continues on trees in the first two categories, at least for some indefinite period, growth stops when the foliage is covered. Tolerance to submersion is much less than tolerance to lesser depths of water.

Sedimentation—Deep deposits of soil left by flood water may injure trees. Sedimentation can cause decreased growth rates or even mortality in some

"Healthy, vigorous trees show the greatest resistance to flooding and saturated soil."

Two years after being nearly submerged from late September to mid-November, this tree is shedding bark from spots where the cambium was killed by freezing temperatures as the water receded. Fall flooding may interrupt the normal hardening process in a tree and increase its susceptibility to early frost.

species. Single deposits of silt or sand as shallow as three inches may seal over and smother the roots. Deposits of finer soil particles, however, tend to crack upon drying, allowing oxygen to reach the root system (Broadfoot and Williston 1973, Kozlowski 1986). Species vary in tolerance to sedimentation, but all seedlings are susceptible.

Temperature and oxygen—The temperature and oxygen content of flood waters also influence tree survival. Water with low temperature and high oxygen content is less injurious. Although such characteristics are of interest to researchers, they are of little use to a land manager in predicting the adaptability of a species to potential floods.

Mechanical injuries—An often overlooked aspect of flood damage is mechanical injury caused by current, wave action, and floating debris. Current and wave action may be especially damaging to young tree plantings. Trunks may be bent or broken and backfill material washed out of the planting hole. Floating debris can injure both small and large trees.

Specific Tolerance

Table 1 shows the relative tolerance of various trees to intermittent floods. Tolerant species withstand at least 80 days of saturated soil during the growing season without injury. Their roots may remain active or become dormant during floods, and secondary and adventitious roots quickly develop. Intermediately tolerant species withstand at least 30 days. Their roots may deteriorate, but adventitious roots quickly develop. Intolerant species will suffer considerable injury when in saturated soil for longer than 30 days during the growing season. Their roots die, and they are unable to grow adventitious roots.

Ratings are based on observations by the author in the Central Plains and Midwest and on references on tree tolerance to flooding by geographic region, such as the review by Teskey and Hinckley (1977). Tolerance expressed in days assumes that the trees have average vigor prior to flooding and that environmental conditions are conducive to rapid recovery. Trees with low vigor may be severely injured or killed. Trees with exceptional vigor may withstand longer periods without injury. ■

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Table 1. Relative tolerance of various trees to intermittent flooding during the growing season.

Species	Common name	Tolerant	Intermediately tolerant	Intolerant
Acer negundo	boxelder		X	
Acer saccharinum	silver maple	X		
Betula nigra	river birch		X	
Carya cordiformis	bitternut hickory			X
Carya illinoensis	pecan		X	
Carya ovata	shagbark hickory		X	
Celtis occidentalis	hackberry		X	
Cercis canadensis	eastern redbud		X	
Diospyros virginiana	common persimmon		X	
Fraxinus pennsylvanica	green ash	X		
Gleditsia triacanthos	honeylocust		X	
Ilex decidua	deciduous holly	X		
Juglans nigra	black walnut			X
Juniperus virginiana	eastern redcedar			X
Maclura pomifera	Osage-orange		X	
Morus rubra	red mulberry		X	
Platanus occidentalis	American sycamore	X		
Populus deltoides var. *deltoides*	eastern cottonwood	X		
Prunus serotina	black cherry			X
Quercus lyrata	overcup oak	X		
Quercus macrocarpa	bur oak		X	
Quercus marilandica	blackjack oak			X
Quercus muehlenbergii	chinkapin oak			X
Quercus palustris	pin oak	X		
Quercus rubra	northern red oak			X
Quercus stellata	post oak			X
Rhamnus spp.	buckthorn			X
Robinia pseudoacacia	black locust			X
Salix nigra	black willow	X		
Taxodium distichum	baldcypress	X		
Ulmus americana	American elm		X	

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Waterlogging Tolerance of Lowland Tree Species of the South

Waterlogging Tolerance of Lowland Tree Species of the South[1]

Donal D. Hook

ABSTRACT. Many tree species in the South are adapted to periodic and/or prolonged soil waterlogging. However, artificial disturbances of natural water regimes sometimes cause flooding to occur at abnormal times or the flood water to be deeper and waterlogging longer in duration than is normal. As a consequence, it is difficult for forest managers to predict how a species will respond to such disturbances or to decide how to manage an area where the water regime has been significantly altered. This paper discusses some factors which influence the waterlogging tolerance of tree species, compiles several classification systems, indicates the pertinent literature, and offers a new relative waterlogging-tolerance rating for southern lowland tree species.

The area of forested wetlands is decreasing rapidly in the Mississippi River Alluvial Plain (Turner et al. 1981), but is essentially stable in the Southeast (Langdon et al. 1981). Wetlands remaining are subjected to frequent and repeated disturbances that alter their natural water regimes. They are now used for secondary treated sewage disposal areas and storage for excessive storm waters in coastal areas. Also, they have been and are being altered by drainage, dams, and other construction projects and uses. The pressure of the combined uses, the shrinking resource, and alterations in water regimes means that more knowledge about the silvical characteristics of wetland trees is needed to meet management and protection challenges on wetland sites. For example: What impact will permanently or temporarily raising the water table have on the survival of tree species in a forest community? What species should be favored in existing stands or in regenerating new stands on sites where the natural drainage has been altered? These are difficult questions to answer because we lack sufficient knowledge about the response of tree species to soil waterlogging (flooding). Further, the existing literature is scattered and there is a divergence of opinion among researchers.

Due to differences in microclimate, soils, internal drainage, and topography, identical soil waterlogging conditions do not exist on wetland sites even over relatively small areas, much less over the entire South. A species' response to soil waterlogging may vary over its range due to such factors and to inherent genetic variation. Thus, it is difficult to compare all tree species over their entire range on a common soil waterlogging-tolerance scale. As a compromise, the approach here has been to review the literature on the subject, compile the tolerance-rating systems from several publications and to comment on individual species traits where known. Using this background and taking into account recent advancements in understanding the physiological adaptive mechanisms of trees to soil waterlogging, a new relative flood tolerance rating using 5 categories instead of 4 was developed. All of the information has been condensed into Table 1 to aid the user in comparing the various rating systems and in deciding which tolerance rating appears most applicable for his situation.

Waterlogging tolerance refers to a species' ability, from seedling stage to maturity, to tolerate soil saturation or inundation during the growing season. It is used in the context of a species' population in general and not for an individual tree. Waterlogging is used synonomously with flooding in this paper. The former is preferred because it identifies the primary problem, *i.e.* soil waterlogging which occurs whether the soil is flooded or only saturated with water.

SPECIES AND SITE FACTORS

Species factors are variations within and among species, vigor, age, and size. Site factors include soil type and fertility, and frequency, duration, time and state (stagnant or moving water) of inundation or soil saturation.

Species

Although most tree species exhibit some degree of waterlogging tolerance, only a few species can live and thrive in a swamp (wetland) habitat;

[1] Adapted (with permission) from the Section on Forest Ecology (D. D. Hook, senior author) *in* Forestry Handbook, second edition, Karl F. Wenger, ed., John Wiley and Sons, New York, 1984.

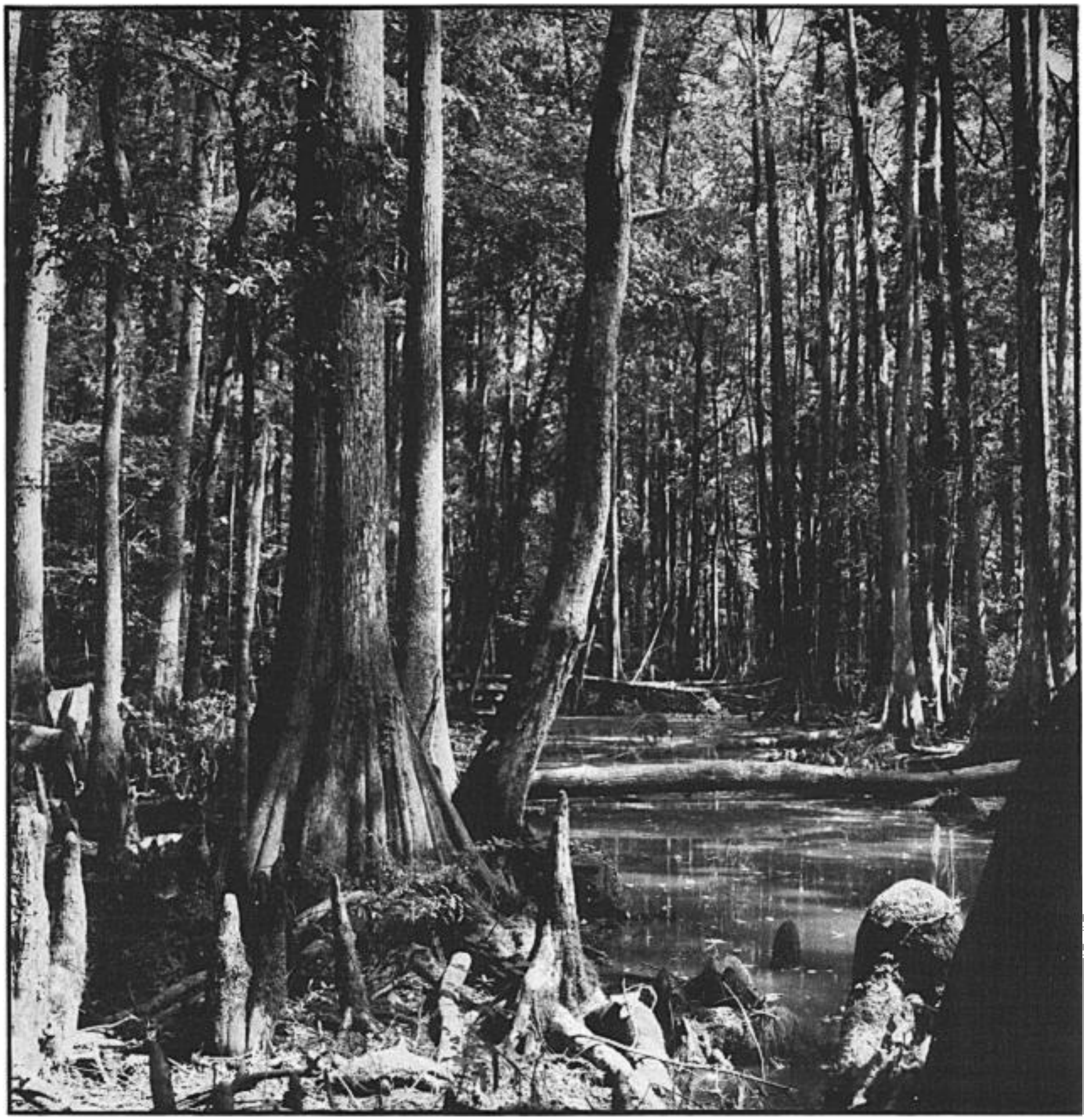

Figure 1. A wetland site along Wiskenboo Creek on the Francis Marion National Forest of South Carolina. Baldcypress and swamp tupelo are the common wetland species. USDA Forest Service Photo.

baldcypress, water tupelo, and swamp tupelo are best known for this trait. Cypress and tupelos will grow on moist well-drained sites, but on such sites they will not compete successfully with oaks, ashes, sweetgum, and other mesic-site species.

A few species do not tolerate waterlogging even for short durations. Yellow-poplar typifies this group. Although dormant yellow-poplar seedlings can withstand considerable flooding, only 2 to 4 days of partial inundation during the growing season can cause high mortality of seedlings of this species (McAlpine 1961).

Between these extremes lies a large group of tree species with varying degrees of waterlogging tolerance. By utilizing the results of physiological and empirical field studies and field observations they can be separated into 2 or 3 groups of waterlogging tolerance (Table 1), although there is some disagreement among researchers for a few species.

Summary Table follows. Text continues on p. 144.

Table 1. A summary of 3 previously published waterlogging-tolerance ratings, a frequency-occurrence scheme, references, and comments on individual species' traits; and a waterlogging-tolerance rating developed by the author using 5 groups of relative tolerance.

Species	Teskey & Hinckley 1977	Whitlow & Harris[1] 1979	McKnight, Hook, Langdon & Johnson 1981	Wharton, Kitchens, & Sipe 1982 Floodplain zones[2] II	III	IV	V	Other references	Comments	Final waterlogging-tolerance rating group
Cephalanthus occidentalis common buttonbush	Very tolerant	Very tolerant	Tolerant		A[3]			Green 1947; Hall and Smith 1955; Hosner 1969; Yeager 1949	Both mature trees and seedlings tolerate deep & prolonged flooding. Seed germinated better when submerged.	Most tolerant[4]
Forestiera acuminata swamp-privet	Very tolerant	Very tolerant	Tolerant	CU				Green 1947; Hosner 1960; Yeager 1949	Less tolerant to deep flooding than buttonbush. 15% survived 2555 days of continuous flooding.	Most tolerant
Fraxinus caroliniana Carolina ash	Not listed	Not listed	Tolerant	A				Harms et al. 1980; Klawitter 1962	Frequent associate of swamp tupelo and water tupelo in SE swamps. Better seed germination under submerged than saturated soil.	Most tolerant
Fraxinus profunda pumpkin ash	Intermediately tolerant	Not listed	Tolerant	C				Harms et al. 1980; Hosner 1962	Tolerates deep flooding. Better growth in saturated than field-capacity soil. Seed remained viable in submerged soil for months.	Most tolerant
Nyssa aquatica water tupelo	Very tolerant	Very tolerant	Tolerant	A				Briscoe 1957; Dickson et al. 1965; Hall and Smith 1955; Harms 1973; Hosner 1962; Hook et al. 1971; Hook and Brown 1973; Keeley 1979; Kennedy 1970; Shunk 1939	Tolerates deep flooding. Sensitive to soil fertility and relatively insensitive to flood level and nature of flood water in alluvial soil; more sensitive to flooding in nonalluvial soils. Does not tolerate complete submergence as well as green ash. Sensitive to silt laden waters. Develops *adventitious* and *soil water roots*. Roots oxidize rhizosphere.	Most tolerant
Nyssa sylvatica var. *biflora* swamp tupelo	Very tolerant	Not listed	Tolerant	A				Briscoe 1957; Hall and Smith 1955; Harms 1973; Harms et al. 1980; Hook et al. 1970a, 1970b and 1971; Keeley 1979	Tolerates prolonged shallow flooding. More sensitive to flood level than soil type in comparison to water tupelo. Occurs in shallow swamps or periphery of deep swamps. Shows variation in flood tolerance in relation to flooding frequency of parent population. Develops *adventitious* and *soil water roots*. Roots oxidize rhizosphere.	Most tolerant
Planera aquatica water elm	Tolerant	Very tolerant	Tolerant	A				Hall and Smith 1955	Cannot tolerate flooding more than 50% of growing season.	Most tolerant
Salix nigra black willow	Very tolerant	Very tolerant	Tolerant		A			Green 1947; Hall and Smith 1955; Hosner 1957, 1958, 1962; Pereira and Kozlowski 1977; Yeager 1949	Tolerant to moderate lengths of inundation but mature trees died after 3 yrs. Can survive moderate siltation. Seeding height growth better in saturated than field-capacity soils. Seed germinated in water. Apparently develops *adventitious* and *soil water roots*. Roots probably oxidize rhizosphere.	Most tolerant

Table 1. Summary: Waterlogging-Tolerance Ratings—contin.

Species	Teskey & Hinckley 1977	Whitlow & Harris[1] 1979	McKnight, Hook, Langdon & Johnson 1981	Wharton, Kitchens, & Sipe 1982 Floodplain zones[2] II	III	IV	V	Other references	Comments	Final waterlogging-tolerance rating group
Taxodium distichum baldcypress	Very tolerant	Very tolerant	Tolerant	A				Applequist 1959; Bedinger 1971; Demaree 1932; Hall et al. 1946; Harms et al. 1980; Hook 1980; Hosner 1962; Langdon 1965; Louckes & Keen 1973; Matoon 1915; Montz and Cherubini 1973	Tolerates deep flooding even in lakes but mortality may increase after 15–25 yrs. or with sudden and sustained deep flooding. Grows best in flooded soils. Also grows along estuaries but apparently will not tolerate salinities above 0.89% salt. Develops *adventitious* and *soil water* roots. Roots oxidize rhizosphere.	Most tolerant
Taxodium distichum var. *nutans* pondcypress	Not listed	Not listed	Tolerant	A				Langdon 1965; Mattoon 1915	Restricted to piney woods swamps, perched ponds, sloughs and wet flats in the lower coastal plain east of the Mississippi River. Develops *adventitious* and *soil water roots*. Roots probably oxidize rhizosphere.	Most tolerant
Carya aquatica water hickory	Intermediately tolerant	Very tolerant	Moderately tolerant		C			Bedinger 1971; Broadfoot 1967; Hall et al. 1946; Hosner 1962	Mature trees remain healthy where inundation occurs less than 50% of the time during the growing season. Flooding from Feb.–July increased radial growth of timber and pole-size trees.	Highly tolerant[5]
Gleditsia aquatica waterlocust	Not listed	Very tolerant	Moderately tolerant		U			Bedinger 1971; Hosner 1962; Yeager 1949	Most frequently found where flooding occurs 29–40% of growing season.	Highly tolerant
Quercus lyrata overcup oak	Tolerant	Very tolerant	Moderately tolerant		A			Broadfoot 1967; Hall and Smith 1955; Hosner 1962	Most frequent where flooding occurred 29–40% of growing season. Feb.–July flooding beneficial to timber-sized trees but not other categories. Submergence reduced seed germination.	Highly tolerant
Acer negundo boxelder	Tolerant	Somewhat tolerant	Moderately tolerant		L	L		Bedinger 1971; Bell and Johnson 1974; Hosner 1958; 1960, and 1962; Hosner and Leaf 1962; Hosner and Boyce 1962; Louckes and Keen 1973; Noble and Murphy 1975	Rated tolerant in III. but less tolerant to flooding farther south. Seedlings tolerated shallow flooding (1 in.) but had higher mortality with 20–25 in. flooding.	Moderately tolerant[6]
Acer rubrum red maple	Tolerant	Tolerant	Moderately tolerant		A			Hall and Smith 1955; Hosner 1957, 1960, 1962; Hosner and Leaf 1962; Hosner and Boyce 1962; McDermott 1954; Williston 1959	Varies considerably in tolerances over its range. The variety *drummondii* may be most common in swamps but authors except Wharton et al. (1982) did not identify to variety level. Remained healthy with flooding less than 37% of growing season. Develops *adventitious water roots*.	Moderately tolerant
Acer saccharinum silver maple	Tolerant	Somewhat tolerant	Moderately tolerant	Not listed				Green 1947; Hosner 1957, 1958, 1960, 1962; Hosner and Leaf 1962; Hosner and Boyce 1962; Louckes and Keen 1973; Yeager 1949	Much variation reported in response to flooding. More tolerant to flooding in the North than the South. Mature trees died after 2 yrs. of continuous flooding. Seedling height was better in saturated than field-capacity soils.	Moderately tolerant

Table 1. Summary: Waterlogging-Tolerance Ratings—contin.

Species	Teskey & Hinckley 1977	Whitlow & Harris[1] 1979	McKnight, Hook, Langdon & Johnson 1981	Wharton, Kitchens, & Sipe 1982 Floodplain zones[2] II	III	IV	V	Other references	Comments	Final waterlogging-tolerance rating group
Betula nigra river birch	Intermediately tolerant	Somewhat tolerant	Moderately tolerant			ALE		Green 1947; Hall and Smith 1955; McDermott 1954	Mature trees had 77% survival for 240 days' flooding but zero after 730 days. Seedlings stunted by flooding. Healthy if flooding occurred less than 24% of growing season.	Moderately tolerant
Chamaecyparis thyoides Atlantic white-cedar	Not listed	Not listed	Moderately tolerant	U				Johnson 1980	Occurs principally on peat deposits (0–40 ft. thick) over sand and in stream swamps. If underlying soil is silt or clay type usually converts to hardwoods. Favored by disturbances, such as fire, flooding, windthrow, and clearcutting.	Moderately tolerant
Crataegus spp.	Intermediately tolerant	Somewhat tolerant (*C. mollis*)	Moderately tolerant	U *zestivalis*		C *marshallii*		Bedinger 1971; Broadfoot 1967; Hall et al. 1946; Hosner 1962	Species not listed by authors. Large variance in flood tolerance within genera (See Wharton et al. 1982)	Moderately tolerant
Diospyros virginiana persimmon	Tolerant	Tolerant	Moderately tolerant		R			Hall and Smith 1955; Hosner 1962; Yeager 1949	Survival of mature trees was 67% after 240 days of flooding. Healthy if flooding occurred less than 31% of growing season. Seedlings relatively tolerant to flooding.	Moderately tolerant
Fraxinus pennsylvanica green ash	Very tolerant	Very tolerant	Moderately tolerant			A		Bell and Johnson 1974; Broadfoot 1967; Broadfoot and Williston 1973; Dickson et al. 1965; Green 1947; Hall and Smith 1955; Hook and Brown 1973; Hosner 1958, 1959, 1960, 1962; Hosner and Boyce 1962; Kennedy and Krinard 1974; Pereira and Kozlowski 1977; Sena Gomez and Kozlowski 1980	Prefers very wet soils but not fully saturated or flooded. Growth of seedlings in flooded soil less than in well drained but better in saturated than field capacity. Mature trees died after 3–4 yrs. flooding. Occurs in low ridges, flats, and sloughs in first bottoms, terrace flats, and sloughs and occasionally new land. Develops *adventitious water* and *soil roots.* Roots have limited ability to oxidize rhizosphere.	Moderately tolerant
Gleditsia triacanthos honeylocust	Intermediately tolerant	Somewhat tolerant	Moderately tolerant			R		Bedinger 1971; Broadfoot 1967; Hall and Smith 1955; Hosner 1962; Noble and Murphy 1975; Yalenosky 1964	Saplings killed or retarded by 105 days flooding during March–July. Mature trees remained healthy if flooding occurred less than 29% of growing season.	Moderately tolerant
Gordonia lasianthus loblolly-bay	Not listed	Not listed	Moderately tolerant	Not listed				Hosner 1962	Tolerance based on associate species.	Moderately tolerant
Ilex decidua possumhaw	Very tolerant	Very tolerant	Moderately tolerant			C		Hosner 1962	Mature trees remain healthy if flooding occurred less than 35% of growing season. Sapling generally recovered from 105 days flooding (March–July).	Moderately tolerant
Liquidambar styraciflua sweetgum	Tolerant	Tolerant	Moderately tolerant			A		Bedinger 1971; Broadfoot 1967; Broadfoot and Williston 1973; Hall and Smith 1955; Hook and Brown 1973; Hosner 1958, 1960, 1962; Hosner and Boyce 1962; Kennedy and Krinard 1974; Noble and Murphy 1975	Mature trees died if flooding occurred 44% of growing season. Seedlings died within 1–3 mos. of flooding or were severely stunted. May have large variation in tolerance to flooding. Occurs in edge of some swamps but more prevalent on mesic sites.	Moderately tolerant

Table 1. Summary: Waterlogging-Tolerance Ratings—contin.

Species	Teskey & Hinckley 1977	Whitlow & Harris[1] 1979	McKnight, Hook, Langdon & Johnson 1981	Wharton, Kitchens, & Sipe 1982 Floodplain zones[2] II	III	IV	V	Other references	Comments	Final waterlogging- tolerance rating group
Magnolia virginiana sweetbay	Not listed	Not listed	Moderately tolerant	CP					Tolerance based on associate species.	Moderately tolerant
Persea borbonia redbay	Not listed	Not listed	Moderately tolerant	CP					Tolerance based on associate species.	Moderately tolerant
Pinus elliottii slash pine	Intermediately tolerant	Not listed	Moderately tolerant	Not listed				Briscoe 1957; Hodges 1980; McMinn and McNabb 1971; Pruitt 1947; Ralston 1965; Walker 1962; Walker et al. 1961	Flooding decreased shoot and root growth. Some variety difference in flood tolerance. Species confined to bay swamps and boggy coastal plain flatwoods.	Moderately tolerant
Pinus serotina pond pine	Intermediately tolerant	Not listed	Moderately tolerant	Not listed				Johnson 1980; Wenger 1965	Mature trees tolerated prolonged flooding but growth was slow. Endures poor soil aeration and high acidity. Confined mostly to ponds and bays of interstream areas.	Moderately tolerant
Pinus taeda loblolly pine	Intermediately tolerant	Intolerant	Moderately tolerant				C	Burton 1971; Crow 1980; Hall and Smith 1955; Hunt 1951; Kennedy and Krinard 1974; Pruitt 1947; Ralston 1965; Wahlenberg 1960; Walker 1962; Walker et al. 1961; Williston 1962	Mortality high if flooded but some trees survived and grew well if soil phosphorus was adequate. A strain more tolerant to wet sites probably exists but no data exist to support this assumption. Flooding usually reduces growth but dormant-season flooding may be beneficial.	Moderately tolerant
Plantanus occidentalis American sycamore	Tolerant	Somewhat tolerant	Moderately tolerant		UL	UL		Bedinger 1971; Bell and Johnson 1974; Briscoe 1959; Dickson et al. 1965; Hook and Brown 1972; Hook and Scholtens 1978; Hosner 1957, 1959, 1969; Kennedy and Krinard 1974; McDermott 1954; Yeager 1949	Occurs on sites too wet for eastern cottonwood. Grows in shallow swamps, sloughs and very wet river bottoms where soil is saturated 2–4 mos. during growing season. Occurs on the edge of muck swamps in SE.	Moderately tolerant
Populus deltoides eastern cottonwood	Very tolerant	Tolerant	Weakly to moderately tolerant		UL	UL		Bedinger 1971; Broadfoot 1967; Bull and Putnam 1941; Green 1947; Hook et al. 1972; Hosner 1957, 1958, 1959, 1962; Hosner and Boyce 1962; Kennedy and Krinard 1974; Loucks and Keen 1973; Pereira and Kozlowski 1977	Mature trees survived 73 days flooding but all died after 2 yrs. flooding. Feb–July flooding increased radial growth 90%. Tolerated moderate siltation. Seedling survival was 47% after 30 days partial inundation. Mortality high with deep flooding. Develops *adventitious water roots.*	Moderately tolerant
Q. nuttalli Nuttall oak	Tolerant	Very tolerant	Moderately tolerant	Not listed				Bedinger 1971; Bell and Johnson 1974; Dickson et al. 1965; Green 1947; Hosner 1959, 1960, 1962; Hosner and Boyce 1962; Yeager 1949	Most abundant where site flooded 10–21% time. Mature trees died after 3 yrs. flooding. Seedlings survived 2 mos. flooding. Germination of acorns not affected by 34 days of inundation.	Moderately tolerant
Q. palustris pin oak	Not listed	Tolerant	Moderately tolerant	Not listed				Bedinger 1971; Bell and Johnson 1974; Dickson et al. 1965; Green 1947; Hosner 1959, 1960, 1962; Hosner and Boyce 1962; Yeager 1949	Mature trees had 71% survival after 240 days flooding and were all dead at 730 dys. Seedlings had best growth under moisture-equivalent watering regime. Saturated soil killed root system and very few *adventitious water roots* developed.	Moderately tolerant

Table 1. Summary: Waterlogging-Tolerance Ratings—contin.

Species	Teskey & Hinckley 1977	Whitlow & Harris[1] 1979	McKnight, Hook, Langdon & Johnson 1981	Wharton, Kitchens, & Sipe 1982 Floodplain zones[2] II	III	IV	V	Other references	Comments	Final waterlogging-tolerance rating group
Q. phellos willow oak	Tolerant	Somewhat tolerant	Weakly to Moderately tolerant			U		Bedinger 1971; Hall and Smith 1965; Hosner 1962; Hosner and Boyce 1962	Mature trees all died first year of partial inundation. Seedling height growth reduced by saturated soil and survival was only 13% after 60 days of soil saturation.	Moderately tolerant
Ulmus americana American elm	Tolerant	Somewhat tolerant	Moderately tolerant			C		Bedinger 1971; Bell and Johnson 1974; Broadfoot and Williston 1973; Hosner 1959, 1960; Hosner and Boyce 1962; McDermott 1954; Newsome et al. 1982; Noble and Murphy 1975; Yeager 1949; Yelenosky 1964	Mature trees died after 2 yrs. partial inundation but Feb.–July flooding increased radial growth 35%. Seedlings had decreased height growth in saturated soil but survival was high.	Moderately tolerant
U. crassifolia cedar elm	Not listed	Not listed	Moderately tolerant	Not listed				Bedinger 1971; Hall and Smith 1955; Hosner 1962	Frequently occurs with overcup oak and water hickory in low-lying, poorly drained flats with clay or silty clay soils and in backwater basins with clay soils.	Moderately tolerant
Carpinus caroliniana American hornbeam or ironwood	Intermediately tolerant	Intolerant	Weakly tolerant			A		Bedinger 1971; Hall and Smith 1955; Hosner 1962	Mature trees remained healthy if flooded less than 24% of growing season but most abundant where flooding occurred 10–21% growing season.	Weakly tolerant[7]
Carya illinoensis pecan	Intermediately tolerant	Very tolerant	Weakly tolerant	Not listed				Hosner 1962; Kennedy and Krinard 1974; Louckes and Keen 1973; Noble and Murphy 1975; Yeager 1949	Mature trees survived 73 days flooding but had stress. Seedling survival was 75% with 4 wks. of total inundation.	Weakly tolerant
C. laciniosa shellbark hickory	Not listed	Intolerant	Weakly tolerant	Not listed					Grows well in heavy loams and silt loams; best growth requires moister situations in floodplain than pignut, mockernut and shagbark hickories.	Weakly tolerant
Celtis laevigata sugarberry	Intermediately tolerant	Tolerant	Moderately tolerant			U		Bedinger 1971; Green 1947; Hall and Smith 1955; Hosner and Boyce 1962	Mature trees all died after 2 yrs. partial inundation. No seedling mortality after 60 days of soil saturation. Survived because it resisted desiccation.	Weakly tolerant
C. occidentalis hackberry	Not listed	Tolerant	Moderately tolerant to Intolerant	Not listed				Bell and Johnson 1974; Broadfoot 1967; Hosner 1959, 1960; Hosner and Boyce 1962; Yeager 1949	Mature trees had 66% survival after 240 days flooding but all died by day 730. Seedling showed dieback after 60 days flooding. Developed sparse *adventitious water roots.*	Weakly tolerant
Ilex opaca American holly	Intolerant	Somewhat tolerant	Weakly tolerant				A	Hall and Smith 1955; Yeager 1949	Mature trees died if flooded more than 17% of growing season.	Weakly tolerant
Juglans nigra black walnut	Intolerant	Intolerant	Weakly tolerant	Not listed				Bell and Johnson 1974; Hosner 1962; Kennedy and Krinard 1974; Louckes and Keen 1973	Mature trees all died during first year of flooding. Seedling tolerated 2 wks. but all died after 4 wks. of total inundation.	Weakly tolerant
Magnolia grandiflora southern magnolia	Not listed	Not listed	Weakly tolerant to intolerant	Not listed				Bennett 1965	Does not occur in bottoms subject to regular overflow. Along the coast, it grows on ground water podzol and half bog soils.	Weakly tolerant

Table 1. Summary: Waterlogging-Tolerance Ratings—contin.

Species	Teskey & Hinckley 1977	Whitlow & Harris[1] 1979	McKnight, Hook, Langdon & Johnson 1981	Wharton, Kitchens, & Sipe 1982 Floodplain zones[2] II	III	IV	V	Other references	Comments	Final waterlogging-tolerance rating group
Morus rubra red mulberry	Intermediately tolerant	Intolerant	Weakly tolerant to intolerant			U		Yeager 1949	Mature trees had 66% survival after 73 days of partial growing season inundation.	Weakly tolerant
Nyssa sylvatica blackgum	Tolerant	Somewhat tolerant	Weakly tolerant	Not listed				Bedinger 1971; Hall and Smith 1955; Keeley 1979	Healthy if flooded less than 17% of growing season. Does not develop adaptive traits as does swamp tupelo.	Weakly tolerant
Pinus glabra spruce pine	Not listed	Not listed	Weakly tolerant				C			Weakly tolerant
Quercus falcata var. *pagodifolia* cherrybark oak	Intolerant	Not listed	Weakly tolerant to intolerant				C	Bricoe 1961; Broadfoot and Williston 1973; Hosner 1960, 1962; Hosner and Boyce 1962	Mature trees all died first year of partial inundation. Seedling height growth reduced by saturated soil and survival was only 12% after 60 days' soil saturation.	Weakly tolerant
Quercus laurifolia laurel oak	Not listed	Not listed	Moderately to weakly tolerant			A		Hosner 1962	Occurs in sandy soils along edges of rivers and swamps and in rainwater flats that are rarely inundated. In central Fla. occurs on mesic hummocks, west Fla. on sandy hills adjacent to swamps.	Weakly tolerant
Q. michauxii swamp chestnut oak	Intolerant	Not listed	Weakly tolerant				C	Hall and Smith 1965; Hook 1969; Hosner 1962	Mature trees remained healthy if flooded less than 28% of growing season. Seedlings intolerant to flooding.	Weakly tolerant
Q. shumardii Shumard oak	Intermediately tolerant	Intolerant	Weakly tolerant				URL	Bedinger 1971; Hosner 1960, 1962	Mature trees not damaged by 2 mos. flooding (6–10 ft. deep) in spring. Seedling height growth and survival was much poorer in saturated than field-capacity soil.	Weakly tolerant
Q. virginiana live oak	Not listed	Not listed	Weakly tolerant				U	Woods 1965	Occurs on variety of soils from dry sandy ridges to wet flats. Forms climax in well-drained ridges bordering coastal marshes and is resistant to salt spray (salinity may reach 2.22%).	Weakly tolerant
Ulmus alata winged elm	Tolerant	Somewhat tolerant	Weakly tolerant to intolerant	Not listed				Bedinger 1971; Hall and Smith 1955; Hosner 1962; McDermott 1954	Mature trees remained healthy if flooding occurred less than 24% of growing season. Seedling survival was 100% in saturated soils for 32 days but growth reduced after 16 days.	Weakly tolerant
Asimina triloba pawpaw	Intolerant	Not listed	Intolerant				C	Hall and Smith 1955	Mature trees tolerated up to 14% of growing season flooding but died quickly after tolerance period.	Least tolerant[8]
Cornus florida flowering dogwood	Intolerant	Intolerant	Intolerant	Not listed				Hall et al. 1946	Most abundant in floodplain where flooding occurred once every 2–8 yrs.	Least tolerant
Fagus grandifolia American beech	Intolerant	Not listed	Intolerant				CE	Hall and Smith 1955; Hall et al. 1946	Healthy if flooded less than 4% of growing season.	Least tolerant
Juniperus virginiana eastern redcedar	Intolerant	Not listed	Not listed	Not listed				Fowells 1965	Mature tree survival was 53% after 73 days partial inundation during growing season.	Least tolerant

Table 1. Summary: Waterlogging-Tolerance Ratings—contin.

Species	Teskey & Hinckley 1977	Whitlow & Harris[1] 1979	McKnight, Hook, Langdon & Johnson 1981	Wharton, Kitchens, & Sipe 1982 Floodplain zones[2] II	III	IV	V	Other references	Comments	Final waterlogging-tolerance rating group
Liriodendron tulipfera yellow-poplar	Intolerant	Not listed	Intolerant	Not listed				Hall and Smith 1955; Hosner 1962; Kennedy and Krinard 1974; McAlpine 1959, 1961; Yelenosky 1964; Schultz and Kormanik 1975	Mature trees remained healthy if flooded less than 4% of growing season. Seedlings all died with less than 2 mos. of partial growing season inundation. Most died in a few days. Seedlings tolerated dormant season flooding.	Least tolerant
Ostrya virginiana eastern hophornbeam	Intolerant	Not listed	Intolerant	Not listed				Hall and Smith 1955; Hosner 1962	Mature trees remained healthy if flooded less than 3% of growing season.	Least tolerant
Pinus echinata shortleaf pine	Intolerant	Intolerant	Not listed	Not listed				White 1980; Williston 1962	Seedling had good survival after 7 mos. of partial growing season inundation. Mature trees are intolerant to poorly aerated soils.	Least tolerant
Prunus serotina black cherry	Intolerant	Intolerant	Intolerant	Not listed				Bedinger 1971; Bell and Johnson 1974	Mature trees remained healthy if flooded less than 3% of growing season.	Least tolerant
Quercus alba white oak	Intolerant	Intolerant	Intolerant to weakly tolerant	Not listed				Bedinger 1971; Bell and Johnson 1974; Hosner 1962; Williston 1959; Yelenosky 1964	Most abundant where flooding occurred once every 2–8 yrs.	Least tolerant
Sassafras albidum sassafras	Intolerant	Intolerant	Intolerant	Not listed				Hall and Smith 1955; Hosner 1962	Mature trees will not tolerate more than 3% growing season flooding.	Least tolerant
Ulmus rubra slippery elm	Not listed	Somewhat tolerant	Intolerant	Not listed				Yeager 1949	Grows best on moist well-drained soils of lower slopes, streambanks, river terraces and bottomlands but occurs most on drier sites, particularly those of limestone origin.	Least tolerant

[1] For lower Mississippi Valley Region only.
[2] See Table 2 for description of floodplain zones.
[3] Occurrence: A = abundant, C = common, U = uncommon or localized, R = rare. Species largely restricted to: ecotones (E), levees (L) and peat soils (P).
[4] Most Tolerant—Those species that are capable of living from seedling to maturity in soils that are waterlogged almost continually year after year except for short durations during droughts. The soils are typically anaerobic in character but are less so where the water is moving. Some species in this group adapt by producing *soil water roots* that oxidize their rhizosphere, accelerate anaerobic metabolism but at a controlled rate and tolerate the toxic compounds typical of highly reduced waterlogging soils.
[5] Highly Tolerant—Those species capable of living from seedling to maturity in soils that are waterlogged for 50 to 75% of the year. Waterlogging typically occurs during the winter, spring, and 1–3 months of summer.
[6] Moderately Tolerant—Those species capable of living from seedling to maturity in soils waterlogged about 50% of the time. Waterlogging typically occurs in portions of the winter, spring, and early summer.
[7] Weakly Tolerant—Those species that are capable of living from seedling through maturity in soils that are temporarily waterlogged for durations of 1–4 weeks and usually accounting for 10% of the growing season.
[8] Least Tolerant—Those species that are capable of living from seedling through maturity in soils that are occasionally waterlogged for durations of a few days only, usually accounting for less than 2% of the growing season.

With the exception of baldcypress and pondcypress, conifers are generally less tolerant of waterlogging than hardwoods. However, recent research on loblolly has shown that its tolerance to waterlogging is greatly enhanced by phosphorus fertilization on phosphorus-deficient wet soils (Hook et al. 1983), and there are indications that strains of wet-site loblolly pine may exist. Genetic variability in waterlogging tolerance among hardwood species has also been documented (Keeley 1979).

Table 2. Characteristics of water regimes and soils by zones in the floodplains of the Southeast (adapted from Wharton et al. 1982).

Characteristic	Zones II	III	IV	V	VI
Degree of inundation and saturation	Intermittently exposed; nearly permanent inundation and saturation	Semipermanently inundated or saturated	Seasonally inundated or saturated	Temporarily inundated or saturated	Intermittently inundated or saturated
Timing of flooding	Year-round except during extreme droughts	Spring and summer during most of the growing season	Spring for 1–2 months of the growing season	Periodically for up to 1 month of growing season	During exceptionally high floods or extreme wet periods
Probability of annual flooding	100%	51%–100%	51%–100%	10%–50%	1%–20%
Duration of flooding	100% of the growing season	>25% of the growing season	12.5%–25% of the growing season	2%–12% of growing season	<2% of the growing season
Soil texture	Dominated by silty clays or sands	Dominated by dense clays	Clays dominate surface; some coarser fractions (sands) increase with depth	Clay and sandy loams dominate; sandy soils frequent	Sands to clays
Sand : silt : clay (% composition)[a]					
Blackwater	69 : 20 : 12	—	74 : 14 : 12	—	—
Alluvial	29 : 23 : 48	34 : 22 : 44	34 : 20 : 45	71 : 16 : 14	—
Organic matter %[b]					
Blackwater	18.0	—	7.9	—	—
Alluvial	4.5	3.4	2.8	3.8	—
Oxygenation	Moving water aerobic; stagnant water anaerobic	Anaerobic for portions of the year	Alternating anaerobic and aerobic conditions	Alternating: mostly aerobic, occasionally anaerobic	
Soil color	Gray to olive gray with bluish gray, and grayish green mottles	Gray with olive gray mottles	Dominantly gray on blackwater floodplains and reddish on alluvial with brownish gray and grayish brown mottles	Dominantly gray or grayish brown with brown, yellowish brown, and reddish brown mottles	Dominantly red, brown, reddish brown, yellow, yellowish red, and yellowish brown, with a wide range of mottled colors

[a] Range included drought years.
[b] Organic matter determined by the Walkley-Black method (see original publication for % errors).

Generally, waterlogging tolerance of a species increases with age and size up to maturity (Gill 1970), but apparently decreases with decreasing crown position (Harms et al. 1980).

It appears that most plants which show some tolerance to waterlogging, develop specific adaptations which enable them to (1) avoid the condition temporarily, or (2) adapt to tolerate varying degrees of inundation for moderate lengths of time, or (3) adapt to waterlogging indefinitely. Three morphological and 3 physiological adaptive traits have been identified as useful in segregating species on the basis of their waterlogging tolerance (Hook and Scholtens 1978). Under the stimulus of prolonged waterlogging they are:

A. Morphological

(1) Secondary roots survive.
(2) Original secondary roots die but new secondary roots develop (designated as *soil water roots*).
(3) *Adventitious water roots* develop (roots that develop on the inundated portion of the stem).

B. Physiological

(1) Roots maintain or accelerate anaerobic respiration; the most tolerant species increase anaerobic respiration rate, but maintain metabolic control. Less tolerant species may

greatly accelerate anaerobic respiration or shift from production of ethanol to malate or other products.

(2) Roots oxidize their rhizosphere.

(3) Roots tolerate high concentration of ethanol, carbon dioxide, methane, hydrogen sulfide, and other reduced compounds that accumulate in reduced soils.

Trees, such as tupelos and baldcypress, which can live indefinitely in swamp habitats normally (a) develop *adventitious water roots* and *soil water roots*, (b) oxidize their rhizosphere (oxygen diffuses from the atmosphere through the stem and roots to the soil), and (c) accelerate but maintain metabolic control of anaerobic respiration under waterlogged conditions (Hook et al. 1971). Species not adapted to prolonged soil waterlogging usually do not develop *soil water roots* or oxidize their rhizosphere, but greatly accelerate anaerobic respiration under waterlogged conditions (Hook and Brown, 1973, Crawford 1978).

Site

Tree species are naturally distributed along a moisture gradient from xeric to hydric sites, but the natural elevation gradient in a flood-plain from the highlands to the river may have abrupt topographic features that cause changes in elevation, drainage, and species composition. At the boundary between the mesic and hydric sites, the increasing soil moisture shifts from unsaturated to saturated. This boundary may be a few feet to several hundred feet wide depending on topography. A sharp or gradual change in species compositon occurs at the boundary depending on the nature of the boundary and the waterlogging tolerance of the species involved. Even among swamps there is considerable variation in the growth rate of the same wetland species. This variance in growth appears to be closely related to water regime (stagnant or moving), soil fertility and type, and the duration and depth of the flood water.

When soils are waterlogged, the water displaces the oxygen that normally occupies the pore space in unsaturated soils. Any oxygen that is trapped in the soil is quickly used up by the micro-organisms and the active growing roots in the soil. Furthermore, the water greatly reduces the rate of diffusion of atmospheric oxygen into the underlying saturated soil, hence, very little new oxygen enters and is available for normal root respiration. Therefore, if a plant is to live and grow in such an environment, its roots must be capable of living in extremely low oxygen or even in the absence of oxygen or adapt by diffusing oxygen through the stem and roots to oxidize the surrounding toxins in the reduced soil.

As soil temperature increases during the growing season, oxygen becomes less soluble in the warmer water and microbial activity increases. Both processes tend to lower soil aeration. If the water is stagnant and organic matter and soil temperature are high enough, reducing conditions develop quickly and deplete the soil oxygen. Under these conditions reduced compounds are readily produced and accumulate to the point that they become toxic to all but the most waterlogging-tolerant plant species. Moving water tends to flush toxins from the soil and restore oxygen, albeit at a low level, to the soil. Floodplain zones are char-

Figure 2. Water tupelo, a wetland species, forests this site in the floodplain of the Mississippi River north of Greenwood, Mississippi. Photo by Southern Hardwoods Laboratory.

acterized in Table 2 as to flooding durations, soil aerations and physical and chemical properties of soils.

DISCUSSION

As mentioned above, the normal hydroperiods of wetlands are continuously altered by disturbances caused by man. The relative waterlogging-tolerance ratings of Table 1 can be used to predict in general what may happen to the population of a species in question under specific conditions. But in doing so, one must take into account the prior waterlogging history of the population, age, general vigor of the trees, type, duration, frequency, and timing of waterlogging. For instance, if a stand of trees has had a history of shallow and brief periods of waterlogging and is suddenly inundated 2 or 3 ft. deep, even for a few months during the growing season, it is apt to show a much higher mortality rate than if it had a history of deeper or more sustained waterlogging. Even baldcypress appears to exhibit this response with long-term flooding. In Florida, baldcypress in sloughs along the Ocklawaha River showed essentially no increased mortality with an additional 20 cm of sustained year-round flooding, but with 120 cm sustained year-round flooding mortality increased by about 50% during a 4-year period (Harms et al. 1980).

Deeper flooding tends to compound the problems of soil aeration by greatly reducing the diffusion of atmospheric oxygen into the soil and interferes with oxygen transport from the atmosphere to roots via covering stem lenticels where atmospheric oxygen normally diffuses into the tree. Hence, a species' tolerance to deep flooding is less than its tolerance to shallow flooding. Similarly, prolonged flooding is more detrimental than short-term flooding, and, in combination with more frequent flooding may be detrimental to all species except those in the *most tolerant* group (Table 1). Flooding during the hottest part of the growing season is more detrimental to most species than early-season flooding because of the highly reduced soil conditions that tend to develop in such cases.

Predicting the response to individual trees to changes in degree or to the nature of waterlogging is even more difficult than for a population in general. In addition to considering the factors discussed above, the crown class, size, and vigor of the tree appear to be important, *i.e.* tolerance of a species to waterlogging appears to decrease as the tree becomes more suppressed in the stand (Harms et al. 1980). Trees in the dominant crown classes survive waterlogging much better than lower crown classes and more vigorous individuals appear to survive better than less vigorous ones. Also, the tree's individual microsite condition becomes involved; some individuals may survive longer than expected due to hummocks or better than average site aeration that may not be apparent from casual observation.

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Options in Energy Wood Farming

W. V. McConnell

ABSTRACT. A U.S. Air Force-sponsored study identified 5 potential management options for woody biomass production at Eglin Air Force Base (AFB), Florida. The preferred option was short rotations of densely stocked Choctawhatchee sand pine (Pinus clausa *var.* immuginata) *on Lakeland soils. This low-energy subsidy approach may have application on much of the 8 million acres of sandhill soils in the South.*

The term *silvicultural biomass farm* conjures up visions of extensive areas of intensively managed and closely spaced trees, probably hardwoods, grown on a rotation of from 6 to 8 years. Such energy plantations would indeed be "farms" complete with the ground preparation, planting, irrigation, fertilization, cultivation and weed and insect control common to intensive agriculture. Such short-rotation-intensive-culture (SRIC) systems have been under investigation since 1971 by the North Central Forest Experiment Station (USDA Forest Service 1980). Application of this concept was explored by Mitre Corporation in studies for the Energy Research and Development Corporation (now DOE) (Howlett and Gamache 1977, Salo et al. 1979), and was reported in the *Journal of Forestry* by Fege et al. (1979). Research into capital- and energy-intensive modes of energy wood production is now underway under DOE's Short-Rotation Woody Crops Program. The relevance of such production methods to future needs cannot be disputed.

A less intensive approach to energy farming may be more appropriate to most southern forests. Presented here is an assessment of alternative energy wood production modes made by Ultrasystems, Inc. (Huff et al. 1982) for the U.S. Army Facility Engineering Support Agency and sponsored by the Air Force Engineering and Services Center (Tyndall AFB, Florida). The primary goal was to determine the feasibility of achieving energy self sufficiency at Eglin AFB. Eglin is located in the Florida panhandle and has over 400,000 acres of forested land.

Earlier studies (Lowther 1978, Huff and Bond 1981) identified Eglin as the Air Force's prime candidate for achieving independence from external energy sources through the use of woody biomass. The base energy requirements could be met with about 540,000 green tons of wood chips per year. In the study we determined which combination of species and production mode could most economically and reliably meet this need on the available land.

Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

Effects of Flood Duration and Depth on Germination of Cherrybark, Post, Southern Red, White, and Willow Oak Acorns

EFFECTS OF FLOOD DURATION AND DEPTH ON GERMINATION OF CHERRYBARK, POST, SOUTHERN RED, WHITE, AND WILLOW OAK ACORNS

Yanfei Guo, Michael G. Shelton, and Eric Heitzman[1]

Abstract—Effects of flood duration (0, 10, 20, and 30 days) and depth (10 and 100 centimeters below a water surface) on acorn germination were tested for two bottomland oaks (cherrybark oak [*Quercus pagoda* Raf.] and willow oak [*Q. phellos* L.]) and three upland oaks (post oak [*Q. stellata* Wang.], southern red oak [*Q. falcata* Michx.], and white oak [*Q. alba* L.]). The study was a 4 x 2 factorial with a completely randomized design. Acorns of the five species were collected in November 1995 in Drew County, Arkansas and stored in a refrigerator at 4 degrees Centigrade until stratification. Acorns were stratified for 45 days in plastic germination flats with 20-cubic centimeter cells filled with a silt loam soil and then flooded in a small pond from March 19 to April 18, 1996. After flooding, acorns were germinated for 60 days. Flood depth did not significantly affect germination of any species, but flood duration affected germination of the three upland species. There was no interaction between flood duration and depth for any species. Among the upland species, germination of white oak acorns with 20 days or more of flooding was almost totally prohibited, while germination of southern red oak acorns gradually decreased as flood duration increased. Although germination of post oak was significantly reduced by 20 and 30 days of flooding, more than 65 percent of the acorns germinated. Results of our study indicate that the effects of flooding on the species composition of bottomlands begin with the germination process.

INTRODUCTION

Seasonal flooding frequently occurs in bottomlands and is a principal factor in determining tree species distribution (Hodges and Switzer 1979). Flooding may affect tree growth by displacing soil air and limiting root respiration along with other effects, and extended flooding can kill flood-intolerant trees (Kramer and Kozlowski 1979). Flood tolerance of the major bottomland hardwood species, including many oaks, has been summarized (Hook 1984; Allen and Kennedy 1989), but little is known about the flood tolerance of tree seeds. For instance, some species can develop aerenchymatous tissue to facilitate transport of oxygen to the roots, but this is not possible for seeds (Norton 1986). For the oaks, acorns of some species may be damaged by extended flooding, and damaged acorns may not be able to germinate or produce vigorous seedlings. There is some indication that acorns of the bottomland oaks can tolerate more flooding than upland species. For instance, 15 days of flooding severely reduced acorn germination of white oak (*Quercus alba* L.) (Bell 1975), but acorns of Nuttall oak (*Q. nuttallii* Palmer) were not affected by 34 days of flooding (Briscoe 1961). Guo and others (1998) found that spring flooding significantly reduced epicotyl emergence of black (*Q. velutina* Lam.) and northern red oak (*Q. rubra* L.) acorns but did not affect cherrybark (*Q. pagoda* Raf.) or water oak (*Q. nigra* L.).

Water depth may vary greatly during flooding based on location within the floodplain and intensity of the flood. Water depth may affect aeration, temperature, and pressure, which may influence acorn viability. The effect of flood depth on acorn germination has not been studied. Therefore, the objective of this study was to test the effects of flood duration and depth on acorn germination of five oak species common to the southern United States. The species were two bottomland oaks (cherrybark and willow oak [*Q. phellos* L.]) and three upland oaks (post oak [*Q. stellata* Wang.], southern red oak [*Q. falcata* Michx.], and white oak).

METHODS

In November 1995, acorns from an individual tree of the five oak species were collected in Drew County, AR. After conducting a float test, acorns were air dried overnight and stored in polyethylene bags at 4 degrees Centigrade. A silt loam soil (Typic Ochraquults) was collected in Drew County, AR. The soil was air dried and hand-processed to pass a 5-millimeter sieve. Plastic germination flats with sixty 20-cubic centimeter cells per flat were filled with soil, and twelve acorns of each of the five species were buried 1 centimeter below the soil surface with one acorn per cell. Acorns were buried in soil because small mammals commonly bury acorns and survival of acorns on the forest floor is generally low (Bowersox 1993). After sowing, the soil was saturated with distilled water, and flats were

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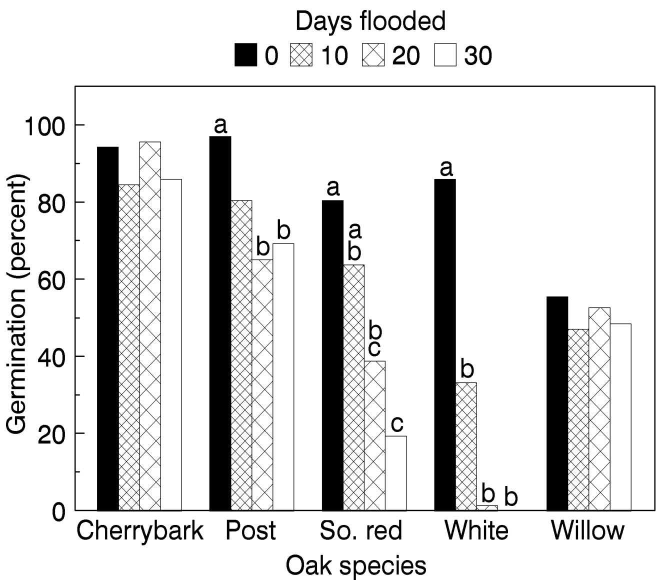

Figure 1—Effects of flood duration on germination of cherrybark, post, southern red, white, and willow oak acorns. Bars of a cluster with different letters differ at α =0.05.

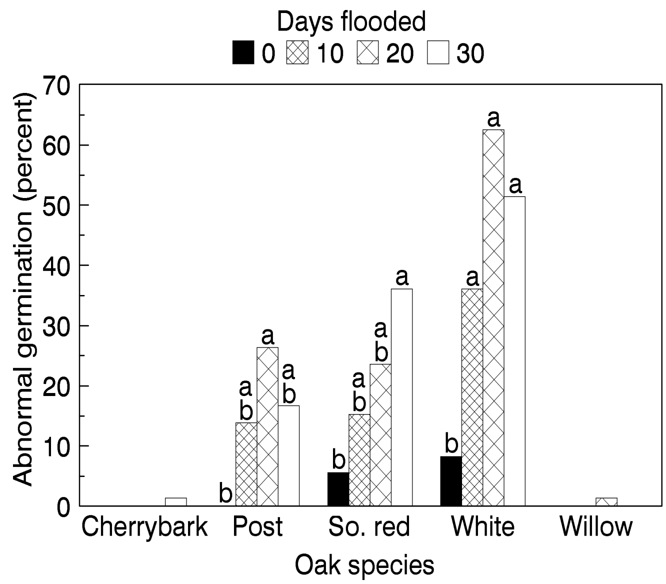

Figure 2—Effects of flood duration on the abnormal germination (a radicle or roots produced with no accompanying epicotyl or shoot) of cherrybark, post, southern red, white, and willow oak acorns. Bars of a cluster with different letters differ at α =0.05.

stored for 45 days at 4 degrees Centigrade to stratify acorns, assuring a uniform state of dormancy.

The study design was a 4 x 2 factorial with a completely randomized layout with treatments of flood duration and depth. There were four flood durations: 0 (control), 10, 20, and 30 days, and two flood depths: 10 and 100 centimeters below a water surface. Each treatment combination was replicated three times with 12 acorns per replicate. Flooding was conducted in a 0.2-ha pond in Drew County, AR from March 19 to April 18, 1996. Plastic germination flats with the 10-centimeter depth were protected with a wire screen (1.2-centimeter mesh) to keep out seed-consuming animals. A maximum-minimum thermometer was submerged with germination flats, and water temperature was recorded every 10 days. Flooding of replicates of the 10- and 20-day treatments was staggered in time so that environmental gradients occurring over the 30-day period could affect all treatment levels. Plastic germination flats awaiting flooding and those with completed flooding treatments were drained and stored at 4 degrees Centigrade until day 30 when all germination flats were collected. Minimum water temperatures for the 10-centimeter depth were 10.1, 11.0, and 14.6 degrees Centigrade, respectfully, for the three 10-day flooding periods, and maximum temperatures were 17.4, 19.3, and 22.3 degrees Centigrade. Corresponding minimum temperatures for the 100-centimeter depth were 10.6, 11.9, and 14.6 degrees Centigrade, and maximum temperatures were 14.4, 16.8, and 18.2 degrees Centigrade.

For germination tests, the plastic germination flats were placed in a laboratory with a bay of south-facing windows, exposing flats to diffuse sunlight. The germination flats were periodically irrigated with distilled water to keep the soil moist. Temperature in the laboratory was maintained at 20 degrees Centigrade. Epicotyl emergence of each acorn was recorded weekly over an 8-week period when length exceeded 2 centimeters. Seedlings were allowed to continue development in the germination flats after acorns were recorded as germinated. To assess possible germination activity at the time of flooding, subsamples of acorns were established that were identical to the unflooded control, except that they were removed from soil and examined at the beginning of the germination test; the four activity classes were none, acorn split, radicle $\leq$ 5 millimeters, and radicle >5 millimeters. At the end of the germination test, all ungerminated acorns were examined for decay and abnormal germination (a radicle or roots exceeding 2 centimeters but no corresponding shoot).

Germination results were analyzed by GLM of SAS (SAS Institute Inc. 1986). Significance was accepted at α = 0.05. Means were separated by the Ryan-Einot-Gabriel-Welsch multiple range test at α = 0.05.

RESULTS

Flood duration significantly affected germination of post (P = 0.03), southern red (P < 0.01), and white (P < 0.01) oak acorns, but did not affect cherrybark (P = 0.12) and willow (P = 0.89) oak acorns. Flood depth did not significantly affect germination of any species, and there was also no significant interaction between flood duration and depth. Temperatures averaged 15.8 degrees Centigrade for the 10-centimeter depth and 14.4 degrees Centigrade for the 100-centimeter depth, but the slight lowering of average temperature with increasing water depth was apparently not enough to affect flood damage.

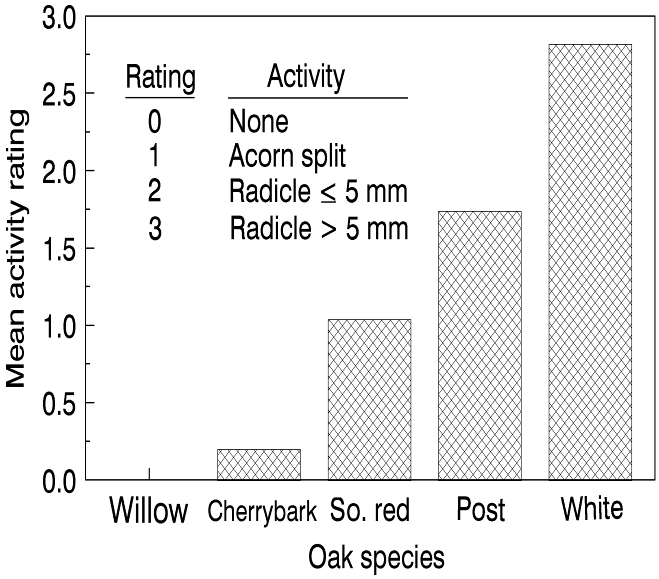

Figure 3—Activity rating of unflooded acorns of cherrybark, post, southern red, white, and willow oaks determined after 75 days of stratification which coincided with the end of the flooding treatments.

Germination rate of the control for post oak acorns was 97 percent, which did not differ from the 10-day flooding (81 percent) but was significantly greater than the 69 and 65 percent of the 20- and 30-day flooding treatments (figure 1). No difference was found among the three flood duration treatments. For southern red oak acorns, germination rate of the control was 81 percent. That was not different from the 10-day flood treatment at 64 percent but was significantly different from the 20- and 30-day treatments (39 and 19 percent). There were no differences between the 10- and 20-day treatments and between 20- and 30-day treatments. Compared to post and southern red oak, acorns of white oak were more severely affected by flooding. Germination rate of the control was 86 percent. With 10-day flooding, germination was reduced to 33 percent, which was significantly different from the control. Almost no germination occurred with the 20- and 30-day durations.

Cherrybark oak germination varied from 95 to 85 percent with the greatest germination rate occurring with 20-day flooding. Willow oak acorns varied within a narrow range (47-55 percent), but the germination rate was much lower than that of cherrybark oak.

Germination failures of post, southern red, and white oaks were mostly accounted for by abnormal germination, where radicles or roots developed without accompanying epicotyls or shoots (figure 2). Abnormal germination generally increased for these species with increasing flood duration. In contrast, abnormal germination was nearly nil for cherrybark and willow oak. For willow oak, most of the acorns that did not germinate were classified as being decayed, averaging 42 percent across all durations with no significant treatment effects.

The activity of unflooded acorns at the end of 75 days of stratification was considerably less for bottomland species than for upland species (figure 3). Willow and cherrybark oak acorns showed almost no activity. Most of the southern red oak acorns were split, but no radicles had emerged. In contrast, most post oak acorns had radicles less than 5 millimeters long, while most radicles of white oak were longer than 5 millimeters.

DISCUSSION

Among the five tested species, post, southern red, and white oaks are upland species, while cherrybark and willow oaks are bottomland species. However, cherrybark oak is seldom abundant on wet or swampy soils, and it grows best on loamy sites on the first bottom ridges (Krinard 1990). Willow oak is found on ridges and high flats of first bottoms of major streams, and on ridges, flats, and sloughs on second bottoms, but it grows best on clay loam ridges of new alluvium (Schlaegel 1990).

Cherrybark oak acorns are tolerant to flooding at least up to 30 days (Guo and others 1998). This study further shows that flooding in deep water in spring does not affect acorn germination of the species. Germination rates of the acorns were high, ranging from 81 to 97 percent across the treatments. In contrast, germination of willow oak acorns was only around 50 percent, including the control. It is not clear why the willow oak acorns had such low germination rates. Bonner (1974) found different germination rates for willow oak acorns collected at different dates; acorns collected on October 6 had a germination rate of 59 percent, compared to 86 percent on October 18, and 96 percent on November 1. Although our acorns were collected in November, they could have possibly fallen to the ground earlier.

For the three species affected by flooding, post oak showed considerable tolerance to flood damage. Even after 30 days of flooding, more than 65 percent of the post oak acorns germinated normally. Thus, flooding damage to acorns is probably not a significant factor limiting the distribution of post oak. Southern red oak also showed some tolerance to short-term flooding; the germination rate was more than 50 percent for 10 days of flooding. Thus, a short flooding period about 10 days is not likely to substantially reduce southern red oak acorn establishment. Compared to post and southern red oak, however, white oak acorns are very sensitive to flooding. Ten days of flooding reduced germination appreciably, and 20 days of flooding almost eliminated any possibility of germination. Bell (1975) also found that acorn germination of white oak was severely limited by 15 days of flooding. This sensitivity may be caused by the characteristic that white oak acorns germinate soon after they fall to ground. In this study, most acorns germinated during stratification. Increased metabolism within the acorns apparently made them susceptible to flooding. Martin and others (1991) pointed out that increased anaerobic metabolism can damage seeds through the buildup of toxic materials.

Although germination of southern red oak acorns was reduced significantly after 20 days of flooding in this study, different results were reported by Larsen (1963) who tested the effects of water soaking for up to 8 weeks on acorn germination of southern red oak, willow oak, laurel oak (*Q. laurifolia* Michx.), and overcup oak (*Q. lyrata* Walt.). Flooding did not affect germination of southern red and willow oak acorns, and both species had germination rates between 40 and 45 percent. The response of willow oak acorns to flooding is similar to that found in this study. However, the germination of southern red oak acorns without flooding in Larsen's study was much lower than that in our study, which may indicate considerable variation among the seed lots.

For upland species, the embryo axes of acorns were most severely damaged by flooding. Guo and others (1998) found similar damage for black and northern red oak acorns. However, radicles or roots often developed from the connective tissue between the embryo axis and the cotyledons, especially for white oak acorns. Some of the radicles and roots were still alive after 30 days of flooding and the 60-day germination test even though the embryo axes were apparently dead. However, no seedlings developed from the flood-damaged acorns because of the dead embryo axes.

One factor that affects distribution of species is flooding on alluvial sites. Tree seeds must be able to withstand flooding before seedlings can occupy alluvial sites. Cherrybark and willow oaks apparently have no problem becoming established on sites with spring flooding of up to 30 days. They may withstand additional flooding but further research is needed to confirm this. An interesting finding of our study is the tolerance of the post oak acorns to flooding. Post oak typically grows on dry sites on upper slopes (Stransky 1990), yet its acorns showed a fairly high tolerance to flooding. It is likely that the exclusion of this species on alluvial sites is due to some other factor than damage of acorns by flooding.

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Great Trinity Forest Management Plan

HARDWOOD SILVICULTURE

An Old-Growth Definition for Western Hardwood Gallery Forests

(USDA Forest Service, Southern Research Station, General Technical Report SRS - 22)

United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS-22

An Old-Growth Definition for Western Hardwood Gallery Forests

Kelly Kindscher and Jenny Holah

A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

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An Old-Growth Definition for Western Hardwood Gallery Forests

Kelly Kindscher and Jenny Holah

Introduction

Old-growth western hardwood gallery forests are found across the Great Plains and are an important plant community associated with stream corridors. This plant community is dominated by the plains cottonwood (*Populus deltoides* var. *occidentalis* Rydb.) and associated stands of willow (*Salix* spp.) trees. Its description is important for both future research and regional planning purposes. Hydrological changes associated with dewatering of streams, irrigation, and flood-control measures have significantly affected the composition of this forest type.

General Description of Forest-Type Group

Western hardwood gallery forests are located along streams and rivers in the Great Plains. The dominant species is the plains cottonwood. The range of the western hardwood gallery forest type (hereafter referred to as gallery forest) extends from southern Saskatchewan to northern Texas, from the Rocky Mountains in Wyoming, Montana, and Colorado to the western borders of Minnesota and Iowa, and the eastern borders of Kansas (Bradley and Smith 1986). In this report, we define "old-growth" forests as stands in which the dominant species, plains cottonwood, is over 80 years old.

Several cottonwood species and subspecies can be found in this type, although *P. deltoides* ssp. *monilifera* (Ait.) is the common variety. *Populus deltoides* ssp. *wislizenii* (Wats.) occurs in the extreme southwestern part of the gallery forest's range and is often mistaken for a variety of Fremont's cottonwood (*P. fremontii* Wats.) (Eckenwalder 1977). Hybridization does occur between plains cottonwood and narrowleaf cottonwood (*P. augustifolia* James) (found west of the Rocky Mountains), which results in *P.* × *acuminata* Rydb. This hybrid is widespread along Rocky Mountain streams from Alberta to northern Texas. *Populus* × *jackii* Sarg. is a hybrid of *P. deltoides* and *P. balsamifera* L. (a northern cottonwood species) that occurs on flood plains along the U.S.–Canada border and in eastern Wyoming (Eckenwalder 1984). Other characteristic species of the gallery forest include peachleaf willow (*S. amygdaloides* Anderss.), black willow (*S. nigra* Marsh.), sandbar willow (*S. exigua* Nutt.), winter grape (*Vitis vulpina* L.), and Virginia creeper [*Parthenocissus quinquefolia* (L.) Planch.].

Western gallery forests occur only along major rivers and streams in narrow strips that generally range from 32.8 feet to 393.6 feet [10 to 120 meters (m)] wide (Eyre 1980, Bradley and Smith 1986). These gallery forests are rarely found more than a few meters above the river level (Johnson et al. 1976, Rothenberger 1985, Johnson 1994). The major rivers associated with this forest type are the Canadian, Cimarron, Arkansas, Kansas, Republican, Platte, Niobrara, Missouri, Little Missouri, Red, and Milk. Prairie vegetation historically surrounded these gallery forests, but today much of the surrounding vegetation is under cultivation (Keammerer et al. 1975, Rothenberger 1985).

The floristics of this community are unique. Ten percent of the species found along bottom-land forests in North Dakota are usually restricted to either western or eastern temperate America but are found together in gallery forests (Keammerer et al. 1975). Young western hardwood gallery forests are composed of dense stands of willow and cottonwood, but hardwood diversity is greater in older stands where willows are a minor component (Johnson et al. 1976).

Gallery forest soil development depends greatly on flooding. The soils consist of recently deposited alluvium substrates that include deep, sandy, and clay loams with good drainage and are often nitrogen poor (Wilson 1970, Keammerer et al. 1975, Rothenberger 1985). Soil pH can range from 6.6 to 8.4 (Rice 1965, Girard et al. 1989). Soil texture is highly variable, ranging from silty clay loam to clay loam to clay to loam (Girard et al. 1989). Gallery forest soils do not appear to be modified significantly by forest vegetation (Johnson et al. 1976). The role of vegetation in soil development may be more important in the future because reservoirs and increased groundwater mining have altered the hydrology of major rivers in this forest type.

Precipitation is variable and generally increases from west to east in the range of gallery forests. Upland vegetation also changes gradually from shortgrass prairie in the west to tallgrass prairie in the east. In western North Dakota gallery forests, the precipitation can be as little as 13 to 16 inches [33 to 41 centimeters (cm)] per year (Johnson et al. 1976, Girard et al. 1987), whereas in the eastern and southern parts of the range they can receive over 30 inches (76 cm) annually. Precipitation in much of the Great Plains area, especially the western region, is less than potential evapotranspiration. Thus, the dominant woody vegetation of gallery forests depends on the water table rather than on precipitation for moisture (Keammerer et al. 1975, Johnson et al. 1976).

Summer temperatures can be extreme, exceeding 105 °F (58 °C) in Texas, Oklahoma, and southern Kansas. Surface temperature in the sandy floodplain along the Missouri in South Dakota can exceed 125 °F (69 °C) (Van Bruggen 1961). Because of the extreme Great Plains climate, few mesophytic eastern species survive on the open prairie, but some eastern herbaceous plants, such as columbine (*Aquilegia canadensis* L.), enchanter's nightshade [*Circaea quadrisulcata* (Maxim.)], and Solomon's seal [*Polygonatum biflorum* (Walt.) Ell.] find refuge in the riparian forests (Keammerer et al. 1975).

In the central Great Plains before the 1880's, riparian forests were uncommon and widely scattered along major rivers such as the western reaches of the Arkansas and Platte (Crouch 1979, Tomelleri 1984). This was probably due to the highly variable hydrology of the Great Plains rivers and the high frequency of fires on the prairie (Wells 1968, Johnson et al. 1976). Rivers such as the Missouri and Platte would flood severely in the spring and then have little discharge during the fall (Johnson et al. 1976, Rothenberger 1985). It is not clear which factors originally influenced tree growth along major rivers (Girard et al. 1987). There is general agreement that fires were a major part of the prairie ecosystem (Wells 1968, Higgins 1986), but the frequency and effect of lightning-caused wildfires on gallery forests is unknown (Higgins 1986). Some argue that the riparian woodlands escaped fire and were adapted to it, or both, whereas others argue that homesteading and a decrease in fire frequency allowed gallery forests to expand their range (Wells 1968, Higgins 1986). Most of the early public land surveys show that forests were sparse along the major rivers.

Great Plains rivers, such as the Missouri in North Dakota, meandered more in the past than they do today. Although the Missouri still meanders, the absence of icy, scouring spring floods has prevented any significant changes in its channel morphology. Discharges of the Missouri and many other rivers are no longer seasonal but are controlled by reservoir releases (Johnson et al. 1976).

In the 1900's, tree establishment along the Arkansas and other rivers in the Great Plains increased as water removed for surface irrigation decreased the intensity of peak spring discharges (Tomelleri 1984). Many of the old cottonwoods in the gallery forests of western Kansas and eastern Colorado were established during this period. Growth of cottonwood and willow species has sharply decreased in the past 30 years because of reductions in groundwater due to mining for irrigation (Tomelleri 1984) and the construction of large reservoirs (Johnson et al. 1976).

Saltcedar (*Tamarix parviflora* L.) has crowded river channels in the southwest part of the region, reducing establishment sites for willow and cottonwood (Gesink et al. 1970). In Nebraska and other areas of the Great Plains, the loss of the old deciduous woodlands has been due largely to agricultural expansion (Rothenberger 1985).

Extensive grazing by cattle has also affected old-growth stands. Before settlement, gallery forests were grazed by bison, whose impact on pre-settlement forests was low, perhaps even negligible (Norland and Marlow 1984). Bison tend to spend less time than cattle do in watering areas. Bison also prefer open grassland to forest and favor grasses and forbs over browse. Cattle grazing and heavy deer browsing seem to have decreased saplings locally, especially elm (*Ulmus* spp.), along the Missouri River in North Dakota (Johnson et al. 1976). In contrast to undisturbed sites, more introduced species, such as prickly lettuce (*Lactuca serriola* L.), green foxtail [*Setaria viridis* (L.) Beauv.], and burdock [*Arctium minus* (Hill) Bernh.] were found in disturbed gallery forests in North Dakota, possibly as a result of past cultivation in the area (Keammerer et al. 1975). Other studies in more upland forests on the Great Plains have also shown changes in species composition associated with extensive grazing (Girard et al. 1987). Floristic composition changes with varying degrees of grazing in woody draws in North Dakota (Girard et al. 1987). Herbaceous cover was found to differ between grazed and ungrazed forests in Oklahoma. Extensive areas of Virginia wild rye (*Elymus virginicus* L.) occur in ungrazed areas and a greater abundance of giant ragweed (*Ambrosia trifida* L.), wing-stem (*Verbesina helianthoides* Michx.), pokeweed (*Phytollaca americana* L.), and Johnson-grass [*Sorghum halepense* (L.) Pers.] occur in grazed areas (Rice 1965).

Old Growth versus Younger Stands

The various trees, shrubs, and herbs found in gallery forests are listed in table 1. Woody plant composition in old gallery forests tends to vary greatly, especially the degree of dominance by cottonwood, American elm (*U. americana* L.), green ash (*Fraxinus pennsylvanica* Marsh.), and boxelder (*Acer negundo* L.). This may suggest that environmental variables not necessarily associated with stand age may influence the structure of old gallery forests. Variable patterns of erosion and sediment deposition may promote gallery forest heterogeneity in terms of tree age and spatial distribution of different plant communities (Johnson et al. 1976). Because of past disturbances, old gallery forests generally tended to occupy less area on the floodplains than younger gallery forests. This was found to be the case in North Dakota (Everitt 1968), although the situation is probably reversed today.

Plant diversity was found to be a function of stand age in gallery forests along the Missouri River in North Dakota. Diversity increased proportionally with stand age, dropping off just slightly in stands over 200 years old (Johnson et al. 1976). Old stands also had more water available due to fine textured soils with abundant organic material (Johnson et al. 1976). Moist soil conditions in old forests may account for the high diversity of herbs, shrubs, and trees.

Old stands have more dead limbs with total dead limb length ranging from 1,717 to 3,527 feet per acre [21 to 43 m per 0.04 hectare (ha) plot], standing snags ranging from 4.9 to 9.3 feet per acre (12 to 23 per ha), and a higher number of cavities ranging from 19 to 30 cavities per acre (46 to 73 cavities per ha) than younger stands. These cavities are used extensively by cavity-nesting birds such as the American kestrel, northern flicker, and red-headed woodpecker (Sedgwick and Knopf 1990).

Potential Old-Growth Reference Stands

Although no representative stands recognized as this forest type have been field verified, the following stands, cited in the literature, potentially could be recognized as representative:

1. South Dakota: scattered stands between Lake Sakakawea and Oahe Reservoir in the central Missouri River Valley (Keammerer et al. 1975, Johnson et al. 1976).

2. Alberta, Canada: southeastern part of the province along the Milk River, 18.63 miles [30 kilometers (km)] upstream from Fresno Reservoir (Bradley and Smith 1986).

3. Montana: north-central part of the State along the Milk River, 15.53 miles (25 km) down from the Fresno Reservoir (Bradley and Smith 1986).

4. North Dakota: a 0.621-mile (1-km) section along the Little Missouri River in the North Unit, Theodore Roosevelt National Park (Everitt 1968).

5. Colorado: an 18.63-mile (30-km) stretch along the South Platte River near Crook, Logan County (Sedgwick and Knopf 1986).

6. Nebraska: stands along the Lower Platte River Valley approximately 18.63 miles (30 km) southwest of Omaha (Rothenberger 1985).

Composition of Western Gallery Hardwood Forests

Cottonwood is the most characteristic tree species of this type. It is found in all the successional stages and occupies the greatest basal area at most stages (table 2). Willow species, such as peachleaf willow (*Salix amygdaloides* Anderss.), sandbar willow (*S. exigua* Nutt.), black willow (*S. nigra* Marsh.), yellow willow (*S. lutea* Nutt.), and pussy willow (*S. eriocephala* Michx.), are also characteristic of gallery forests but are dominant primarily in the early successional stages (Weaver 1960). The vegetation composition of gallery forest varies greatly because of its wide geographic extent. American elm is found throughout the range of the gallery forest type, but its importance increases in the eastern and northern parts of the forest range, especially in the late successional stages. However, Dutch elm disease has diminished the importance of American elm in gallery forests, as it has in many other community types in the Eastern United States.

Green ash is also found throughout the range, except in Texas, extreme western Oklahoma, and southern Colorado. It generally increases in importance as stands age. Green ash establishes itself in mesic conditions typical of the Eastern United States. These conditions occur only at the later stages of floodplain succession (Wilson 1970), and green ash is often the dominant species in terms of abundance (Johnson 1950). Slippery elm (*U. rubra* Muhl.)

Table 1—Trees, shrubs, and herbs found in the various regions of western gallery forests[a b]

Common trees	Common shrubs	Common herbs and grasses
Acer negundo L.	*Amelanchier alnifolia* (Nutt.) Nutt. (3)	*Ambrosia trifida* L. (1)
A. saccarinum L. (2)	*Amorpha fruticosa* L. (2)	*Anemone canadensis* L. (3)
Carya illinoensis (Wangenh.) K. Koch (1)	*Celastrus scandens* L.	*Andropogon gerardii* Vitman (2)
Catalpa speciosa Warder ex Engelm. (2)	*Clematis ligusticifolia* Nutt.	*Apocynum cannabinum* L. (2)
Celtis occidentalis L. (1, 2)	*Cocculus carolinus* (L.) DC. (1)	*Aster laevis* L. (3)
Diospyros virginiana L. (1)	*Cornus amomum* Mill. (3)	*Astragalus gracilis* Nutt. (3)
Fraxinum pennsylvanica Marsh.	*C. drummondi* Meyer	*Bromus tectorum* L. (2)*
Gleditsia triacanthos L. (2)	*C. foemina* Mill. (3)	*Carex* spp.
Juglans nigra L.	*C. racemosa* Lam. (3)	*Conium maculatum* L. (2)
Juniperus scopulorum Sarg. (3)	*C. stolonifera* Michx. (3)	*Cyperus esculentus* L. (1)
J. virginiana L. (2)	*Corylus americana* Walt. (2)	*Digitaria sanguinalis* (L.) Scop. (1)
Plantanus occidentalis L. (2)	*Elaeagnus augustifolia* L.*	*Distichlis stricta* (Torr.) Rydb. (2)
Populus deltoides var. *occidentalis* Rydb.	*Maclura pomifera* (Raf.) Schneid. (2)*	*Echinochloa crusgalli* (L.) Beauv. (2)
Prunus serotina Ehrh. (2)	*Morus alba* L. (3)	*Elymus canadensis* L.
Quercus macrocarpa Michx. (3)	*M. rubra* L. (2)	*E. virginicus* L. (1)
Salix amygdaloides Anderss.	*Parthenocissus quinquefolia* (L.) Planch.	*Equisetum* spp.
S. eriocephala Michx. (2, 3)	*Prunus americana* Marsh. (2)	*Erigeron philadelphicus* L. (3)
S. exigua Nutt. (2)	*P. virginiana* L.	*Galium aparine* L. (2)*
S. lutea Nutt. (2, 3)	*Rhamnus lanceolata* Pursh (2)	*Gaura parviflora* Dougl. (2)
S. nigra Marsh.	*Rhus glabra* L.	*Helianthus grosseserratus* Martens (2)
Sapindus drummondii Hook. & Arn. (1)	*R. trilobata* var. Barkley (2)	*H. tuberosa* L. (2)
Tamarix parviflora L.*	*Ribes missouriense* Nutt.	*Heliopsis helianthoides* (L.) (2)
T. ramosissima Ledeb..	*Rosa woodsii* Lindl.	*Kochia scoparia* (L.) Roth (2)*
Tilia americana L.	*Rubus occidentalis* L.	*Medicago lupulina* L.*
Ulmus americana L.	*Sambucus canadensis* L. (2)	*Melilotus officinalis* (L.) Lam. (3)*
U. pumila L. (2)*	*Shepherdia argentea* Nutt. (3)	*Oxalis stricta* L. (3)
U. rubra Muhl. (2)	*Smilax hispida* (Muhl.) Fern.	*Panicum virgatum* L. (3)
	Symphoricarpos occidentalis Hook.	*Phalaris arundinacea* L. (3)*
	S. orbiculatus Moench (1)	*Phlox pilosa* L. (3)
	Toxicodendron radicans Ktze.	*Phragmites communis* Trin. (2)*
	Vitis vulpina L.	*Phytollaca americana* L. (1)
	Zanthoxylum americanum L. (3)	*Poa pratensis* L. (3)*
		Rumex crispus L. (2)*
		Salsola kali L. (2)*
		Smilacina stellata (L.) Desf.
		Solidago altissima sensu Mackenz.
		Sorghum halepense (L.) Pers. (1)*
		Spartina pectinata Link. (2)
		Sporobolus airoides Torr. (2)
		Strophostyles helvola (L.) Ell. (3)
		Thalictrum venulosum Trel. (3)
		Verbesina helianthoides Michx. (1)
		Xanthium spp. (1, 2)*

(1) = species found primarily in the southern range; (2) = species found primarily in the central part of the range; (3) = species found in the northern extent of the forest range; * = nonnative species.

[a] Species without numbers in parentheses are common throughout the range of the gallery forest.
[b] Nomenclature follows *Flora of the Great Plains* (Great Plains Flora Association 1986).

Table 2 (English units)—Table of old-growth attributes for western gallery hardwood forests

Quantitative attribute	Selected examples	Mean	No. of stands
	Number per acre		
Stand density	Total: 482 (NE)[a], 117 (ND)[b], 230 (ND)[c]	Total trees: 276	54
Acer negundo L.	42 (ND)[c]		
Fraxinus pennsylvanica Marsh.	75 (ND)[b], 77 (ND)[c]		
Populus deltoides ssp. *monilifera* (Ait.) Eckenwalder	60 (ND)[b], 77 (ND)[c], 10 (CO)[d]		
Salix amygdaloides Anderss.	2 (ND)[c]		
Ulmus americana L.	28 (ND)[c]		
	Feet² per acre		
Stand basal area	Total: 279 (NE)[a], 124 (ND)[c]	Total: 202	53
A. negundo L.	1.7 (NE)[a], 19 (ND)[c]		
Celtis occidentalis L.	3.9 (NE)[a]		
Trees >1 in. for [a] *Cornus drummondii* C.A. Meyer	3 (NE)[a]		
Trees >4 in. for [c] *F. pennsylvanica* Marsh.	8 (NE)[a], 20 (ND)[c]		
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	186 (NE)[a], 60 (ND)[c], 15 (CO)[d]		
S. amygdaloides Anderss.	4.7 (NE)[a], 23 (ND)[c]		
U. americana L.	0.9 (NE)[a], 22 (ND)[c]		
	Years		
Age of large trees	Total: 100–141+ (KS)[e]		5
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	90+ (KS)[f], 80+ (SD)[g], 200+ (ND)[c h], 90–110 (MT/Canada)[i]	145	
Quercus macrocarpa Michx.	300–350 (ND)[c]		
S. amygdaloides Anderss.	200–250 (ND)[c]		
U. americana L.	300–350 (ND)[c]		
	Inches		
Maximum d.b.h.			
F. pennsylvanica Marsh.	27 (ND)[c]		6
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	30–41 (NE)[a], 58 (CO)[d], 72+ (KS)[f], 24–36 (ND)[h j], 76 (ND)[c]	53	
U. americana L.	41 (ND)[c]		
Standing snags	Total: 33.7 (OK)[k]		11
F. pennsylvanica Marsh.	13.2 (OK)[k]		
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	0.1 (OK)[k], 0.3 (CO)[d]	0.2	
U. americana L.	8.9 (OK)[k]		

Table 2 (English units)—Table of old-growth attributes for western gallery hardwood forests (continued)

Quantitative attribute	Selected examples	Mean	No. of stands
	Number per acre		
Downed logs	Downed cottonwood cited as "common" in older forest[c]		
Decadent trees	Majority of trees cited as "decadent"[d]		
	Number		
Canopy layers	2: dense shrub layer and an open cottonwood canopy (SD)[g] "multiple synusiums" in old-growth forests (ND)[c j]		
Canopy in gaps	Canopy described as "open" Large trees widely spaced (SD, ND)[b c g j l]		
	Feet		
Other: canopy height	Total: 49–52 (CO)[m]		3
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	59–79 (ND)[c], 98 (ND)[j]	23	

CO = Colorado, KS = Kansas, MT = Montana, NE = Nebraska, ND = North Dakota, OK = Oklahoma, SD = South Dakota.

References: [a] Rothenberger 1985, [b] Girard et al. 1989, [c] Johnson et al. 1976, [d] Sedgwick and Knopf 1986, [e] Spencer et al. 1984, [f] Tomelleri 1984, [g] Johnson 1950, [h] Everitt 1968, [i] Bradley and Smith 1986, [j] Keammerer et al. 1975, [k] Penfound 1956, [l] Girard et al. 1983, [m] Sedgewick and Knopf 1990.

Table 2 (metric units)—Table of old-growth attributes for western gallery hardwood forests

Quantitative attribute	Selected examples	Mean	No. of stands
	Number per hectare		
Stand density	Total: 1191 (NE)[a], 289 (ND)[b], 568 (ND)[c]	Total trees: 682	54
Acer negundo L.	104 (ND)[c]		
Fraxinus pennsylvanica Marsh.	185 (ND)[b], 190 (ND)[c]		
Populus deltoides ssp. *monilifera* (Ait) Eckenwalder	48 (ND)[b], 190 (ND)[c], 25 (CO)[d]		
Salix amygdaloides Anderss.	5 (ND)[c]		
Ulmus americana L.	64 (ND)[c]		
	Meters² per hectare		
Stand basal area	Total: 279 (NE)[a], 28.5 (ND)	Total: 46.4	53
A. negundo L.	0.390 (NE)[a], 4.36 (ND)[c]		
Celtis occidentalis L.	0.895 (NE)[a]		
Trees >2.54 cm for [a] *Cornus drummondii* C.A. Meyer	3 (NE)[a]		
Trees >10.16 cm for [c] *F. pennsylvanica* Marsh.	8 (NE)[a], 20 (ND)[c]		
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	186 (NE)[a], 60 (ND)[c], 15 (CO)[d]		
S. amygdaloides Anderss.	4.7 (NE)[a], 23 (ND)[c]		
U. americana L.	0.9 (NE)[a], 22 (ND)[c]		
	Years		
Age of large trees	Total: 100–141+ (KS)[e]		5
P.deltoides ssp. *monilifera* (Ait.) Eckenwalder	90+ (KS)[f], 80+ (SD)[g], 200+ (ND)[c h], 90–110 (MT/Canada)[i]	145	
Quercus macrocarpa Michx.	300–350 (ND)[c]		
S. amygdaloides Anderss.	200–250 (ND)[c]		
U. americana L.	300–350 (ND)[c]		
	Centimeters		
Maximum d.b.h.			
F. pennsylvanica Marsh.	68.6 (ND)[c]	134.6	
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	76.2–104.1 (NE)[a], 147.3 (CO)[d], 182.9+ (KS)[f], 61.0–91.4 (ND)[c j], 193.0 (ND)[c]		
U. americana L.	104.1 (ND)[c]		
Standing snags	Total: 83.3 (OK)[k]	0.494	11
F. pennsylvanica Marsh.	32.6 (OK)[k]		
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	0.247 (OK)[k], 0.741 (CO)[d]		
U. americana L.	22.0 (OK)[k]		

Table 2 (metric units)—Table of old-growth attributes for western gallery hardwood forests (continued)

Quantitative attribute	Selected examples	Mean	No. of stands
	Number per hectare		
Downed logs	Downed cottonwood cited as "common" in older forest[c]		
Decadent trees	Majority of trees cited as "decadent"[d]		
	Number		
Canopy layers	2: dense shrub layer and an open cottonwood canopy (SD)[g] "multiple synusiums" in old-growth forests (ND)[c j]		
Canopy in gaps	Canopy described as "open" Large trees widely spaced (SD, ND)[b c g j l]		
	Meters		
Other: canopy height	Total: 14.9–15.8 (CO)[m]		
P. deltoides ssp. *monilifera* (Ait) Eckenwalder	18.0–24.1 (ND)[c], 29.9 (ND)[j]	7.01	3

CO = Colorado, KS = Kansas, MT = Montana, NE = Nebraska, ND = North Dakota, OK = Oklahoma, SD = South Dakota.

References: [a] Rothenberger 1985, [b] Girard et al. 1989, [c] Johnson et al. 1976, [d] Sedgwick and Knopf 1986, [e] Spencer et al. 1984, [f] Tomelleri 1984, [g] Johnson 1950, [h] Everitt 1968, [i] Bradley and Smith 1986, [j] Keammerer et al. 1975, [k] Penfound 1956, [l] Girard et al. 1983, [m] Sedgewick and Knopf 1990.

occurs throughout the eastern part of the region. Siberian elm (*U. pumila* L.), an introduced species from Asia, is common throughout the gallery forests. Persimmon (*Diospyros virginiana* L.) and pecan [*Carya illinoense* (Wangenh.) K. Koch] are found primarily in the southern part of the gallery forest range in Oklahoma, Texas, and eastern Kansas (Brumwell 1951). Hackberry (*Celtis occidentalis* L.) is found throughout the range except for the western region. Sycamore (*Platanus occidentalis* L.) is also a common floodplain tree that occurs in the southeastern part of the gallery forest range. Black walnut (*Juglans nigra* L.) and basswood (*Tilia americana* L.) are common in the older forests in the eastern range. Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) is common in the northwestern part of the range, and eastern redcedar (*J. virginiana* L.) is common in the central and eastern parts. The range of redcedar has been expanding due to a decrease in fire frequency across the Great Plains (Rothenberger 1985).

Saltcedar, a species introduced from Eurasia for windbreak plantings, has dramatically increased in abundance within the past 50 years, especially in eastern Colorado, New Mexico, and western Kansas and Oklahoma. The increase in establishment sites for saltcedar seems to be due primarily to a decrease in springtime flash floods and water level fluctuations (Gesink et al. 1970).

The most common shrubs and lianes found throughout this type are winter grape, Virginia creeper, and poison ivy [*Toxicodendron radicans* (L.) Kuntze]. Another important shrub is hazelnut (*Corylus americana* L.), common in North Dakota and the eastern parts of South Dakota, Nebraska, Kansas, and northeastern Oklahoma. Roughleaf dogwood (*Cornus drummondii* C.A. Meyer) is quite common in gallery forests in the southeastern part of their range, but its basal area is minimal due to its small size: between .99 and 3.11 inches (2.5 and 7.9 cm in diameter at breast height) (Gesink et al. 1970, Rothenberger 1975). Osage-orange [*Maclura pomifera* (Raf.) Schneid.] is a common native tree in eastern Texas and Oklahoma, but now occurs north and west of its native range into southeastern South Dakota. Buffalo berry [*Shepherdia argentea* (Pursh) Nutt.] and Saskatoon serviceberry [*Amelanchier alnifolia* (Nutt.) Nutt.] occur commonly in the northern part of the gallery forest range.

The oldest stands always contain very old, large, relic cottonwoods but few young cottonwoods because of their inability to reproduce in the shade (Everitt 1968, Keammerer et al. 1975). Green ash is becoming a more important component in northern gallery forests along the Missouri River as establishment sites for cottonwood, willow, elm, and boxelder decrease due to flood control (Johnson et al. 1976). In some North Dakota gallery forests, Rocky Mountain juniper is becoming an increasingly dominant tree in the older forests (Everitt 1968).

Age of trees and geographic location, which vary greatly, help determine the dominant canopy of a western gallery forest. A bottom-land forest in Oklahoma along the South Canadian River, for example, is dominated by green ash, with cottonwood a major secondary species and willow absent as a major species (Rice and Penfound 1956). In the same area, sandy flats along the river are nearly barren except for sandbar willow, cottonwood, and saltcedar. In western Kansas, early pioneers of the late 1800's cited only four woody species commonly present along the Arkansas River: plains cottonwood, sandbar and peachleaved willow, and false indigo (*Amorpha fruticosa* L.). Today, peachleaved willow and false indigo are rarely found in this area (Tomelleri 1984), though both can be found in eastern Kansas (Gesink et al. 1970).

Boxelder is a small tree that is commonly found but often in poorly drained areas with frequent standing water (Rothenberger 1985). Gallery forests in the eastern portion of the range, with higher terraces above the floodplain, may have a mixture of bur oak (*Quercus macrocarpa* Michx.) with the more mesic tree species, such as elm and ash, forming the boundary between forest and prairie (Keammerer et al. 1975).

The shrub component in old gallery forest is generally described as impenetrable because the extremely dense shrub and vine cover make walking difficult (Johnson 1950). Sumac (*Rhus* spp.) can be dominant in the Missouri River forests in South Dakota when human disturbance is absent (Johnson 1950). Gallery forests in North Dakota and eastern Colorado have a high cover of wolfberry (*Symphoricarpos occidentalis* Hook) and Wood's rose (*Rosa Woodsii* Lindl.), as well as a dense understory of green ash saplings (Sedgewick and Knopf 1986, Girard et al. 1989). Woody vines can be particularly abundant in moist areas in the older forests, including winter grape, poison ivy, virgin's-bower (*Clematis virginia* L.), and Virginia creeper. Chokecherry (*Prunus virginiana* L.) and Russian-olive (*Elaeagnus augustifolia* L.), an exotic but now naturalized species in the region, can occasionally attain tree size in northern gallery forests. Chokecherry is found in the older, more mesic forest stands and Russian-olive in younger cottonwood stands (Johnson et al. 1976). Old forests in North Dakota rarely have a closed crown cover, allowing sufficient light for a highly prolific herb and shrub component (Keammerer et al. 1975).

The herbaceous and grass species found in gallery forests vary greatly with geographic location. The prairie grasses, forbs, and shrubs that occur adjacent to this forest type are generally found within the transition zone between forest and prairie. Big blue-stem (*Andropogon gerardii* Vitman) and other tallgrass species are found within gallery forests in Kansas (Weaver 1960) and Oklahoma, mixed tall and shortgrass prairie species, as well as sand sagebrush (*Artemisia filifolia* L.), are found near gallery forests of eastern Colorado (Sedgwick and Knopf 1986), and shortgrass species are found in the transitional area between northern gallery forests and grassland (Johnson et al. 1976). Herbaceous ground cover also varies with grazing intensity, as was found in Oklahoma bottom-land forests (Rice 1965) and North Dakota riparian woodlands (Girard et al. 1987). Green ash and American elm are particularly susceptible to grazing damage (Girard et al. 1987). Today, much of the land bordering gallery forests is agricultural (Rothenberger 1985, Sedgwick and Knopf 1990).

Old-Growth Quantitative Attributes

Table 2 lists the major quantitative attributes found in old-growth western gallery forests. The total density of tree stems varies greatly among sites, as well as among species. The number of trees per acre ranged from 117 to 482 (289 to 1191 per ha) in Nebraska along the Platte River. Although peachleaved willow is one of the few woody species to establish itself in the early successional stages, its density and basal areas are quite limited in the old-growth type, ranging from 1.1 square feet per acre (0.0413 m^2 per ha) in Nebraska along the Platte, to 5.4 square feet per acre (0.203 m^2 per ha) along the Missouri in North Dakota. In North Dakota gallery forests, both peachleaved willow and cottonwood increase in importance with increasing proximity to the river's edge, regardless of the age of the stand. The opposite relationship is found for green ash, boxelder, and American elm (Johnson et al. 1976). Old forests can have an extremely thick layer of green ash saplings, ranging from 400 to 2,400 stems per acre (488 to 5,930 stems per ha), and over 400 American elm and boxelder saplings per acre (988 per ha) (Johnson et al. 1976, Girard et al. 1989). Few cottonwood and willow saplings were found in gallery forests of various ages in North Dakota due to their inability to reproduce under their own dense shade (Johnson et al. 1976).

Although green ash can outnumber cottonwood, and American elm can come close, neither rival the basal area cottonwood contributes to old-growth stands due to the massive size of old trees with diameters close to 6 feet (1.83 m). Bur oak is often found to be the oldest tree in this type with some trees over 300 years old. However, as stands age it becomes increasingly difficult to determine tree age, especially for cottonwood because of its porous growth rings (Everitt 1968) and the increased decay inside older trees. Growth cores generally underestimate actual age (Bradley and Smith 1986).

In a Nebraska study, the absolute frequency of lianes (number of lianes per total number of trees) is higher for this forest than for upland and transitional type forests (Rothenberger 1985). Nearly 36 percent of all woody species in these western hardwood gallery forests are vines.

Downed woody debris and standing snags are characteristic of old-growth gallery forests, with downed wood, especially cottonwood, frequently cited as "common." Standing snags range from 33.7 trees per acre (83.3 trees per ha) in bottom-land forests of Oklahoma to 0.3 cottonwood trees per acre (0.741 per ha) in northeastern Colorado.

Canopy height can range from 59.06 feet to 98.4 feet (18 to 30 m) for cottonwood trees found along the Platte River in Nebraska (Rothenberger 1985). The forests here have multiple layers, although two layers are most distinct: the open canopy and a dense, shrubby, "impenetrable" undergrowth.

Historic versus Present-Day Forests

Before the era of extensive flood control, which began in the 1960's, drought and overgrazing were cited as causing deterioration of an old bottom-land forest in Oklahoma (Penfound 1953). Historically, the forests did not establish readily along rivers due in part to the extremely variable nature of the environment, as well as fire (Gesink et al. 1970, Tomelleri 1984, Rothenberger 1985). Along the South Canadian River in Oklahoma and the Missouri River in South Dakota, flash flooding and shifting sand uprooted establishing plants (Ware and Penfound 1949, Van Bruggen 1961). Drought, high evaporation rates, and the intense heat of the sandy flats also inhibit germination of many species. Cottonwood, willow, and saltcedar are able to establish during the flood season and grow extensive root systems and tall stems quickly, improving their chances of survival. Saltcedar, unlike willow and cottonwood, is able to disperse seeds throughout the growing season, which increases its competitive ability in such areas (Ware and Penfound 1949).

Although gallery forests were widely scattered and rather sparse in the past, the small stands were important to early settlers and pioneers in eastern Colorado and western Kansas for firewood and construction (Gesink et al. 1970). When travel along the Santa Fe and Oregon Trails was at its peak, the north side of the Arkansas River was virtually bare of all trees, in part due to the heavy usage of timber by pioneers who traveled on this side of the river (Tomelleri 1984). Today there is a decrease in wooded area along the Arkansas River from east to west due to increased cultivation and grazing pressure in this region as well as increased mining of ground water for irrigation (Gesink et al. 1970).

The reduction in fire frequency in these areas today has led, in part, to a general expansion of shrubs and mesic species, especially in upland areas with historically high fire frequencies. The increase of eastern redcedar, a fire-sensitive species, along the Platte in Nebraska is attributed to decreased fire frequency in the area (Rothenberger 1985).

Historically, the establishment and growth of cottonwood forests were highly correlated with the river dynamics (Johnson et al. 1976, Rothenberger 1985, Bradley and Smith 1986). The current lack of spring flooding due to the presence of reservoirs is cited for the absence of young cottonwood stands along the Missouri, the Platte in Nebraska and Colorado, and the Milk in Montana. Flood control increases channel downcutting, reducing both floodplain width and "meandering." The high deposition that takes place in these meander areas, especially during floods, provides an adequate seedbed for cottonwood and willow species (Johnson et al. 1976). Minor flooding today can be caused by ice jams, but differences in peak flows are caused primarily by dam releases. Periodic flooding probably limits the distribution of American elm and green ash to the higher terraces of the floodplain. These higher terraces develop over many years of deposition around the established pioneer species of willow and cottonwood. The variability in historic meandering rates along the Missouri may help explain the varied age and composition of these forests (Johnson et al. 1976).

A study done in North Dakota along the Little Missouri River found that young cottonwood forests occupied more area than old-growth forests. This apparently was due to destruction of older forests by river channel migration, which constantly precluded formation of new suitable sites for seedling establishment (Everitt 1968). Today, with increased flood control and a subsequent decrease in meandering and channel migration, the situation probably would be reversed, with less area occupied by younger forests. A study done in southern Alberta above a series of dams along the Milk River and below the dams in northern Montana found that cottonwood recruitment was very low below the dams due to reduced peak flows, frequency of floods, rates of sedimentation, and meandering (Bradley and Smith 1986). Areas above the dams had higher densities of cottonwood along meandering areas. Cottonwoods produce viable seeds yearly in the spring, but successful establishment is sporadic and associated with a 5-year flooding cycle. Disruption of these flooding events has implications for the maintenance of this forest type (Bradley and Smith 1986).

Although historic accounts of wildlife present in gallery forests are limited, an expedition traveling in 1820 along the Platte River in northeastern Colorado observed bison, prairie wolves, antelope, and wild horses. The bottom-land habitat along rivers, such as the Platte, Missouri, and Arkansas, was probably poor for species requiring year-round water since these rivers would be periodically dry, usually in the fall and winter (Crouch 1979, 1984). Today these areas may provide better habitat for some wildlife because of increased year-round flow due to flooding control. However, the steady loss of large, old cottonwoods, coupled with poor regeneration, will affect cavity-nesting birds (Sedgwick and Knopf 1990) and other wildlife in these gallery forests (Rothenberger 1985).

Future Ramifications

The decrease in flooding and a corresponding decrease in the meandering rate caused by flood-management practices have changed the western hardwood gallery forest in terms of both its extent and its composition. Gallery forests are now limited to areas where trees were established before flood control, and species dominance in old forests is changing from cottonwood and willow to green ash. On a local scale, cultivation and increased grazing in these areas have also restricted forest distribution and changed overall composition (Johnson et al. 1976, Rothenberger 1985). Additionally, the presence of reservoirs and increased irrigation seems to have decreased the growth rate of the residual old trees as evidenced by significantly narrower growth rings in cottonwoods after reservoir installation along the Missouri (Johnson et al. 1976). In some western areas, loss of water to irrigation has killed some trees. Overall, flood control has decreased gallery forest area and landscape diversity along Great Plains rivers. This has jeopardized wildlife dependent on gallery forests for habitat, winter cover, and relief from summer heat. In general, survival of cottonwood on prairie rivers today is far from certain (Bradley and Smith 1986).

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Western hardwood gallery forests are found across an extremely large, diverse geographical area that encompasses the Great Plains in the United States and Canada. Remnant forests of this type still exist in the "Prairie Peninsula," which historically projected an eastern finger into Ohio. The forests are restricted to floodplains of major rivers and are in sharp contrast to the surrounding prairie. The name "gallery" forest refers only to forests that form a corridor of trees along river systems in the region. Disturbances associated with flooding, such as water and ice scouring as well as soil deposition, are required for the establishment of cottonwood and willow stands, pioneer species of this type. Today, the historic hydrology of all Great Plains rivers has drastically changed with the creation of dams and other flood-control measures. The western hardwood gallery forest has changed as well, with composition shifting from shade-intolerant species, such as cottonwood and willow, to shade-tolerant species, such as green ash. Consequently, there is little regeneration of this forest type.

Keywords: Cottonwood, gallery forests, old growth, willow.

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