United States
Department of
Agriculture

Forest Service

**Southern Forest
Experiment Station**

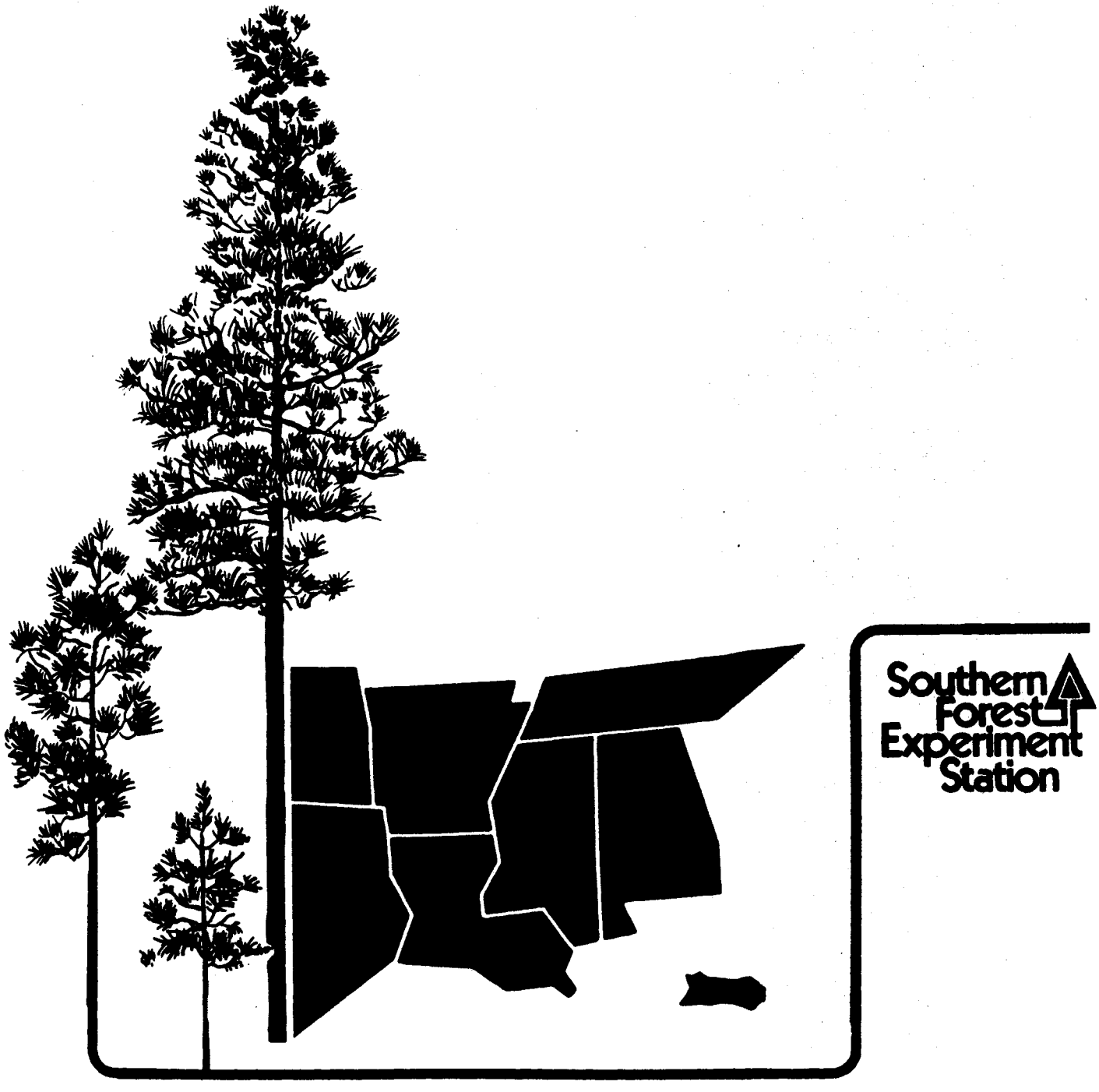
New Orleans,
Louisiana

Proceedings Reprint

SILVICULTURAL ALTERNATIVES IN BOTTOMLAND HARDWOODS AND THEIR IMPACT ON STAND QUALITY

Harvey E. Kennedy, Jr., and Robert L. Johnson

Reprinted from Proc., 14th Annual Southern
Forest Economics Workshop, Memphis, TN
March 13-15, 1984, p.6-18.



SILVICULTURAL ALTERNATIVES IN BOTTOMLAND HARDWOODS AND THEIR IMPACT ON STAND QUALITY

Harvey E. Kennedy, Jr., and Robert L. Johnson[1/]

Abstract.--Bottomland hardwoods occur on some 35 million acres of forest land in swamps, creek margins, river bottoms, and brown loam bluffs from Virginia to Texas. These hardwood types are very important because the wood has great value and is in demand by forest industries. This article discusses silvicultural alternatives such as site-species relationships, how hardwood timber is used, protection, timber stand improvement, thinning, choosing harvesting systems, and artificial regeneration as an alternative or supplement to natural regeneration. If the various alternatives are intensely and correctly applied, the landowner can produce quality hardwood timber that will command a premium price.

Additional keywords: Brown loam bluffs, site, regeneration, plantations, direct-seeding, forests.

Bottomland hardwoods occur on about 33 million acres of forest land in swamps, minor stream bottoms, and river bottoms from Virginia to Texas (McKnight and Johnson 1980). Another 2.0 million acres along the brown loam bluffs of the lower Mississippi Valley also produce high quality hardwoods (Sternitzke 1976).

The bottomland hardwood types are very important because the wood has great value and beauty and is highly sought after by forest industries. It is excellent as habitat for waterfowl, deer, squirrels, turkeys, and many varieties of non-game song birds.

The southern hardwoods are extremely diverse in species, site requirements, wood qualities, and uses. Certain species grow on particular sites; some occur in even-aged stands, but most grow in uneven-aged communities or forests. Factors entering into management decisions are complex. The landowner should study and know the various management alternatives but recognize that sound judgment, experience, and if needed, the advice of a professional forester can increase returns from management.

SITE-SPECIES RELATIONSHIPS

Most natural hardwood stands are hodgepodges of species ranging in age from seedlings to mature trees growing on a variety of soils. Johnson (1981), citing data from Putnam et al. (1960) and Hodges and Switzer (1979), lists eight species groups and associated physiographic positions in major stream valleys; these are:

1/ Principal Silviculturists, Southern Hardwoods Laboratory, Stoneville, Miss., maintained by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

Species group	Physiographic site
1. Cottonwood	New land
2. Elm--sycamore--pecan--sugarberry	High front or ridge
3. Sweetgum--water oaks	First bottom ridge
4. Red oaks--white oaks--mixed species	Second bottom ridge
5. Black willow	New land
6. Overcup oak--water hickory	Slough or low flat
7. Elm--ash--sugarberry	Flat
8. Cypress--water tupelo	Swamp

Species groups 1 through 4 generally, though not always, are found on relatively well-drained, medium-textured soils, while the others are found on poorly-drained, fine-textured soils (Johnson 1981).

Soils series, which are differentiated because of having different physical and chemical properties, comprise one of the more important variables related to species occurrence and stand development. Broadfoot (1976) describes 40 of the most important Midsouth soils that support quality hardwoods and the species that occur on each. Johnson (1981) computed occurrence and associated site indices for species of commercial importance that frequently make up natural stands based on 21 of the most common of these soils. These data are shown in table 1.

Many species occur over a wide range of soils (table 1). Commerce silt loam and Sharkey clay are two of the more common soils of the Midsouth. These soils differ greatly in physical and chemical properties. Sharkey has a very high nutrient level, but the high clay content makes the physical properties less desirable. It is very difficult to find soil moisture at a level where this soil can be worked. Commerce, on the other hand, has very good physical properties, works easily, and the nutrient levels, though lower than those of Sharkey, are high enough to supply trees with needed nutrient elements.

Many of the same species occur on these very different soils, but only four occur frequently and should be favored in management on both sites (Broadfoot 1976).

Once established, some species may produce nearly twice the volume during the first 10 to 15 years on Commerce than on Sharkey, especially in plantations. High pH, often associated with Commerce, may limit growth of most oaks. Cherrybark (Quercus falcata var. pagodifolia Ell.), water (Q. nigra L.) and Nuttall (Q. nuttallii Palmer) oaks seem unable to adjust to high pH (Kennedy 1984). Plantings of Shumard oak (Q. shumardii Buckl.), however, have survived and grown well.

Depth to the permanent water table and timing, frequency, and duration of flooding are very important variables in the establishment, survival, and growth of hardwoods. Some species such as cypress (Taxodium distichum (L.) Rich.) and water tupelo (Nyssa aquatica L.) can survive extended flooding, whereas other species such as cherrybark oak cannot. Species represented on an area will usually reflect whether it is a well- or poorly-drained site.

Table 1.--Species occurrence and associated site indices based on 21 common lowland soils (Broadfoot 1976)

Species	Frequent occurrence	Maximum site index[a]	
		Average	Range
	No. of soils[b]	Feet	
Sweetgum	19	108	95-120
Elms	16	84	70- 90
Green ash	13	91	80-100
Water oak	13	102	95-110
Willow oak	13	104	90-110
Cherrybark oak	10	110	90-120
Sugarberry	10	92	85-100
Hickories	8	91	75- 95
Nuttall oak	7	103	95-110
Water hickory	5	83	75- 90
Cottonwood	5	118	105-125
Overcup oak	4	88	85- 95
Honeylocust	3	83	75- 90
Pecan	3	107	90-115
Sycamore	3	125	120-130
Black tupelo	2	90	90
Swamp tupelo	1	90	90
Red maple	1	90	90
River birch	1	90	90

[a] Cottonwood values are based on 30 years, other species on 50 years.
[b] Out of 21 described by Broadfoot (Johnson 1981).

Drainage practices and harvesting systems used by man may complicate species occurrence and site evaluation. Many times, only certain species and sizes are harvested. His efforts may improve the forest but very often may reduce forest productivity by cutting trees that would enhance stand development.

If quality hardwoods are management's objective, then it is of utmost importance to have and manage the right species on the right sites.

HARDWOOD TIMBER USAGE

The end use of hardwoods determines the recommended type and intensity of management. Timber products range from extremely valuable face veneer to dunnage. Putnam et al. (1960) list the various products, primary form, value, species, and markets for hardwood products. Factory lumber is probably the most important in terms of volume. This lumber is used in furniture, flooring, architectural trim, and specialty products. The qualities sought after are beauty, hardness, and texture. The value of factory lumber is determined by the amount of clear wood between defects such as knots and insect damage. The veneer industry is the second-leading consumer of southern hardwoods (McKnight and Johnson 1980).

The round product that ranks second in volume consumed is pulpwood. Another product that has become very important in the past few years is fuelwood, either for home heating or industrial use. Although prices paid for these products are low compared to those for veneer or factory lumber, the pulpwood and fuelwood markets are important because they provide an outlet for low grade products from thinnings and other improvement cuttings.

Because large trees are the most valuable, they must not be damaged while trees are being felled during selective harvest. Harvesting techniques that cause the trunk to split or splinter can destroy much of the value of a butt log.

STAND DEVELOPMENT

Most useful hardwoods are intolerant, that is they do not grow or even long survive in shade. Reproduction of desirable species usually develops only in openings large enough to provide adequate sunlight. Seeds of Nuttall, willow (Q. phellos L.), laurel (Q. laurifolia Michx.), and overcup (Q. lyrata Walt.) oaks will germinate under a closed canopy, but the seedlings must be released within 3 or 4 years or they will die. Scattered individuals or groups may slowly develop for a number of years in partial light of small openings. Without release, however, they usually die before reaching commercial size. Other species such as tupelos, yellow-poplar (Liriodendron tulipifera L.), and sweetgum (Liquidambar styraciflua L.) may germinate profusely but survive only as long as sunlight is available from above (McKnight and Johnson 1980).

Eastern cottonwood (Populus deltoides Bartr. ex Marsh.) and black willow (Salix nigra Marsh.) originate and develop in pure, even-aged stands. They require bare, moist, mineral soil for germination and for the first few weeks of growth. They will tolerate only limited overhead shade for short periods.

Baldcypress and tupelos will regenerate well only in swamps where seedbeds are moist, where other species are unable to cope with flooding, and where competition is limited to annual herbs and water-tolerant shrubs or small trees. Seeds will not germinate under water but will remain viable and germinate after flood waters recede. Once trees get above the annual high water, they develop rapidly with abundant sunlight.

Tolerant species are those that persist in the shade. Many, such as beech (Fagus grandifolia Ehrh.), mulberry (Morus rubra L.), dogwood (Cornus florida L.), American hornbeam (Carpinus caroliniana Walt.), persimmon (Diospyros virginiana L.), hickories, and magnolia (Magnolia grandiflora L.) are less desirable in management. They respond to release and can suppress reproduction of more desirable species. When given an equal start in full sunlight, however, intolerant species will outgrow the less desirable tolerants.

Sweetgum often develops in even-aged stands in old fields. Seedlings do well on these areas because they can withstand competition from weeds. Even-aged sweetgum stands often develop from sprouts (root and stump), following logging operations or where trees are killed back by fire. Yellow-poplar will also develop even-aged stands where fire or clearcutting has exposed bare, mineral soil (McKnight and Johnson 1980).

BEGINNING MANAGEMENT

The first step in hardwood management is not different from any other forest land management--you must find out what there is to work with and then plan management schemes. A simple reconnaissance will give the preliminary information needed for beginning management. Early work should locate areas of especially valuable timber and open areas or unproductive sites. Damage to growing stock and density of cull or weed trees should be determined. For operable areas, logging conditions and available markets should be determined. Season of cutting will depend upon drainage, soil conditions, accessibility, and frequency and duration of flooding. Also, in the preliminary work, possibilities for enhancing game habitat as well as opportunities to improve recreation and esthetics should be noted.

Protection

It is important to eliminate fires completely. Hot fires can kill young trees and damage larger hardwoods. Wounds on hardwoods provide entry sites for insects or decay-causing organisms. Rots may advance up the trunk at the rate of 1 to 2 feet per decade.

Seasonal or periodic droughts cause forests to dry and create conditions that allow fires on sites that are normally too wet to burn. The landowner must stay alert during periods of high fire danger. Fires may start on drier pine sites and sweep through hardwoods on wetter sites. Fires built by hunters for warmth or to smoke game out of den trees is another potential hazard (McKnight and Johnson 1980).

Regeneration can be threatened by uncontrolled grazing or browsing of animals. Hogs will eat the mast of oaks and hickories and pull seedlings out of the ground. Cattle and deer will browse the current year's growth on trees less than 5 feet tall. Large concentrations of cattle and hogs can retard growth in older trees and reduce regeneration through soil compaction and thus less water percolation. Beavers build dams that cause water to flood wide areas of bottomlands and kill the hardwood timber. They also girdle and cut down prime growing stock.

Timber Stand Improvement

A history of fire, highgrading, liquidation cuts, and other destructive influences have created numerable forests with a high proportion of trees that are undesirable as future growing stock. Low-grade, overmature, damaged or cull trees and trees of undesirable species will be occupying space and competing for light, water, and nutrients that should support more valuable trees. Therefore, the first step a forester can take after arranging for protection is an improvement cut to clean up the forest.

Many times the stand will withstand a commercial improvement cutting to remove overmature, damaged, or dying trees of marketable size and quality. Some growing stock trees may have to be cut to make openings for regeneration or to have enough timber for buyers to be interested. However, one should not remove a large component of desirable growing stock just to make a sale. Such trees often are producing quality wood at a relatively high interest rate and should be held to allow the landowner to take advantage of high stumpage prices for hardwoods.

After improvement cuts, cull and weed trees should be killed to enlarge or clear openings for regeneration. Such trees are usually numerous in previously unmanaged stands, and killing them makes room for desirable trees and provides growing space for trees already established.

Several good herbicides are available for injecting trees. Users should be careful and follow label directions when applying any herbicide. Species, site, and time of herbicide application cause variations in results, so blanket recommendations cannot be made. Generally, the time of full leafing in the spring gives good results, but satisfactory results have been obtained with applications in other seasons.

Faust (1983) reported that timber stand improvement cuts on property of the Emory River Land Company[2/] were paying their own way. The Company has gradually worked over its property during a 29-year period. In addition to improvement cuts, Emory started removing culls and undesirable species with a number of girdling and poisoning techniques. Best results were from injecting Tordon 101R, and 24,000 acres were gone over at a cost of $3.65 per acre. Cull trees were reduced from six per acre in 1964 to two per acre in 1983.

Faust reported that from 1954 through 1982 Emory increased total sawtimber volume from 72.5 to 186.2 million board feet, a 250 percent increase; average sawtimber volume from 2,400 to 5,100 board feet per acre, a 210 percent increase; annual growth per acre from 137 to 262 board feet, a 190 percent increase; and volume in preferred species from 36 percent to 65 percent, a 190 percent increase. The Company can now sustain an annual harvest of 5 million board feet, which would remove 58 percent of the annual growth, with 42 percent being added to the reserve stand.

THINNING

Although the trend is changing, there have been very few thinnings in pulpwood-size hardwood and practically no precommercial thinning (Johnson 1981). However, increasing pulpwood and firewood markets may make it profitable to do thinnings in small hardwoods. Historically, the first commercial thinnings have started when trees reached small sawtimber size, about 14 inches dbh. A second thinning may be done when trees reach 20 to 22 inches dbh.

Because of inherent growth differences among species, it would be hard to give an average age for the first thinning. Cottonwood may reach merchantable size by age 5 to 10, whereas it may take green ash (Fraxinus pennsylvanica Marsh.) 20 to 30 years to reach pulpwood or small sawtimber size.

Findings thus far in natural and planted stands offer some guidelines for thinning (Johnson 1981). Thinning should begin early, and larger trees with well-developed crowns should be favored. For good diameter growth, most species require a minimum live crown to total height ratio of 40 percent. Trees with less crown are usually in a subordinate position, so thinning is from below. The main advantages of frequent, light thinnings over heavy, infrequent

---

[2/] The use of trade, firm, or corporation names in this paper does not constitute endorsement by the Forest Service or the U.S. Department of Agriculture.

thinnings are fuller utilization of the site and less chance for epicormic branches to develop on leave trees. Epicormic branches are particularly prone to develop on sweetgum. The disadvantage of frequent thinnings is the greater chance of logging damage to residual trees.

Thinning will allow for utilization of trees that would otherwise die and will allow distribution of growth over fewer, larger trees. A rule for thinning black willow is to provide a tree spacing in feet equal to 1.75 times the average tree diameter in inches (Johnson and McKnight 1969). After thinning, basal areas per acre of 70 for sweetgum (Johnson 1968) and 100 for cypress (Williston et al. 1980) have been recommended.

Schlaegel (1982)[3/] examined thinning in six natural stand studies and one plantation spacing trial. In all cases, even light thinning treatments proved better economically than no thinning. Heavier thinnings were better financially, but several factors need to be considered. Long-term objectives of the owner are the main consideration, but discount rates also affect the outcome. High discount rates favor heavier thinnings by placing more weight on the value removed at thinning; lower rates favor lighter thinnings.

REGENERATION SYSTEMS

Five harvest or regeneration systems are recognized that will, in varying degrees, naturally regenerate hardwood forests (McKnight and Johnson 1980); a brief discussion of each follows:

Single-tree Selection

Single commercially mature, suppressed, or damaged trees are removed at frequent intervals. The amount of cuttings is controlled by the growth of the stand. There are a number of advantages and disadvantages to this system. Some disadvantages are that it opens the stand up gradually, and unless correctly applied, can encourage less desirable species to become established in small openings, damage to residual trees, and epicormic branching. Some advantages are that it allows flexibility for natural site-species variation, permits more control over reproduction, favors growing stock wherever it may occur, and allows adjustment to changing markets (McKnight 1967).

Group Selection

Group selection amounts to clearcutting in patches ranging from a fraction of an acre to several acres. Trees around the perimeter of the opening cast seed over the cut area and thus aid in regeneration, yet few growing stock trees are cut. This system, if applied correctly, can accomplish desired timber management objectives without disturbing esthetics.

Shelterwood

Trees are harvested in stages to nurture reproduction. In effect, the system consists of heavy thinning and complete weeding before final harvest.

[3/] Schlaegel, Bryce E. 1982. Thinning bottomland hardwoods makes dollars and sense. 21 p. (Unpublished paper presented at the Southeast. Section, Soc. Am. For. Annu. Meeting, Mobile, AL, Jan. 20-22, 1982.)

It is used primarily to regenerate the heavy seeded species, particularly the oaks. After the desired reproduction is established, the shelter trees are removed in one or more cuts. This system should not be used for species that are intolerant in the seedling stage.

Seed Tree

This system is used primarily to regenerate light-seeded species over a large area. Eight to ten well-spaced seed trees per acre are left. Site preparation may be necessary if the desired species require bare, wet, mineral soil to get started. This method has not produced the desired results and is generally not recommended.

Clearcut

All merchantable trees are cut over an area of at least 10 acres (McKnight and Johnson 1980), and the remaining trees are either cut or removed. Clearcutting is best used where there is adequate advance reproduction and/or the trend is toward management in large blocks. This system will go through a jungle-like stage for about 10 years before individual stems restore a forest-like appearance to the area.

Most intolerant, light-seeded species require a bare, moist seedbed to become established. Conversely, seedlings of tolerant species such as hickories, oaks, elms, ashes, American hornbeam, eastern hophornbeam (Ostrya virginiana (Mill. K. Koch), and others may become established in small openings and persist for some time. If advance reproduction of these species is present when the overstory is removed, trees of these and similar species will assume dominance. If large holes are made in the overstory in one cutting, both the seedbed and light will usually favor light-seeded, intolerant species.

Sprouts from stumps and roots of cut trees may account for a high percentage of reproduction of sweetgum, oaks, ashes, hickories, ironwood, and blue beech. Rapid sprout growth enables them to assume a dominant position, and if sprouts are numerous, even fast-growing seedlings may have difficulty in competing.

Good regeneration following regeneration cuts using several of the above systems has been reported (Johnson and Krinard 1983, Hurst and Bourland 1980, Hurst and Myers 1982). Table 2 summarizes the harvest systems as they might apply in favoring certain species. Silvicultural relationships as well as financial management must be considered in choosing a harvesting system.

OAK DIRECT SEEDING

Most oak direct-sowings have failed in the South and elsewhere because rodents destroy the seed before germination (McKnight and Johnson 1980). There is still not a good rodent repellent on the market. Johnson (1983) has reported good results when freshly collected, untreated acorns of Nuttall, cherrybark, and Shumard oaks have been sown. Acorns performed best when sown 1 to 2 inches deep in large openings (at least 300 feet square) cleared within a forest. Rodents appear not to venture into openings this large, but they will destroy seedings in smaller openings.

Table 2.--Expected regeneration following harvest cutting systems in different species associations (Johnson 1981)

Species associations	Silvicultural systems	Species usually favored
Cottonwood	Seed tree with site preparation	Cottonwood
	Clearcut	Sycamore, sweet pecan, ash, boxelder
Black willow	Seed tree with site preparation	Black willow
	Clearcut	Hackberry, green ash, cypress, American elm, overcup oak, bitter pecan, Nuttall oak, privet
Cypress--tupelo	Group selection	Cypress, tupelo, and sometimes ash, overcup oak, bitter pecan, sweetbay
	Clearcut	Cypress, tupelo, and sometimes ash, overcup oak, bitter pecan or elm, maple, buttonbush, sweetbay
Elm--Sycamore--pecan--sugarberry	Group selection	Mixed hardwoods--sweetgum, water oaks, sycamore, sweet pecan, hackberry, ash
	Clearcut	Same as above
Elm--ash--hackberry	Clearcut	Elm, ash, hackberry, Nuttall and willow oak, swamp dogwood, deciduous holly
	Group selection	Elm, ash, hackberry, Nuttall and willow oak
Sweetgum--water oaks	Group selection	Sweetgum, water oak, ash
	Clearcut	Heavy to sweetgum, but also water oaks, ash
	Shelterwood	Water oaks, sweetgum, ash
Overcup oak--bitter pecan	Group selection	Overcup oak, bitter pecan
	Shelterwood	Overcup oak, bitter pecan, Nuttall oak, ash
Red oaks--white oaks--mixed spp.	Shelterwood	Red oaks, white oaks, water oaks, hickory, ash, ironwood, sweetgum
	Group selection	Same as above

Most direct-seeded oaks grow slowly for at least the first 5 years. They cannot compete with sprouts of several commercial species or seedlings of fast-growing, intolerant species. But, if the oaks become established and are not immediately overtopped, their growth rate and competitiveness improve with age.

Well-defined guidelines on oak direct-seeding are being developed at the Southern Hardwoods Laboratory at Stoneville, Mississippi (McKnight and Johnson 1980).

PLANTING

Knowledge gathered in recent years on hardwood planting indicates that it can be dependable with most species on suitable sites. Cottonwood has been the most widely planted species in the South. Sycamore (Platanus occidentalis L.) and sweetgum have also been fairly widely planted with good success. Other prime candidates for planting are green ash, several oaks, pecan (Carya illinoensis (Wangenh.) K. Koch), and yellow-poplar.

Research has provided five major rules for hardwood planting. These rules, given below, must be adhered to for successful plantings.

Species Must Be Suited to the Site

Guides have been developed to help the landowner get the proper species on the right site (Broadfoot 1976, Baker and Broadfoot 1979). In general, sandy and silt loam soils are better than coarse sands and clays. Both internal and surface drainage of soil are important.

Prepare the Site

Most planted hardwoods of intolerant, rapidly growing species are unable to compete with the weeds, vines, grasses, and other understory vegetation that grow on good hardwood sites. Such vegetation must be removed and the site prepared for clean cultivation (disking) before planting. If it is an old-field site, subsoiling to break any hardpans and summer fallowing to eliminate competing vegetation are recommended.

Use Good Planting Stock

Vigorous seedlings of good size should be used. Root-collar diameters should not be smaller than 0.25 inch and preferably 0.38 inch. Heights of 24 to 30 inches are desirable. If cottonwood cuttings are used, they should be taken from trees of apparently superior parentage, with diameters not smaller than 0.38 inch at the small end. Instructions from the nursery should be followed in handling the seedlings before planting.

Plant Properly

Hardwoods can be damaged by improper handling, such as letting roots dry or freeze. Seedlings should be planted with the root collar slightly below ground level. In Stoneville tests, 2- and 3-year-old oaks have been planted with the root collar 1 to 2 feet underground. Tops may be pruned to 1 or 2 feet above ground. Root pruning can be done on most species but should not be excessive. General guidelines on planting are given in table 3.

Table 3.--Hardwood and cypress planting information[a/]

Species and form of stock	Prune roots to: (in)	Good top length[b/] (in)	Adaptable to machine planting	Usual first-year growth	Survival on wet sites	Animal damage	Insect damage
Cottonwood cuttings	—	20[c/]	Yes	Good	Very poor	Deer, beaver	Borers, leaf beetles
Cottonwood seedlings	8	24	Yes	Good	Very poor	Deer, rodents, beavers	Borers, leaf beetles
Sweetgum seedlings	8	24[d]	Yes	Poor	Poor	Rabbits, deer, rodents, beavers	Forest tent caterpillar
Green ash seedlings	8	24	Yes	Good	Good	Rabbits, rodents, beavers	Ash borer, fall webworm
Sycamore seedlings	8	24	Yes	Poor to good	Poor	Deer	Sycamore lacebug, bagworm[g/]
Sycamore cuttings	—	20[e/]	Yes	Poor to good	Very poor[f/]	Deer	Sycamore lacebug, bagworm[g/]
Yellow-poplar seedlings	8	24	Yes	Good	Very poor	Deer, rodents	Tuliptree scale
Oak seedlings	8	24[d/]	Yes	Poor to fair	Nuttall, willow, water, overcup, others very poor	Rabbits, rodents, beavers	Twig girdlers, cicadas
Black walnut seedlings	8	15	Probably	Poor	Very poor[f/]	Rodents	Walnut caterpillar
Water tupelo seedlings	8	24	Site may prohibit	Fair	Good	Deer	Forest tent caterpillar
Baldcypress seedlings	8	24	Site may prohibit	Fair to good	Good	Rabbits	Spider mites, bagworm
Sweet pecan	8	18	Yes	Poor	Poor	Deer, rabbits, beavers	

[a/] McKnight and Johnson (1980) from Bonner, F. T. 1965. Seeding and Planting Southern Hardwoods. Auburn University Hardwood Short Course Proc. 1964: 28-40.

[b/] Determined mainly on basis of handling ease. All species can be top-pruned except ash, which forks because of its opposite-bud morphology. Root collar diameter should be 3/8" or larger.

[c/] May be shorter on sites where drought never occurs.

[d/] Seedlings should not be lifted from nursery until leaves have fallen off.

[e/] Only basal cuttings seem to root well.

[f/] Very exacting in site requirements; plant only on moist, well-drained soils.

[g/] The disease Anthracnose can be serious in localized areas.

Care for the Plantation

Cultivation to control weeds, vines, and grasses is desirable, even necessary, for most planted hardwoods (Kennedy and Henderson 1976). It improves survival and greatly increases growth. The degree of cultivation is a decision to be made by each landowner, but too little may jeopardize the whole investment.

Best growth for planted hardwoods occurs on good sites with medium-textured, moist, well-drained soils. Assuming that trees are planted on good sites where they naturally occur, depending on species, growth rates of 2 to 12 feet per year in height may be expected through the first 5 years. Most oaks, sweetgum, pecan, and green ash will grow 2 to 4 feet per year; sycamore and yellow-poplar, 3 to 6 feet; and cottonwood, 6 to 12 feet.

Plantation spacing should be about 12 feet apart if a multi-product rotation is used and the stand is to be thinned. If pulpwood is the only objective, then a spacing of 9 by 9 or 10 by 10 feet may be used.

Early thinnings are necessary to keep crop trees free to grow. The first two thinnings probably should be mechanical by rows. The remaining thinnings would be selective. Over 15 years, test plantings with cottonwood have grown more than 3 cords per acre of merchantable wood or over 450 board feet (Doyle) annually (McKnight and Johnson 1980).

Silviculture in bottomland hardwoods will become more intensive; economics will provide the incentive (Johnson 1981). There will be different degrees of intensity, depending on site productivity and treatment opportunities. But, if the management alternatives discussed in this paper are intensively and correctly applied on good sites, the land manager will produce quality hardwood timber that will command a premium price when it is harvested.

LITERATURE CITED

Baker, James B., and Broadfoot, W. M. 1979. Site evaluation for commercially important southern hardwoods. USDA For. Serv. Gen. Tech. Rep. SO-26, 51 p. South. For. Exp. Stn., New Orleans, La.

Broadfoot, W. M. 1976. Hardwood suitability for and properties of important Midsouth soils. USDA For. Serv. Res. Pap. SO-127, 84 p. South. For. Exp. Stn., New Orleans, La.

Faust, Edgar. 1983. Improvement cuts can pay way to good hardwood stands. For. Farmer 42(10): 12-13.

Hodges, J. D., and Switzer, G. L. 1979. Some aspects of the ecology of southern bottomland hardwoods. In North America's Forests: Gateway to Opportunity, p. 360-365. Joint Conv. of Soc. Am. For. and Can. Inst. For. [St. Louis, Mo., Oct. 22-25, 1978.] Soc. Am. For., Washington, D.C.

Hurst, George A., and Bourland, Thomas A. 1980. Hardwood density and species composition in bottomland areas treated for regeneration. South. J. Appl. For. 4(3): 122-127.

Hurst, George A., and Myers, Ronnie C. 1982. Regeneration following a commercial improvement cut in a bottomland hardwood forest. Miss. Agric. and For. Exp. Stn. Res. Rep., Vol. 7, No. 18, 4 p.

Johnson, R. L. 1968. Thinning improves growth in stagnated sweetgum stands. USDA For. Serv. Res. Note SO-82, 5 p. South. For. Exp. Stn., New Orleans, La.

Johnson, Robert L. 1981. Wetland silvicultural systems. In Timber Harvesting in Wetlands, Proc. La. State Univ. 30th Annu. For. Symp., p. 63-79. Div. Contin. Educ., La. State Univ., Baton Rouge, La.

Johnson, Robert L. 1983. Nuttall oak direct seedings still successful after 11 years. USDA For. Serv. Res. Pap. SO-301, 3 p. South. For. Exp. Stn., New Orleans, La.

Johnson, R. L., and Krinard, R. M. 1983. Regeneration in small and large sawtimber sweetgum-red oak stands following selection and seed tree harvest: 23-year results. South. J. Appl. For. 7(4): 176-184.

Johnson, R. L., and McKnight, J. S. 1969. Benefits from thinning black willow. USDA For. Serv. Res. Note SO-89, 6 p. South. For. Exp. Stn., New Orleans, La.

Kennedy, Harvey E., Jr. 1984. Hardwood growth and foliar nutrient concentrations best in clean cultivation treatments. For. Ecol. and Manage. 8: 117-126.

Kennedy, Harvey E., Jr., and Henderson, Wilbur H. 1976. Cultivation in cottonwood plantations--practices and equipment. In Proc., Symp. East. Cottonwood and Related Species, p. 379-384. [Greenville, Miss., Sept. 28-Oct. 2, 1976.] La. Div. Contin. Educ., La. State Univ., Baton Rouge, La.

McKnight, J. S. 1967. Application of uneven-aged silviculture to southern hardwood forests. In Proc., Symp. on Hardwoods of the Piedmont and Coastal Plain, p. 61-64. Ga. For. Res. Counc., Macon, Ga.

McKnight, J. S., and Johnson, R. L. 1980. Hardwood management in southern bottomlands. For. Farmer [23rd Manual Ed.] 39(5): 30-39.

Putnam, John A., Furnival, George M., and McKnight, J. S. 1960. Management and inventory of southern hardwoods. USDA Agric. Handb. 181, 102 p. Washington, D.C.

Sternitzke, Herbert S. 1976. Impact of changing land use on Delta hardwood forests. J. For. 74(1): 25-27.

Williston, H. L., Shropshire, F. W., and Balmer, W. E. 1980. Cypress management: a forgotten opportunity. USDA For. Serv. For. Rep. SA-FR 8, 8 p. Southeast. Area, Atlanta, Ga.