Regional Silviculture of the United States

Third Edition

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The Southern Bottomland Hardwood Region and Brown Loam Bluffs Subregion

John D. Hodges

LOCATION

Geographically, the region in which Southern Bottomland hardwoods occur corresponds to the Coastal Plain province of the Atlantic Plain physiographic division as delineated by the U.S. Geological Survey (Fenneman, 1938). It extends from the eastern tip of Pennsylvania south along the entire Atlantic coast and west along the Gulf coast to the Rio Grande. It extends north along the Mississippi alluvial plain to the southern tip of Illinois (Fig. 6-1). In the Coastal Plain province, bottomland hardwoods occur along stream courses (floodplains) and in other wetland areas such as inland muck swamps, coastal and estuarial swamps, bays, and hammocks. In addition, bottomland hardwoods occur to some extent along all the major and minor streams in all states east of the Great Plains.

The Brown Loam Bluffs are a strip of loess-covered, deeply dissected uplands lying along the eastern side of the Mississippi River valley. This subregion extends from just north of Baton Rouge, Louisiana, to about Cairo, Illinois, in the north. It

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Figure 6-1. Location of the Southern Bottomland Hardwood Region and the Brown Loam Bluffs Subregion (diagonal lines). Bottomland hardwoods occur across the Atlantic and Gulf Coastal Plain. Major stream bottoms are indicated by the cross-hatched areas.

varies in width from 5 to 25 miles and is widest near the Mississippi-Tennessee border (Fig. 6-1). This subregion is also called the Loess Hills, Loess Bluffs, or simply the Bluffs.

FOREST STATISTICS

Area

Estimates of the area of the Bottomland Hardwood Forest are approximations at best because of the rapid changes that have occurred over the past 60 years. Most of that change is a loss in hardwood forests as a result of conversion to agricultural uses. Much of the loss took place from the late 1950s to the mid-1970s, especially in the lower Mississippi River valley (Frey and Dill, 1971; USDA For. Serv., 1988).

In 1952 there were about 40 million acres of the Bottomland Hardwood Forest in the South, but by 1977 clearing, largely for agriculture, had reduced the area to about 32 million acres (USDA For. Serv., 1988). Rate of loss slowed after the late 1970s (McWilliams and Faulkner, 1991), and the latest inventories (1987–1992) by the USDA Forest Service show about 29.8 million acres of bottomland hardwoods in the South. Exact figures are unavailable, but advent of the Conservation Reserve

Program in 1989 and land purchases by the U.S. government and other public agencies have resulted in further slowing the loss of bottomland hardwoods. For example, in Mississippi almost 50,000 acres of cropland have been planted or seeded to hardwoods under the Conservation Reserve Program, and more than 49,000 acres of cropland have been purchased by the U.S. government in the last 10 years, mostly for mitigation purposes and the establishment of wildlife refuges.

There are approximately 4.5 million acres in the Brown Loam Bluffs (Johnson, 1991). Much of that area is in Mississippi and Tennessee. Estimates based on survey data from the Southern Forest Experiment Station indicate that about 2.5 million acres are in forests.

Character of Forestland Ownership

In 1988 more than 90 percent of the Bottomland Hardwood Forest of the South were in private ownership. Private nonindustrial owners, mostly farmers, controlled about 66 percent of the land, while forest industries owned about 25 percent (Saucier and Cost, 1988; McWilliams and Faulkner, 1991). In recent years, since these data were obtained, there has been an increase in public ownership primarily as a result of mitigation purchases by the federal government and establishment of wildlife refuges by state and federal agencies. This trend for increased public ownership is expected to continue (USDA For. Serv., 1988). Also, an increasing amount of land is being purchased by hunting clubs and used primarily for purposes other than timber production, such as wildlife habitat.

Less than 15 percent of the Brown Loam Bluffs is in public ownership. There is a small amount of industrial ownership, but most of the land is owned by individuals.

Forest Inventory

Data from the latest USDA Forest Service inventories indicate that the Southern Bottomland Hardwood Region contains approximately 45 billion cubic feet of growing stock (Table 6-1). Sawtimber volume is approximately 160 billion board feet.

In the south-central portion of the Southern Bottomland Hardwood Region, the ratio of current growth to removal is 1.4:1.0. Despite the loss in bottomland hardwood area, inventory volume increased by 8 percent during the last inventory period (McWilliams and Faulkner, 1991). However, most of the stands in this area are badly understocked, with almost 60 percent of the area supporting stands of less than 5000 board feet per acre and 22 percent with less than 1500 board feet per acre. In the southeastern portion of the region, about 50 percent of the area has stands with less than 4000 board feet of sawtimber per acre, and 30 percent has more than 8000 board feet per acre (Saucier and Cost, 1988). For the entire region, net annual growth averages less than 50 cubic feet per acre per year. What may be most important is that, even with the overall increase in inventory, there is a decrease in volume of top-quality hardwoods (Beltz et al., 1990).

Inventory data specifically for the Brown Loam Bluffs are not available. How-

TABLE 6-1 Summary of Southern Bottomland and Wetland Hardwood Resource Data

State	Area (thousand acres)	Net Volume Growing Stock (million cubic feet)
Alabama	2,275	3,554
Arkansas	2,941	2,995
Florida	4,354	7,180
Georgia	2,564	6,423
Kentucky	670	825
Louisiana	4,755	5,712
Mississippi	3,201	4,037
North Carolina	2,666	5,499
Oklahoma	421	275
Pennsylvania	363	393
South Carolina	2,520	4,563
Tennessee	682	857
Texas	1,578	1,585
Virginia	635	1,122
West Virginia	169	176
Total	29,794	45,196

Sources: Data are taken from latest forest surveys by USDA For. Serv., Southern For. Exp. Sta., Southeastern For. Exp. Sta., and Northeastern For. Exp. Sta. Surveys were published between 1987 and 1992.

ever, estimates derived from the latest USDA Forest Service inventories show about 3 billion cubic feet of hardwood and 0.6 billion cubic feet of softwoods. Sawtimber volumes average less than 5000 board feet per acre. Growth averages about 67 cubic feet per acre per year.

PHYSICAL ENVIRONMENT

Physiography

The topography of major bottomlands is characteristically flat, but even slight variations in relief are associated with considerable differences in soils, drainage conditions, and species composition. A generalized view of the physiographic features along a major stream is shown in Figure 6-2. Natural features of relief shown here occur in all bottoms, but species associations may vary. For example, in the Mississippi drainage system, the fronts could support large numbers of sweet pecan and elm as well as the soft hardwoods; the flats would support elm–ash–sugarberry (hackberry) stands; and, depending on past history, the ridges may be primarily water oak and sweetgum.

Two main physiographic features of a major stream valley, the first bottoms or floodplains, and terraces, were first described by Putnam (1951). The floodplains were formed by the present drainage system and are subject to frequent flooding, if

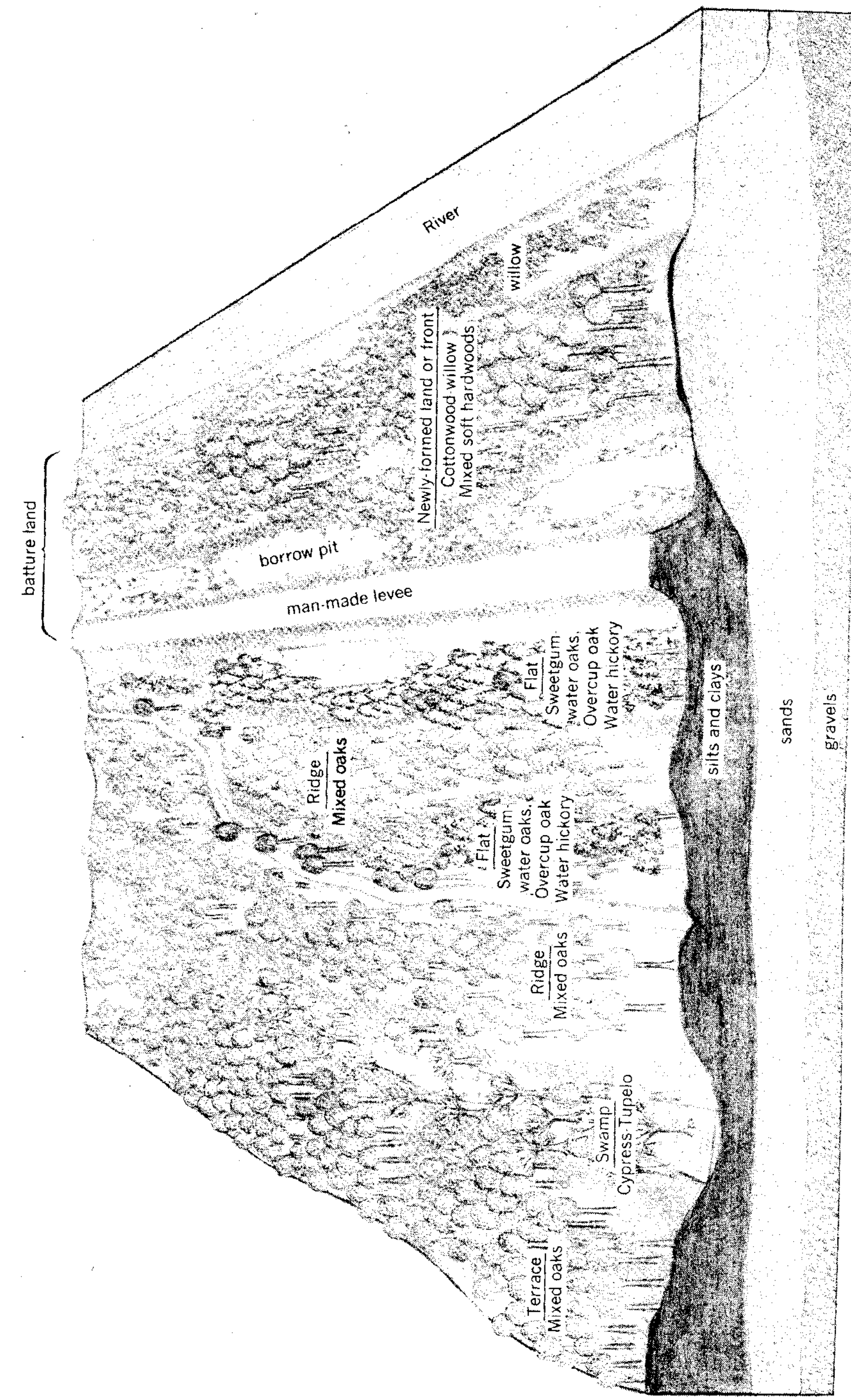

Figure 6-2. *Generalized view of the floodplain of a large river, showing differences in physiography and associated species.* (From J. Barrett. 1962. *Regional Silviculture of the United States.* John Wiley & Sons, New York.)

ıot protected by human-made levees. Terraces are former floodplains that were ormed by older drainage systems. The transition from floodplain to terrace may be |uite distinct or rather gradual. Sometimes there are even abrupt rises to adjacent ıplands. Where unprotected, low terraces may flood occasionally, but upper teraces flood only during extremely high floods. Bottomland hardwoods are generally onsidered to be restricted to the floodplain sites. Terrace sites are generally not as uitable for bottomland hardwoods because the soils are older, less fertile, have less vailable moisture, and often have genetic pans or restrictive layers. Most terrace ites have been converted to agriculture or to pine production.

Variations in elevation in the floodplain of only a few feet lead to vastly different ite conditions. These minor topographic variations are recognized by such terms as ars, fronts, flats, ridges, sloughs, and swamps (Hodges and Switzer, 1979). Bars ɔoint bars, sandbars, and towheads) are constantly formed by the river when rosion occurs on one bank and the sediment is deposited downstream on the pposite bank. With continued deposition they may increase in elevation to the level f the *fronts,* which are natural levees and often the highest point in the floodplains. *'lats* constitute the general terrain between the ridges and generally have a very light slope. *Ridges* are commonly 1 to 10 feet above the adjoining flats and in some ases are as high or higher than the fronts; they are the banks or fronts of former treams. *Sloughs* are shallow depressions in which water collects but normally isappears during the first half of the growing season; they are remains of nearly illed stream courses or present drainage ways. *Swamps* are distinct depressions in hich water stands throughout the year except during periods of extreme drought.

Interspersed throughout the Coastal Plain pinelands are numerous floodplain ɔrests associated with smaller streams and creeks. They are commonly referred to s *minor bottoms*. They differ from major bottoms not only in terms of stream size ut, more importantly, in terms of soils, drainage, and length of flooding, as noted ıter. These bottoms are in many ways miniatures of the major bottoms. They xhibit the same topographic features and contain most of the same species but erhaps not in the same position (Fig. 6-3). In aggregate the area in minor bottoms ı the South exceeds that in major bottoms.

There are other wetland hardwood sites within the Coastal Plain that are usually ıot associated with a stream. These are the inland muck swamps, coastal and stuarial swamps, bays, and hammocks. They may be reasonably productive, but he sites are generally not as good as those on the floodplains. The swamps are ısually flooded yearlong from impoundment of rainwater and seepage, whereas the ıays are peaty swamps where the permanent water table appears to be at or near the oil surface. Hammocks (called *bay-galls* in Louisiana) are localized areas on 'oastal Plain flatwoods sites. They may be depressed or raised above the surroundıg terrain and, though not generally associated with a stream, are usually well rained but with ample moisture for growth of hardwoods.

The Brown Loam Bluffs vary in elevation from 100 to 600 feet above sea level. 'he rich loess soil is deepest (up to 100 feet) near the western edge of the bluffs and ıins to the east, giving way to the clays and sands common to the uplands of ʻlississippi and Tennessee. Several streams dissect the hills, and some have formed

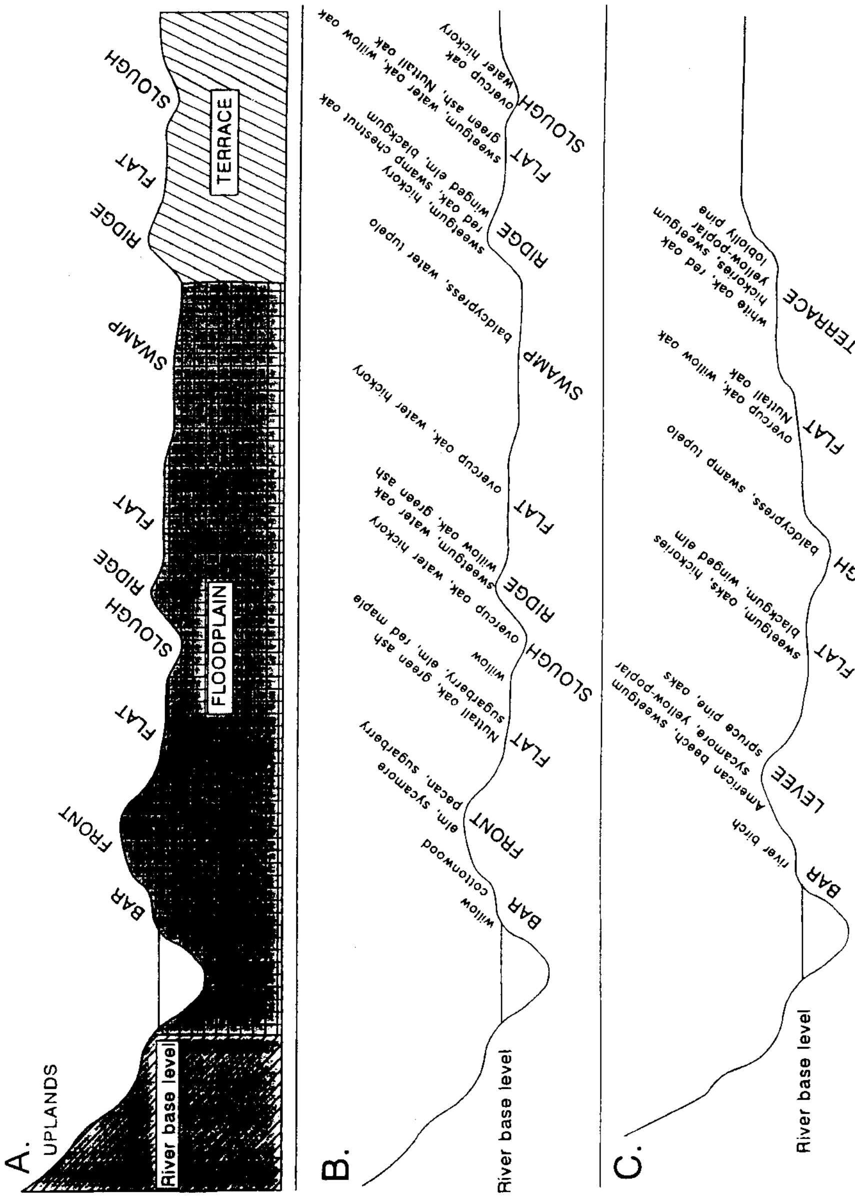

Figure 6-3. *Generalized cross sections of major and minor stream bottoms of the Coastal Plain. A. Major stream valley showing topographic variations. B. Species associated with topographic variations within a major stream valley. C. Topographic variations and associated species in a minor stream valley. (After Hodges and Switzer, 1979.) Used with permission of The Society of American Foresters.*

relatively wide, fertile bottoms, most of which are in agriculture. The soils are very erosive, and the bluff area is deeply gullied with many narrow ridges and steep slopes.

Geology and Soils

The character of the present landscape of the major bottomland areas of the South was formed during the Quaternary period (Fenneman, 1938). A sequence of marine deposition of sands, silts, and clays associated with intermittent rises in the sea level and subsequent uplifting of the land surface resulted in development of a series of terraces making up the Coastal Plain of the southeastern United States. While the land surface was being raised, an undulating topography was formed as the seaward drainage patterns developed. Continual erosion of the uplands and deposition of eroded materials along the streams and at the sea outlets have resulted in the pattern of alluvial bottomlands depicted in Figure 6-2. Large inland swamps, such as the Dismal Swamp of Virginia and the Okefenokee Swamp of Georgia, were formed when later terraces blocked the seaward drainage of low-lying land areas. Broad tidal estuaries and coastal swamps also formed as the streams discharged into the sea. The land in these swamps varies from permanently inundated low areas of organic soils to better-drained ridges or hammocks of mineral soil.

The nature or character of the soils in an alluvial valley is determined by the nature of the materials present in the river's drainage area, which serves as the erosional source of the deposits of mineral soil. This is a primary difference between major and minor river bottoms because the depositional material of minor bottoms is of a local origin whereas that for major bottoms may come from hundreds of miles away. Alluvial soils derived from sandy materials of the lower Coastal Plain, typical of minor stream bottoms, will be coarse textured. In major bottoms, alluvial soils may be derived from erosion of the less-weathered, grassland prairie soils, which may be high in expanding clays. The lower Mississippi River valley and such tributaries as the Red River are examples of the latter. Thus, bottomland soils may be clayey, silty, or sandy depending on the origin of the deposits and their location in relation to the river.

The normal pattern of deposition within the stream bottom is illustrated in Figure 6-4. As the stream overflows its banks, coarse materials (sands) are deposited first,

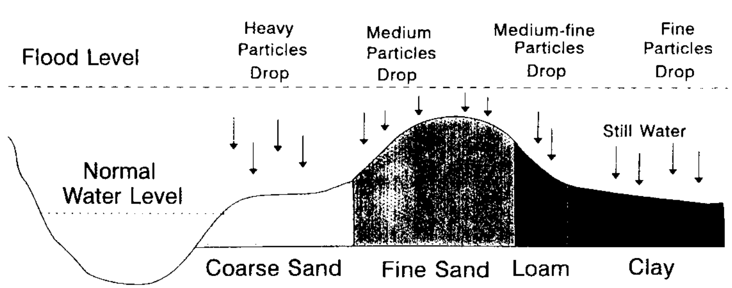

Figure 6-4. *Patterns of deposition within an alluvial stream valley.*

with progressively finer sediments deposited in sequence away from the river. A series of alternating sandbars and silty clay sloughs are formed as a result of constantly shifting river channels. The sandbars are soon covered by cottonwoods and willows and the sloughs by willows. As the young trees trap the load of sediments carried by floodwaters, layers of silty clay may cover the previous sandbars, while sloughs act as settling basins to accumulate very fine clays and silts. When subject to frequent flooding and deposition, as is the case of the *batture land* (land between the levee and the river; see Fig. 6-2), soils often show stratification of different-sized soil particles. Soils of the fronts along stream channels usually consist of silt loams, very fine sandy loams, and silty clay loams. The depressed and flat back-swamp soils are generally poorly drained clays (Lytle, 1960; Hodges and Switzer, 1979).

A feature common to all bottomland soils is an indistinct profile development, even though the soils are very complex and differ markedly in age and in physical and chemical properties. Variations in texture range from newly deposited sands to older deposits of clay. Soil structure may vary from the single grains of sands to the compact blocky structure of clays. Soil reaction in the major bottoms generally ranges from slightly acidic (pH 6) to alkaline. Soils in minor bottoms, especially in the lower Coastal Plain, are generally more acidic. Bottomland soils usually contain ample available water, moderate amounts of organic matter, and are well supplied with the required mineral nutrients for tree growth (Lytle, 1960). However, nutrient status varies greatly between floodplains and within floodplains depending on differences in soil colloids. Soil aeration and drainage also vary considerably, and variations in species associations are most often reflections of aeration and drainage conditions in bottomland soils.

The Brown Loam Bluffs are potentially one of the most productive hardwood areas in the nation (Johnson, 1958; 1991). Soils of the Bluffs developed from wind-deposited silts during late Pleistocene epoch. The deposits occurred during at least three different periods between 12,500 and 40,000 years ago. The loess forms a mantle ranging in thickness from 2 feet to more than 100 feet over unconsolidated sands, sandy clays, and gravels of earlier Pleistocene age. The soils are well drained and moderately permeable but highly erosive, and in parts of the subregion that occur on steeply sloping and hilly topography. The surface soils are brown silt loams with brown to yellowish red silty clay loam subsoils. Soil reaction varies from near neutral on some lower slopes and bottoms to strongly acidic on ridgetops, especially those with a history of agricultural use. Site quality varies depending primarily on past land use and depth of the loess. Quality generally increases from the ridgetops to the lower slopes and bottoms. Site indices for cherrybark oak and sweetgum (50 years) range from 90 to 120 (Johnson, 1991).

Climate and Weather

The climate of the Southern Bottomland Hardwood Region and the Brown Loam Bluffs Subregion may be classed as humid to subhumid. Annual precipitation, chiefly rainfall, is between 42 and 64 inches and is generally well distributed throughout the year. Warm-season precipitation (April to September, inclusive) ranges between 22 and 34 inches (USDA For. Serv., 1969). Late summer to early fall is customarily the driest part of the year. Moderate droughts occur irregularly every few years, while severe prolonged droughts may occur once every two or three decades.

The region is characterized by a relatively long frost-free season, ranging from about 210 days at the northern limit to over 300 days in the coastal areas (USDA For. Serv., 1969). In general, average temperatures increase from north to south in the Southern Bottomlands. Mean January temperatures range from about 40°F in the northern sections to about 55°F along the Gulf coast. Mean July temperatures average about 81°F throughout the region, but maximum summer temperatures often exceed 100°F. Unseasonably early autumn frosts and late spring freezes sometimes occur and profoundly affect the growth of trees and increase seedling mortality. Also, abrupt temperature changes, especially during the winter months, are characteristic of much of the region.

Prolonged droughts, ice storms, hurricane winds in coastal areas, and tornadoes inland are infrequent but characteristic climatic phenomena of the region. Such infrequent climatic occurrences do, however, significantly affect the condition and composition of the forests. For example, the blight or dieback and eventual mortality of sweetgum growing on tight clay soils has been attributed to drought conditions extending over several consecutive years (Toole and Broadfoot, 1959). Also, there is ample evidence that blowdown by hurricanes and tornadoes has altered the normal successional patterns on many hardwood sites.

HISTORY OF FOREST USE

Past Use of the Forest

Much of the early cutting of bottomland forests throughout the South was to clear land for agriculture. Extensive areas were cleared, and the land was planted in cotton and later in other crops. Logs and lumber for local construction and fuelwood were the chief outlets for the timber, both from the land-clearing operations and from high grading of stands left in timber. Extensive commercial clearcutting did not get underway until about 1900. The earliest loggers in the bottomlands took only the largest trees of the best species. Species utilization changed and quality requirements were lowered each time the area was cut. These practices generally have continued into the present.

As discussed earlier, extensive land clearing for agriculture has significantly reduced the acreage of the Bottomland Hardwood Forest. The reduction has been most severe in the Mississippi River alluvial plain, especially in Arkansas, northern Louisiana, and Mississippi. Hardwood forest area in the lower Mississippi River valley decreased from about 12 million acres in the mid-1930s to less than 6 million

acres in 1991 (Sternitzke and Christopher, 1970; McWilliams and Faulkner, 1991). Other major river bottoms throughout the South have been subjected to a similar pattern of land use and timber harvest. Farming is an important enterprise along many of these rivers, but the floodplains were not subjected to the extensive land clearing that took place in the Mississippi River valley from 1960 to 1980.

Sections of the Brown Loam Bluffs, especially the bottoms, were among the first areas in Mississippi to be cleared and farmed. In fact, most forests except those on very steep topography were cleared and farmed starting more than 150 years ago. Commercial timber harvesting in the original stands consisted largely of high grading to remove the largest trees of the best species. This same type of harvesting has prevailed in the second- and third-growth forests which, for the most part, originated on abandoned farmland.

The Forests Today

The forests of the Southern Bottomlands and Brown Loam Bluffs are extremely diverse in terms of species composition and type of sites. At least 75 different tree species occur in Bluff forests and include species typical of the Mixed Mesophytic Forest to the north, bottomland forests to the west, and the mixed upland hardwood forest to the south and east (Johnson, 1991). More than 70 tree species occur in the Southern Bottomlands (Putnam et al., 1960), and about 40 of these are commercial species (Hosner, 1962). This species diversity, especially in the bottomlands, is associated with minor differences in topography (elevation), as discussed earlier (see Fig. 6-3). Forest type or composition changes are not so abrupt in the Bluffs and tend to be associated with slope position and depth of the loess.

Although great diversity still exists, the quality and composition of the forests have been dramatically influenced by past land use such as harvesting practices, agricultural use, grazing, and uncontrolled fires. The end result has been a general lowering of desired composition and quality even though volumes are increasing.

In the bottomlands, harvesting practices that high-graded the stands for the highest-quality trees of only those species in demand at the time have resulted in stands containing a much higher proportion of inferior and less desirable species than was present in the original forests. Forest Service inventory data show that in the south-central region of the Coastal Plain about 18 percent of the growing stock, excluding saplings, is in rough or rotten trees (McWilliams and Faulkner, 1991). Also, only about 31 percent of the growing stock volume is in trees 17 inches in diameter and larger. Less than 40 percent of the present volume is in the most desirable species such as oaks and ash.

In the original forests of the Brown Loam Bluffs, oaks occurred primarily on the ridgetops and thin loess. After clearing for agriculture and abandonment more than 100 years ago, oaks are now common on most slopes as well as ridges. Oaks account for more than 50 percent of the commercially valuable sawtimber in most of today's Bluff forests (Johnson, 1991). However, as with the bottomlands, most stands have been badly high-graded, and the present stands do not represent the true potential of the sites. They are understocked and contain a high proportion of less desirable species such as hickories, American beech, American hornbeam, and eastern hophornbeam. Yellow-poplar is also becoming more prevalent at the expense of the more desirable oaks.

MAJOR FOREST TYPE GROUPS

Bottomland Hardwoods

The Bottomland Hardwood Forest of the South presents an extremely heterogeneous mixture of species, except in the permanently flooded swamps and on newly formed land. The Society of American Foresters (Eyre, 1980) recognizes 23 types that occur in the bottomlands of the Coastal Plain. However, recognition of some types may be difficult because composition can be extremely variable. Composition varies between locations, especially between major and minor bottoms, and the mixtures are strongly influenced by minor differences in elevation, natural disturbances, and past cutting practices. For this reason, it is deemed best to use a type-group classification as shown in Table 6-2 for discussion of the silviculture of bottomland hardwoods. For inventory purposes, the USDA Forest Service recognizes only two type groups: oak–gum–cypress and elm–ash–cottonwood. The classification given in Table 6-2, at least for the mixed bottomland hardwoods type, is somewhat arbitrary because of variation in species composition. The desired mixture will vary by geographic location, type bottom (minor versus major), site variation in the bottom, and product objective.

The relative value, growth rate, and tolerance of major species occurring in bottomlands are given in Table 6-3. The value of a given species will vary greatly depending on location and local use, tree size, form, and defects.

Forests of the Brown Loam Bluffs

The Bluff forests are extremely diverse in terms of species composition. As noted above, species typical of the Mixed Mesophytic Forest, the Mississippi Alluvial Plain, and sandy uplands can be found in these forests. Forest-cover types (Eyre, 1980) are far less distinct than in bottomland forests. Variations in composition that do occur are related to slope position and differences in site quality. Soil depth and moisture availability tend to increase from the somewhat dry ridges downslope to the moist ravine bottoms. Loblolly–hardwood (forest-cover type 82) is fairly common on the drier ridges and the yellow-poplar (57) and a variation of the sweetgum–yellow-poplar (87) on the lower slopes and bottoms. Other cover types more typical of the Central Region, such as white oak (53) and yellow-poplar–white oak–northern red oak (59), are occasionally found in small areas on the slopes.

SILVICULTURE OF THE MAJOR TYPE GROUPS

Forest Ecology

Silviculture of the Bottomland Hardwood Forest requires first an understanding of the ecology of these areas, which tends to be more complicated than for most forest types. As noted earlier for floodplain forests, there is great diversity in both species composition and sites (see Fig. 6-3). Species diversity may be almost as great as in the Mixed Mesophytic Forest, and sites can change greatly over relatively short distances. Furthermore, the sites themselves may change over relatively short periods of time. In addition, there are large differences in sites and species composition between floodplain forests and those on other wetland areas. These factors lead to unique patterns of succession and changes following cutting or disturbance of the forest.

Natural succession in major stream bottoms such as the Mississippi follow one of two general patterns, as illustrated in Figure 6-5A,B. On poorly drained sites at low elevations, such as abandoned stream channels or drained lakes, the pioneer species is most often black willow. Succession depends primarily on rate of deposition (Fig. 6-5A). The cypress–tupelo or combination cypress–tupelo and swamp-privet types represent an "arrested" stage of succession that may endure for hundreds of years. The boxelder–sugarberry type in the south or boxelder–hackberry–silver maple type in the north tends to be a transitory type between the black willow and elm–ash–sugarberry (hackberry) types. The sweetgum–red oak type is also transitory and, depending on seed source and advance regeneration, may occur after natural disturbances or cutting of the elm–ash–sugarberry type. The elm–ash–sugarberry type is an edaphic climax which can replace itself and persist for hundreds of years. On floodplain sites in the major bottoms, the regional climax type (oak–hickory) generally does not occur until deposition ceases and soils mature.

Cottonwood is the most prevalent pioneer species in major bottoms on better-drained, higher-elevation sites such as the accretion land of river fronts (Fig. 6-5B). Black willow is sometimes common in the early stages, but cottonwood quickly dominates the site.

Stand composition following cottonwood is variable, depending largely on how the cottonwood stand breaks up. If it is rapid, the next stand may be composed largely of the riverfront association of the sycamore–sweetgum–American elm type. In the Mississippi River system it would also include sweet pecan. If breakup of the cottonwood stand is slower, the more tolerant boxelder and sugarberry in the south and boxelder–hackberry–silver maple type in the north will become established beneath the cottonwood and will dominate the next stand. In either case, without natural disturbance or cutting, natural succession will eventually lead to the elm–ash–sugarberry (hackberry) type, which may persist for several hundred years. The sweetgum–oak type is transitory, resulting from natural disturbances or harvesting. Without management it will revert to the elm–ash–sugarberry type.

In minor bottoms of the Coastal Plain, river birch is often the pioneer species on

(text continues on p. 247)

TABLE 6-2. Description of the Major Type Groups of Southern Bottomland Hardwoods

Type Group	Commercial Value/Extent	Sites Occupied	Major Species	Associated Species	Comments
Cottonwood–willow	Cottonwood medium; willow low to medium value; minor area	Newly formed land; cottonwood predominating on fronts and ridges; willow on wetter low flats, sloughs, and depressions	Eastern cottonwood Black willow	Pecan American sycamore Sugarberry Hackberry Green ash American elm Sweetgum Water oak Red maple Silver maple Boxelder Baldcypress Waterlocust Honeylocust	Pioneer species are succeeded by the associated, more tolerant species. Cottonwood has a very rapid growth rate, good quality, and is valuable for veneer and pulp. Willow also grows rapidly but is less valuable. Both are extremely intolerant and require bare, mineral seedbeds for natural regneration.
Baldcypress–tupelo	Medium to high value when cypress predominates; otherwise low to medium; minor area except in lower Mississippi River valley and coastal areas	Chiefly in low poorly drained flats, deep sloughs, and swamps in floodplains; common in swamps of coastal plains and river estuaries	Baldcypress Water tupelo Swamp tupelo	Pondcypress Swamp cottonwood Red maple Water hickory Black willow American elm Overcup oak Nuttall oak Swamp laurel oak (diamondleaf oak) Waterlocust	The type is permanent until the site changes. It is commonly in mixture, but each species may be found in pure even-aged stands. Water tupelo is the component in swamps of alluvial floodplains and estuaries. Swamp tupelo predominates in nonalluvial and coastal swamps.
Mixed bottomland hardwoods	Value depends on species; mostly medium to high value, except overcup oak and water hickory; major type, found on all major and minor stream bottoms and other wetlands	All but wettest sites; species vary by site; cherrybark, sweetgum, and cow oak occur on ridges, better-drained flats; sweetgum and water oak on heavy-textured soils of flats and low ridges; overcup oak, willow oak, green ash, and water hickory on heavy clays of low, poorly drained flats and shallow sloughs	Sweetgum Water oak Willow oak Nuttall oak Swamp chestnut oak (cow oak) Cherrybark oak Green ash Sugarberry Hackberry American elm Overcup oak Water hickory	Persimmon Sweetbay Green ash Swamp laurel oak Pin oak Shumard oak White oak Pecan American sycamore Boxelder Hickory spp. Red maple Silver maple Cedar elm Winged elm Persimmon Honeylocust Waterlocust Pumpkin ash White ash River birch Baldcypress Black tupelo Swamp tupelo American beech Southern magnolia	Mixtures depend on site and successional stage. Some mixtures are transitional between pioneer the cottonwood–willow type and more permanent associations. Past high grading has increased proportion of poorer species such as the elms, sugarberry, boxelder, and maple. Mixtures tend to be less site-specific in the minor bottoms, and these bottoms will usually contain a smaller proportion of wet-site species.

Source: Adapted from Putnam (1951) and Putnam et al. (1960).

TABLE 6-3. Relative Value, Growth Rate, Tolerance, and Management Possibilities of Common Bottomlands Hardwoods

Species	Growth Rate	Tolerance to Competition	Tolerance to Periodic Flooding	Management Possibilities
		Highest Value		
Green ash	Medium	Intolerant	Tolerant	Favor in management; seedlings need early release; sprouts well for planting.
Pumpkin ash	Medium	Intolerant	Tolerant	Favor on good sites.
Cherrybark oak	Good to excellent	Intolerant	Very intolerant	Best red oak; favor in management.
Shumard oak	Good to excellent	Intolerant	Very intolerant	Favor on good ridge soils and well-drained bottoms; occurs most often as scattered individuals.
Swamp chestnut oak (cow oak)	Medium to good	Moderately intolerant	Intolerant	One of best white oaks; favor in management; good mast tree.
Nuttall oak	Good to excellent	Intolerant	Intermediate	Favor on wet sites (flats) in recent alluvium.
Water oak	Good to excellent	Intolerant	Intermediate	Favor on best flats and ridges; subject to epicormic branching when released.
Delta post oak	Medium	Intolerant	Very intolerant	Favor on well-drained sites in lower Mississippi valley.
Baldcypress	Slow to medium	Moderately tolerant	Tolerant	Favor; edaphic climax; stands often need of thinning to prevent stagnation; regeneration difficult because of sites.
Eastern cottonwood	Very rapid	Very intolerant	Tolerant	Can manage in natural stands or plantations; improved planting stock available.
		Intermediate Value		
Sweetgum	Medium to good	Intolerant	Intermediate	Easy to regenerate; an efficient sprouter from both roots and stumps; planted for pulpwood.
Hackberry	Medium	Very tolerant	Intermediate	Needs release from shading for best form and growth; favor on flats in northern part of region.
Sugarberry	Medium	Very tolerant	Intermediate	Best form and growth when released from shading early; favor on flats if better species are not present.
Willow oak	Good to excellent	Intolerant	Tolerant	Favored on flats; growth poor on wet flats with shallow soils.
Pecan	Medium to good	Moderately intolerant	Intermediate	Favored on recent loamy riverfronts of Mississippi River system; nuts heavily used by wildlife; seedlings subject to grazing.
Southern magnolia	Medium	Tolerant	Intolerant	Mainly in minor bottoms of lower coastal plain; can be managed if sound and not too limby.
Silver maple	Excellent	Intolerant	Tolerant	Favored along major streams; best in southern Ohio River valley.
Swamp tupelo	Medium	Moderately intolerant	Very tolerant	Thin dense stands to prevent stagnation; difficult to regenerate because of site.
Water tupelo	Medium	Intolerant	Very tolerant	Can be managed along with its chief associate, baldcypress; difficult to regenerate on its usual sites.
Black willow	Excellent	Intolerant	Very tolerant	Pioneer species on new lands in Mississippi River system; sprouts vigorously; pure stands stagnate early, so frequent thinnings essential; natural reproduction requires bare, wet mineral soil.
		Low Value		
River birch	Good	Intolerant	Intermediate	Short-lived; prolific reproduction on bare, moist mineral soil.
Swamp cottonwood	Good to excellent	Moderately intolerant	Very tolerant	Commonly associated with baldcypress and tupelos.
American elm	Medium	Tolerant	Intermediate	Generally of poor form; to be managed only if better species absent.
Cedar elm	Poor	Tolerant	Intermediate	Vary hard wood used only for pallets and local-use lumber.

TABLE 6-3. *(Continued)*

Species	Growth Rate	Tolerance to Competition	Tolerance to Periodic Flooding	Management Possibilities
Winged elm	Poor to medium	Tolerant	Intolerant	Normally a small tree; not as good as American elm.
Black tupelo	Poor to medium	Moderately intolerant	Intolerant	Commonly found in minor bottoms; low value; tendency to warp.
Hickory spp.	Poor to good	Very tolerant	Intolerant	Can be managed on ridges and better-drained sites; more comon in minor bottoms.
Honeylocust	Medium	Intolerant	Intermediate	Best growth on better ridges of new alluvium; seed pods are excellent mast, so favor if needed for wildlife purposes.
Waterlocust	Good	Intolerant	Tolerant	Widely scattered; poor form and small size; only fair mast producer.
Red maple	Medium to good	Tolerant	Tolerant	Manage if good form; dependable reproduction on wet sites.
Red mulberry	Poor to medium	Very tolerant	Intolerant	Small understory tree; used for fence posts; seeds readily and sprouts well.
Swamp laurel oak	Good to excellent	Intolerant	Tolerant	Occupies wet flats; very poor pruner; favor other species where possible.
Overcup oak	Poor to medium	Moderately intolerant	Tolerant	Poorest of white oaks; eliminate whenever better species present on site.
Pin oak	Good to excellent	Intolerant	Intermediate	Excessive limbiness precludes management for factory lumber.
Water hickory	Poor	Moderately tolerant	Tolerant	Occurs on low, wet flats with overcup oak; some value for factory lumber; manage if quality is good.
Common persimmon	Poor	Very tolerant	Intermediate	Very high value for specialty products if market is available; Probably should be managed for wildlife food source.
		Weed Species		
Boxelder	Poor	Very tolerant	Intermediate	Rarely of commercial size; invader under cottonwood and riverfront stands; some value for wildlife.
American hornbeam/ Eastern hophornbeam	Poor	Very tolerant	Intolerant	Some use for pulpwood; strong competitor of more desirable species, especially at time of reproduction.
Planertree (water-elm)	Poor	Moderately intolerant	Very tolerant	Will dominate very wet sites and prevent regeneration of more desirable species.
Roughleaf dogwood	Poor	Tolerant	Intermediate	Usually sparse but can preempt open areas on low ridges and better-drained flats.
Swamp-privet	Poor	Tolerant	Tolerant	Dense stands preclude desirable reproduction on wet flats and shallow sloughs.
Common buttonbush	Poor	Moderately intolerant	Very tolerant	Shrub that will take over deep sloughs and swamps after heavy cutting.
Hawthorn spp.	Poor	Very tolerant	Intolerant	Scattered understory tree on ridges and well-drained flats; may create thickets in openings.
Possumhaw	Poor	Tolerant	Tolerant	Grows on heavy soils of flats or low ridges; will prevent desirable reproduction in openings.

Source: Adapted from Putnam (1951); Putnam et al. (1960); USDA For. Serv. (1965).

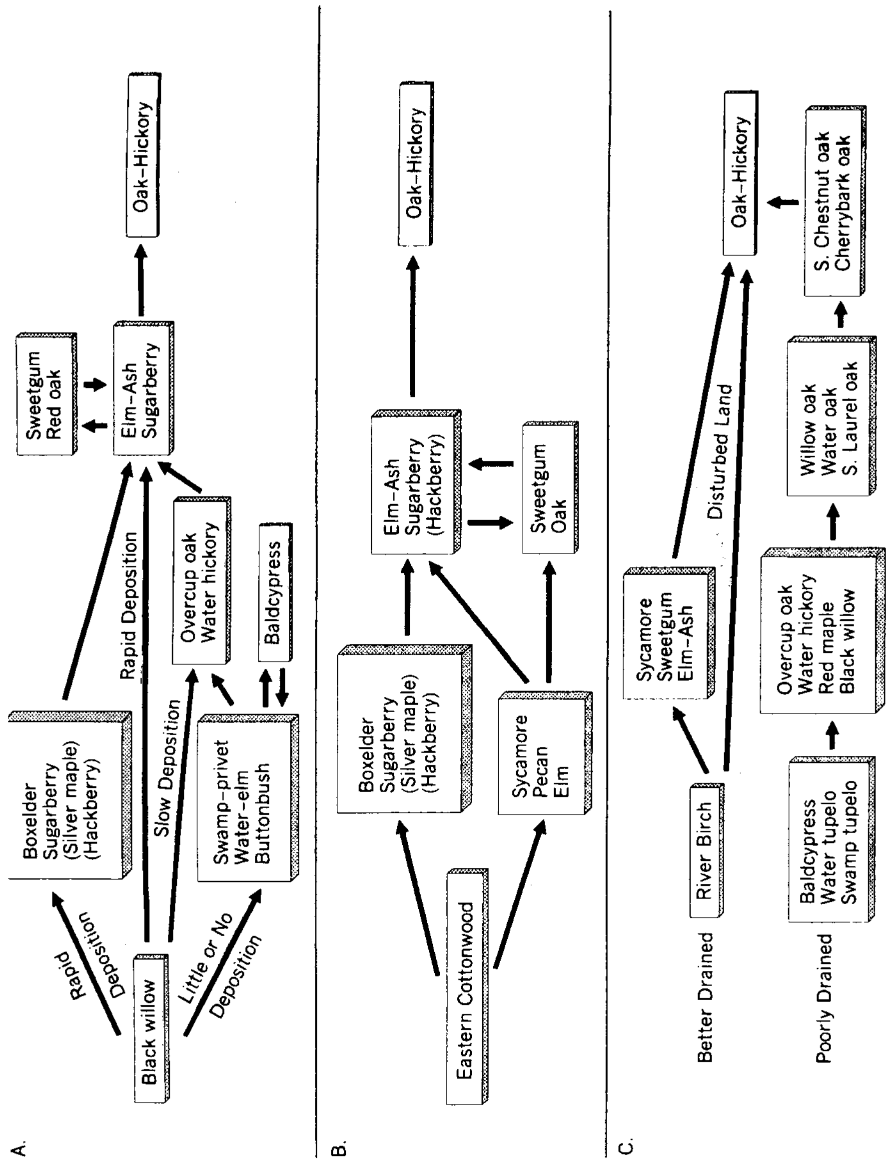

Figure 6-5. *Patterns of natural succession in major and minor stream bottoms of the Southern Bottomland Hardwood Region. A. Succession beginning on poorly drained sites at low elevations in major bottoms. B. Succession beginning on better-drained higher-elevation sites in major bottoms. C. Succession in minor bottoms.*

new or disturbed lands. Soils are usually too acidic for cottonwood, and when black willow occurs it is usually in a mixture with other species. As in major bottoms, the pattern of succession is related to drainage and changes in the site as a result of deposition (Fig. 6-5C). Unlike the major bottoms, the ridges, fronts, and better-drained flats will support the regional oak–hickory climax even though flooding does occur.

Forests on wetland areas such as coastal swamps, muck swamps, and bays, which are not associated with the floodplain of a stream, usually represent an edaphic climax. The sites generally have standing water or permanently saturated soils throughout the year. Forest types occurring in these areas are self-perpetuating unless the site itself is changed.

Cottonwood and Willow Type Group

Eastern cottonwood and black willow are the pioneer species on recent alluvial deposits along the major waterways, most extensively along the Mississippi River and its tributaries. Both species are extremely shade-intolerant, rapid growers, but short lived. They can not tolerate competition from weeds and vines and require moist, bare mineral soil to become established. Because they are so intolerant of shade, they will not succeed themselves. New stands are always even-aged, very dense, and often either pure cottonwood or pure willow (Fig. 6-6). Information on silvics and ecology for eastern cottonwood is given by Cooper and Van Haverbeke (1990) and for black willow by Pitcher and McKnight (1990).

Place in Ecological Succession The place of cottonwood and willow in ecological succession is discussed in a previous section and illustrated in Figure 6-5. Cottonwood usually establishes itself on higher, better-drained, and coarser-textured sediments, while black willow becomes established on the low-lying, wet, fine-textured alluvium. Both are often pioneers on newly formed bars or mud flats, but black willow is more flood-tolerant and persists better on the lower areas with frequent inundation.

Stands of black willow may start to deteriorate as early as age 35 years, and trees seldom live beyond age 60. Cottonwood stands may start to break up as early as age 45, and few trees remain past 80 to 100 years.

Growth Rates Eastern cottonwood is one of the largest eastern hardwoods, one of the tallest species east of the Rocky Mountains, and the fastest-growing tree in North America (Cooper and Van Haverbeke, 1990). Height growth is extremely rapid in youth but culminates at an early age. Early height growth of more than 14 feet per year has been reported (Krinard, 1979). Average diameter growth of plantations at wide spacing can exceed 2 inches per year for the first 5 years (Krinard and Burkhardt, 1984).

Black willow also grows rapidly but not as fast as cottonwood. Dense stands of willow tend to stagnate at an early age, and then growth rates decline to almost nothing. The tallest trees are 140 feet high and about 48 inches in d.b.h. In

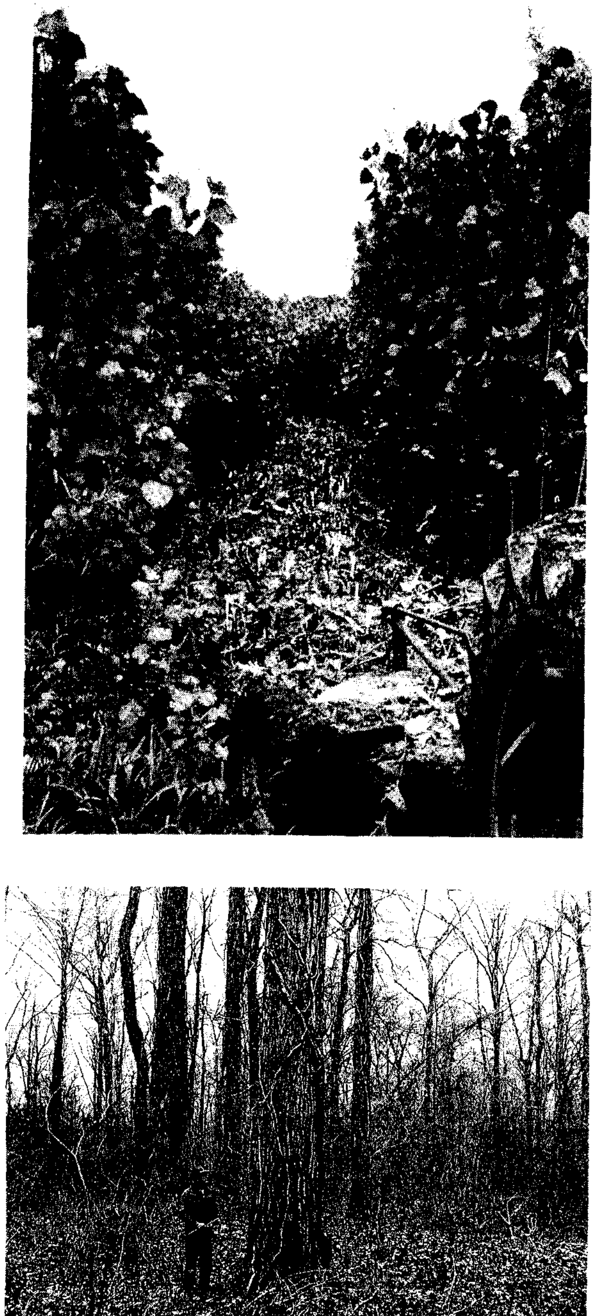

Figure 6-6. *One-year-old stand of cottonwood on a mud flat of the Mississippi River (top) and an older cottonwood stand that is being replaced by more shade-tolerant species (bottom). (Top photograph, courtesy of Mr. E. C. Burkhardt; bottom photograph, courtesy of USDA For. Serv.)*

natural stands of the lower Mississippi River valley, trees can exceed 100 feet and over 19 inches in d.b.h. at age 40.

Rotation Age or Size In natural stands, sawtimber rotation for both species is usually less than 50 years, with 30 to 35 years being most common. Cottonwood can live much longer than 50 years, but willow stands start to deteriorate much earlier (Johnson and Shropshire, 1983). In managed plantations on good sites, cottonwood can be grown on a 12-year rotation for pulpwood and a 20-year rotation for sawlogs. Cottonwood can reach diameters of 26 to 28 inches.

Cultural Practices Regeneration of existing stands of cottonwood and willow is difficult because of the extreme intolerance and exacting seedbed requirements of the species. Neither species provides dense shade, and most stands will have an abundant midstory and understory of more shade-tolerant species such as sugarberry, hackberry, green ash, American elm, silver maple, and boxelder. Mechanical site preparation that exposes mineral soil will favor reestablishment of cottonwood, but success is highly dependent on surface soil moisture (Johnson, 1965).

Both species can be regenerated by the seed-tree method. With black willow it may occur naturally if the site is flooded long enough in the spring to kill competing vegetation and provide mineral soil for the seeds, which are disseminated in May and June. Mechanical site preparation can also be used with both species to control competing vegetation and expose mineral soil. However, the relatively low value of the species generally will not justify the cost of such operations.

Artificial regeneration has been used extensively for cottonwood (Fig. 6-7). Genetic improvement has progressed further with this species than any other southern hardwood, and techniques for establishment and tending of plantations are well established. These techniques generally involve (1) choice of fertile, well-drained sites, (2) intensive site preparation, (3) use of cuttings from genetically improved planting stock, (4) frequent cultivation through the first and perhaps second growing season, and (5) protection, especially from deer. Most cottonwood planting was done from the late 1960s to the early 1980s. Because of the high cost of plantation establishment and tending and the availability of cottonwood from natural stands, relatively little planting is now being done. For more detailed information about cottonwood culture, refer to McKnight and Biesterfeldt (1968), McKnight (1970), Mohn et al., (1970), Zsuffa (1976), and Krinard and Johnson (1980).

The growth of natural, even-aged stands of cottonwood and willow can be enhanced greatly by thinnings, especially if sawtimber is the desired final crop. Young stands tend to be extremely dense, and stagnation of black willow will occur if not thinned early (Putnam, 1951; Obye, 1958). Cottonwood does not completely stagnate, but growth can be severely retarded in dense stands. A precommercial thinning may be desirable for both species to increase growth rates and prevent stagnation. The first commercial thinnings should begin as soon as possible, usually by age 15 or 20 in natural stands. Light thinnings should then be done at intervals of 5 to 10 years (Johnson and Shropshire, 1983). In each thinning, the smaller trees of

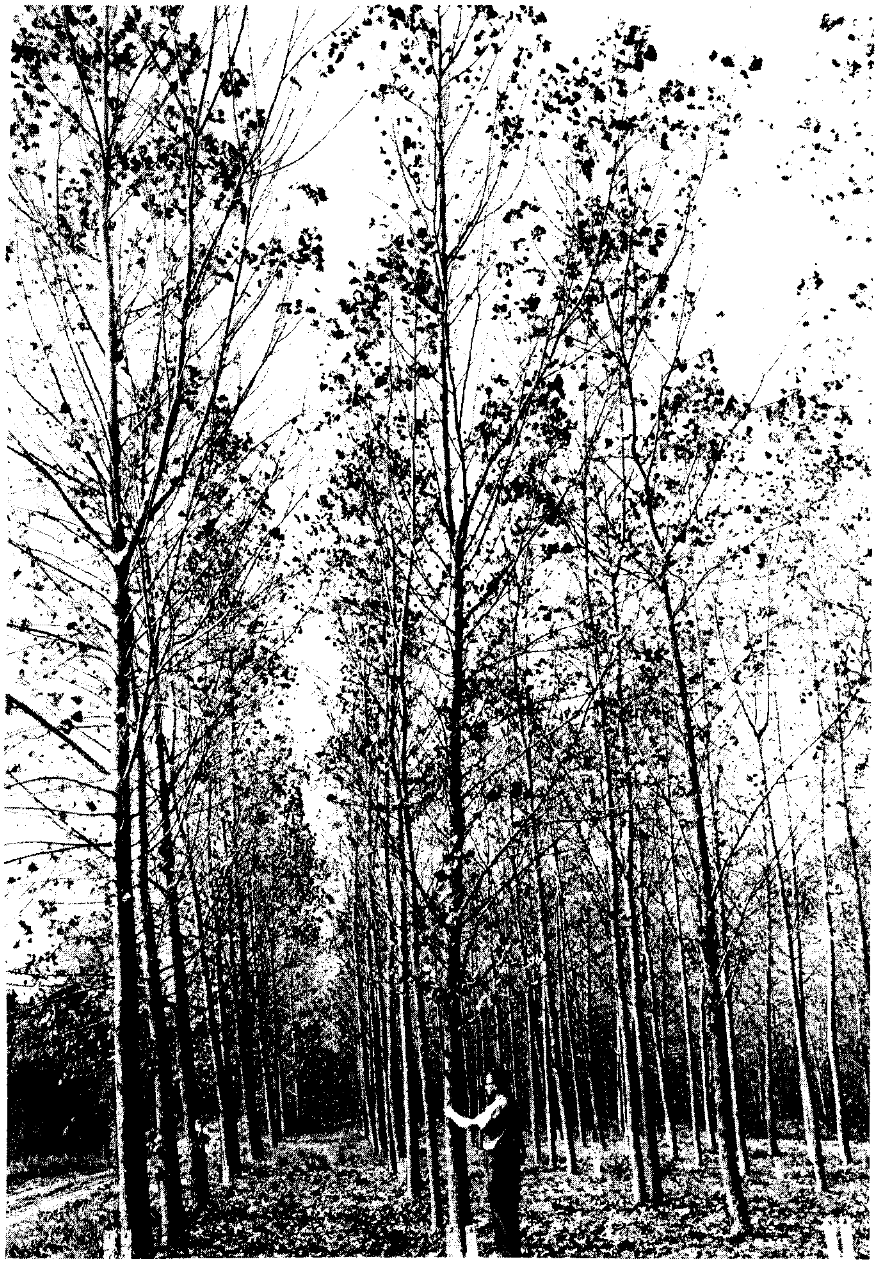

Figure 6-7. *Five-year-old cottonwood plantation on the Mississippi River floodplain in Arkansas. (From USDA For. Serv.)*

poorer quality should be removed and vigorous dominant trees should be provide room to grow; that is, thinning should be done from below (Shropshire, 1971 McKnight and Johnson, 1975). After thinning, minimum basal areas, wher sawtimber is the management objective, should range from 40 square feet per acr in young stands to 90 square feet per acre in sawtimber stands (Johnson an Shropshire, 1983).

Pruning of planted cottonwood is desirable if high-quality sawlogs and venee logs are the intended products. The timing and frequency of thinnings are related t initial spacing and management goals. For maximum growth, regular and heav thinning at 3- to 5-year intervals is necessary to maintain stand density at 80 to 9 square feet of basal area per acre. On good sites the first thinning is usually neede at age 6 to 8 years, and a final harvest of 28-inch saw and veneer timber is possibl at age 28 (McKnight, 1970).

Although not generally noted for their wildlife habitat values, stands of bot black willow and cottonwood offer a diversity in habitats that is very important fo some species. Stands of black willow may be used extensively by some Neotropica migrant birds, and cottonwood plantations have been shown to provide excellen wildlife habitat for a number of game and nongame birds and animals (Wesley e al., 1981).

Susceptibility to Damage Natural stands of cottonwood and willow are tolerant of flooding and siltation under normal conditions. However, seedling stands, especially newly established plantings, suffer significant mortality when inundated for several weeks after foliation (Kennedy and Krinard, 1974; Baker, 1977). Mortality and growth losses are much less severe when flooding occurs during the dormant season or if the tops of foliated seedlings remain above flood levels during the growing season.

Young cottonwood plantations and nurseries are susceptible to damage by a number of insects and diseases (Morris et al., 1975). The more important insects are the cottonwood twig borer, the cottonwood leaf beetle, the clearwing borers, cottonwood borer, poplar borer, and poplar tentmaker. Registered chemicals are available for the control of these insects in cottonwood nurseries and plantations.

No important disease has been epidemic in southern cottonwood plantations (McKnight, 1970). However, several canker diseases, including *Septoria musiva, Cytospora chrysosperma, Fusarium solani, Phomopsis macrospora,* and *Botryodiplodia theobromae,* infect cottonwood and may be responsible for losses of up to 20 percent during the first season in plantations established with unrooted cuttings (Morris et al., 1975). A leaf rust, *Melampsora medusae* sometimes defoliates cottonwood of all ages and thereby reduces growth.

Newly established cottonwood plantations are quite susceptible to browsing damage by deer and domestic livestock, which must be excluded for a year or two. Cottonwood of all ages can be killed or severely damaged by wildfires, and fire control is a must.

Willow suffers little from insects and diseases. Several insects, including the forest tent caterpillar, the cottonwood leaf beetle, the willow sawfly, and the willow leaf beetle, cause defoliation in willow but usually cause little mortality. The cottonwood borer and will-branch borer can cause defects and sometimes death of the tree. Canker diseases of willow can be caused by *Pollaccia saliciperda, Cytospora chrysosperma,* and *Phytophthora cactorum. Melampsora* rust may sometimes partially defoliate trees. Willow is also susceptible to mortality or serious wounding by wildfires. Severe droughts that lower the water table can result in considerable mortality on certain sites.

Baldcypress–Tupelo Type Group

Characteristics of this type are shown in Table 6-2, and information about the species normally associated with the type is presented in Table 6-3. Detailed information on the silvics and ecology for baldcypress is given by Wilhite and Toliver (1990) and for water tupelo by Johnson (1990).

Baldcypress and water tupelo (Fig. 6-8) are the chief species in the deep sloughs and swamps of the floodplains and terraces of major streams, especially the lower

Figure 6-8. Typical stand of baldcypress and water tupelo in the lower Coastal Plain of Alabama. (From USDA For. Serv.)

Mississippi River system. Such sites usually hold water for most of the year. In nonalluvial swamps of the Coastal Plain and along coastal estuaries, swamp tupelo is often the chief associate of baldcypress, but both tupelos may be present. All three species may grow in more or less pure stands. Other common associates are black willow, red maple, waterlocust, overcup oak, water hickory, green ash, pumpkin ash, sweetgum, pondcypress, and redbay. Common understory species include swamp-privet, buttonbush, water-elm, sweetbay, Carolina ash, poison-sumac, southern bayberry, and dahoon (Johnson, 1990).

Place in Ecological Succession Baldcypress or baldcypress-water tupelo may eventually follow black willow on floodplain sites where water stands most of the year (Fig. 6-5). The type represents an arrested state of succession and persists until the site is changed by sedimentation or drainage. Species replacing baldcypress–tupelo will depend on the degree of change in the hydrology of the site and could include water hickory, overcup oak, red maple, Nuttall oak, swamp laurel oak, green ash, sugarberry, American elm, and persimmon.

Baldcypress and the tupelos are extremely tolerant of flooding. Baldcypress is moderately tolerant of shade, while the tupelos are intolerant. They grow in mixtures with other species but will not tolerate overtopping. Baldcypress seedlings will start in heavy shade but usually do not develop into large trees (Conner et al., 1986).

Growth Rates Baldcypress trees should have an annual growth of between 0.2 and 0.3 inch in diameter and about 2 feet in height during the first 50 years (Johnson and Shropshire, 1983). The tupelos do not normally attain the large size or the age of baldcypress growing on similar sites, but the tupelos are faster growers than cypress. On a good site in South Carolina, 30-year-old water tupelo trees averaged 75 feet tall and 13 inches in d.b.h. (Hook et al., 1967). Growth on average sites should average 0.3 inch in diameter and 2 feet in height (Putnam et al., 1960). Swamps and forested wetlands such as those occupied by baldcypress and tupelo are some of the most productive ecosystems. Annual biomass production may exceed 14,000 pounds per acre (Brown, 1981), which is higher density than found in most terrestrial forests in the temperate zone (Conner and Day, 1976).

Rotation Age or Size Baldcypress will live for hundreds of years, sometimes as long as 1200 years (USDA For. Serv., 1965), but height growth ceases at about 200 years and the trees start to die back from the top. However, the present practice is to harvest both baldcypress and the tupelos before they are 100 years old. The desired maximum diameter rather than age will determine length of rotation. Even-aged stands of baldcypress should produce a mean annual growth of 225 to 250 board feet per acre over a 100-year rotation. Even-aged tupelo stands on average sites can be managed on a 75-year rotation (USDA For. Serv., 1965).

Cultural Practices Regeneration of the baldcypress–tupelo type is difficult, and failures, especially for baldcypress, have been common (Hamilton, 1982; Gunderson, 1984; Conner and Toliver, 1990). However, it appears that baldcypress and the tupelos should be managed in even-aged stands. This silvicultural system is dictated by the shade-intolerant nature of the species, the even-aged condition of existing stands, and the sites (swamps) on which they grow (Putnam et al., 1960; Stubbs, 1973; Johnson and Shropshire, 1983). Most water tupelo sites are flooded year-round. Seeds of baldcypress and water tupelo are buoyant and are dispersed primarily by floodwaters. Seeds of swamp tupelo do not float but can be moved by floodwaters and are dispersed by birds and mammals. Seed production is generally adequate for all three species. However, seedling establishment requires that the site be dry for some portion of the growing season in order for germination to take place. When the sites dry up for brief periods, seeds that have been submerged for up to 2 years quickly germinate, and the new seedlings develop rapidly. Seedlings can be killed by 4 or 5 weeks of total submergence during the growing season (Johnson and Shropshire, 1983), so absence of growing-season floods for 1 or 2 years is usually necessary for establishment of the seedlings. These conditions occur infrequently on water tupelo sites, but are more common on swamp tupelo sites. This dependence on water levels explains the even-aged nature of most natural baldcypress–tupelo stands.

The regeneration method most often used for baldcypress–tupelo stands is usually termed clearcutting (Stubbs, 1973; McKnight and Johnson, 1975; Johnson and Shropshire, 1983), but in reality it is a combination of the shelterwood, clearcutting, and coppice methods. If the stand is opened, either by harvest cuts or natural mortality, advance regeneration will usually be present. After a final removal cut, additional regeneration will occur from seed if the site is dry enough, and stump sprouts are a fairly dependable source of regeneration for all three species. However, survival of baldcypress stump sprouts is often poor, and trees produced from stump sprouts may be of poor quality (Conner et al., 1986). Advance regeneration is generally not a problem in stands of swamp tupelo, but lack of advance regeneration may be a major deterrent to successful regeneration in areas of the deeper water typical of baldcypress–water tupelo sites.

In the absence of advance regeneration, a shelterwood or seed-tree method could be used to secure a seed source to regenerate baldcypress–tupelo. However, harvesting is a problem on these sites, and use of the method is not well established. Established seedlings will resprout if they are broken during harvest cuts (Hook and Debell, 1970). Planting of baldcypress seedlings has been very successful in nonswamp areas (Krinard and Johnson, 1987), but less so in flooded swamps (Conner and Toliver, 1990). Regardless of the regeneration method used, some brush control at the time of final harvest may be necessary, especially in baldcypress–swamp tupelo stands.

Most stands are overcrowded, and all three species assert dominance poorly, so growth slows early in life and the stands stagnate. Such a situation will certainly lead to longer sawtimber rotations unless these stands are thinned. McKnight and Johnson (1975) recommend a commercial thinning of even-aged stands when dominant trees average 8 to 10 inches d.b.h., a second thinning when dominants average 14 to 16 inches, and a third when they average 20 to 22 inches. In each thinning, the smaller trees of poorer quality should be removed to favor the more vigorous dominant trees. Basal areas of 250 to 350 square feet are common in baldcypress–tupelo stands, and residual density after thinning may be rather high, but a basal area of 110 square feet or less should be the goal of thinnings. Thinning of a dense 70-year-old cypress–hardwood stand in a muck swamp in Florida resulted in faster growth of individual crop trees but slower growth per acre than in unthinned areas (McGarity, 1979). Heavy crown thinning in baldcypress stands, while yielding faster diameter growth, can result in epicormic branching, especially in trees in the lower crown classes (Dicke and Toliver, 1988). On sites supporting pondcypress, nutrients are most often the limiting factor, and the response to thinning may not be sufficient to balance the costs of thinning (Ewel and Davis, 1992).

In the past, harvesting operations of all types were confined to dry conditions when equipment could operate on the wet sites. That is still generally true for most swamp tupelo sites, but much harvesting in water tupelo is now done by helicopter. Cutting is done by chainsaws or by feller-bunchers, which lay down large wooden mats across the wet sites (even including standing water), over which the machine travels.

Baldcypress–tupelo swamps provide good habitat for fish and wildlife. They are used extensively for recreational fishing as well as commercial fishing and trapping. In Louisiana, commercial crayfishing is important in baldcypress–tupelo swamps (Conner et al., 1993).

Susceptibility to Damage Floodwaters are the principle deterrent to the establishment of baldcypress–tupelo stands. Not only does standing water prevent germination of seed, but young seedlings are killed by 4 or 5 weeks of flooding during the growing season. Flooding, even in the growing season, is generally not harmful to trees and older seedlings that are not completely submerged. In fact, normal flooding helps maintain this type by eliminating competing vegetation. However, major changes in water levels, either by drainage or deeper flooding for long periods, can decrease growth and may eventually cause mortality, especially of the tupelos.

Fire can cause serious damage and death of baldcypress and tupelo trees. Evidence of past fires can be found in older stands. Fortunately, fire is extremely rare because the swamp sites seldom get dry enough to burn, and there is also little litter or ground cover to support a fire.

Relatively few diseases or insects cause widespread damage to baldcypress or tupelo. The only serious disease of baldcypress is the wood-destroying heart rot fungus *(Stereum),* which causes "peckiness" in old trees. This fungus enters rotted branch stubs in the crown and slowly works down in the heartwood to the base of the tree, producing a pitted or chambered effect (Davidson et al., 1960). Several insects, including the cypress looper (Morris, 1975), bagworm (Wilhite and Toliver, 1990), and fruit tree leafroller (Goyer and Lenhard, 1988), can cause defoliation and possibly death of baldcypress. Artificial regeneration of baldcypress may be unsuccessful because of destruction of the seedlings by nutria (Blair and Langlinais, 1960; Conner and Toliver, 1990). Deer and rabbits often clip seedlings of baldcypress and tupelo, but the seedlings survive and resprout.

The forest tent caterpillar is a major insect enemy of the tupelos, defoliating thousands of acres annually. Although repeated defoliations can kill trees, the main effect has been a significant reduction in growth and a loss of seeds (Morris, 1975).

Mixed Bottomland Hardwoods Type Group

As indicated in Table 6-2, this type group occurs on all major and minor stream bottoms throughout the South. Several forest-cover types defined by the Society of American Foresters can be identified in bottomlands, but the types are so intermingled, especially in minor bottoms, and the species composition on many sites is so complex that it is more meaningful to discuss this broad species association rather than specific cover types. Table 6-3 provides specific information on species included in this type group. Detailed information on silvics and ecology of individual species is given in Volume 2 of *Silvics of North America* (Burns and Honkala, 1990).

Place in Ecological Succession Patterns of succession in major and minor bottoms are illustrated in Figure 6-5 and discussed in earlier sections. Successional patterns, and thus species occurrence, are largely determined by alluvial deposition and related changes in moisture (drainage), which in turn are reflected in distinct topographic features within the floodplain (Fig. 6-3). The regional oak–hickory climax type is rare in the floodplains of the Mississippi River system, and in other major bottoms it occurs only on the highest and best-drained sites with the most mature soils. Advanced stages of succession do occur on terraces in the major alluvial valleys.

In the floodplains of most major river bottoms, cherrybark oak, swamp chestnut oak, Shumard oak, water oak, various hickories, and winged elm are common on the ridges. Flats are occupied by sweetgum, willow oak, Nuttall oak, swamp laurel oak, green ash, red maple, and persimmon. Low, wet flats and sloughs often support overcup oak and water hickory.

The smaller river and creek bottoms in the Coastal Plain do not usually exhibit distinct successional stages, and the oak–hickory climax is often found, especially on the higher sites. Composition includes several red oaks, white oaks, sweetgum, and hickories as well as American beech, yellow-poplar, southern magnolia, and pines.

Growth Rates Growth rates vary considerably among the species and even for the same species growing on different sites or under different stand conditions. Johnson and Shropshire (1983) classify sycamore, river birch, and silver maple as fast early growers. Sweetgum and green ash have intermediate early growth rates, although, like other hardwoods, sprouts of these two species grow rapidly for the first 3 or 4 years. Oaks and hickories usually grow slowly until about age 10 or 15 and then assume more rapid growth.

Depending on species and site, crop trees should average between 0.2 and 0.5 inches in diameter growth and 1.5 to 2.5 feet in height growth per year on a 50-year rotation (Broadfoot, 1976). Fully stocked stands can yield more than 250 board feet per acre per year on a 60- or 80-year rotation (Putnam et al., 1960). Mixed bottomland hardwood stands seldom exceed 150 square feet of basal area per acre, and most are between 110 and 130 square feet per acre (Johnson and Shropshire, 1983).

One extensive study found annual hardwood yields in major bottoms of the South to be about 57 cubic feet per acre per year in stands 20 to 60 years old (Smith et al., 1975). In contrast, maximum gross cubic volume growth for cherrybark oak on good sites has been estimated to range from 188 to 275 cubic feet per acre per year (Krinard, 1990).

Rotation Age or Size Most mixed bottomland hardwood stands are grown under an even-aged system, but uneven-aged management is also used. In either case there is generally no fixed rotation age for harvesting stands or trees. Harvest is determined primarily by size, growth rate, and vigor or condition of the more desirable species in the mixture. For sawtimber, age at harvest is commonly 60 to 80 years and many sawmills cannot, or prefer not to, handle trees larger than 26 or 28 inches in d.b.h.

Several landowners across the South are now growing natural stands of mixed bottomland hardwoods for fiber production. Rotation lengths have not been defined, but it is anticipated they will be 20 to 30 years and produce trees 8 to 10 inches in diameter.

Cultural Practices

Natural Stands Natural stand management is used for most mixed hardwood stands. Very little artificial regeneration is used. Furthermore, the more desirable species such as oaks, sweetgum, and yellow-poplar are intolerant or moderately tolerant of shade, and most existing stands were initiated under even-aged conditions. Thus, an even-aged system is most often used for maximum timber production and ease of management, although, as noted later, an uneven-aged system can be used.

The most successful regeneration method for mixed hardwoods requires a complete clearcut. However, the method is not a clearcut in the classical sense, in that the most important source of reproduction is usually advance regeneration established beneath the older stand. Coppice regeneration from stump and root sprouts can be very important in some cases, and some regeneration can be expected from seed.

Many, if not most, mixed bottomland hardwood stands suffer from mismanagement or a lack of management. Stocking, composition, and quality are generally below the desired levels. In such stands the first decision to be made is whether to manage the existing stand or initiate regeneration procedures. That was often a very difficult decision that has to be made with few available guidelines. An expert model has recently been developed which will aid in making that decision (Manuel et al., 1993).

If regeneration is called for, then the first step should be an assessment of the regeneration potential. Techniques for doing this are still being perfected, but the preliminary method proposed by Johnson (1980) can be used for mixed bottomland hardwoods. The method is based on an assessment of number and size of advance regeneration, sprout potential of severed stumps, and presence of light-seeded species in the overstory. If adequate advance reproduction is present and/or sprouting is expected to be adequate, a complete clearcut is recommended. Full release is essential, and this can be accomplished by chain sawing, shearing, or deadening the residuals after a commercial clearcut. The size of the opening is not especially critical for obtaining regeneration, but development of reproduction in openings of less than ½ acre is generally much slower than in openings of 2 acres or more (Johnson and Shropshire, 1983).

Where regeneration potential is not adequate, an alternative to immediate clearcutting for even-aged management is using a modified shelterwood to obtain advance regeneration (Hodges, 1987; Loftis, 1990). The key to success is to provide adequate light to the forest floor. This may in some cases be accomplished by a light shelterwood, but in most stands it will also necessitate control of less desirable species in the midstory and understory (Janzen and Hodges, 1985; Hodges, 1987). Removal of shelterwood trees, which should be done within 5 years after adequate advance reproduction is established, will pose no problem since broken seedlings will resprout (Johnson and Shropshire, 1983).

The seed-tree method is not very useful in bottomland hardwoods. Johnson and Krinard (1976) concluded that seed trees of sweetgum and red oaks did not significantly influence the establishment or development of reproduction on two sites in southeastern Arkansas. Most reproduction was of sprout origin or from seedlings present in the understory at the time of harvest. Other more recent studies in minor bottoms have shown the same results (Hodges, 1987).

Of the uneven-aged methods, group selection appears to be the most feasible for regeneration of mixed bottomland hardwoods since single-tree selection will favor establishment of the more shade-tolerant and usually less desirable species. Openings created by group selection should be at least ½ acre and may range up to several acres in size. Tolerance of the species being regenerated, sprouting ability of the trees to be cut, and reproduction already present for release determine the size of the group to be harvested. While volume regulation can be adhered to, success of the method will depend on creation of an environment favorable to the desired species with little regard to size of the opening. Control of competing vegetation by cutting and/or use of herbicides may be necessary in some cases.

If the decision is made to retain and manage a previously unmanaged stand, then almost always the first cultural practice required will be a combination improvement cut and thinning. In fact, all intermediate cuttings in bottomland hardwood stands should include both objectives. In older unmanaged or mismanaged stands, the emphasis is most often on an improvement cut. In even-aged stands of pulpwood

size, the emphasis will be on thinning to reduce stand density. Thinnings should be made from below to remove low-vigor trees, which tend to develop more epicormic branches when released than do dominant, vigorous trees (Hedlund, 1964). The first commercial thinning can occur when the trees average 8 to 10 inches d.b.h. and should leave approximately 60 to 70 square feet of basal area per acre. Two or three more thinnings are recommended at intervals of 7 to 15 years, depending on site and species (Johnson and Shropshire, 1983). At final harvest, most stands should exceed 120 to 130 square feet of basal area per acre.

Artificial Stands Where natural regeneration cannot be obtained, for example, on open fields or in stands where a desirable seed source is not available, planting is a viable alternative. Commercial plantings have been made for a number of species including American sycamore, sweetgum, green ash, cherrybark oak, Nuttall oak, water oak, willow oak, and yellow-poplar. Several other species, including pecan, water tupelo, and baldcypress, have been established successfully in experimental plantings. A major problem with hardwood planting is the high cost. For most species it requires intensive site preparation and intensive vegetation control, usually by cultivation, for 1 to 5 years (Johnson, 1978). Currently, most hardwood planting is being done by pulp companies to insure a source of a given species to meet mill requirements, especially in wet seasons when logging in natural stands is not possible. Recently, thousands of acres of agricultural land across the South have been planted under the Conservation Reserve Program.

Direct seeding is an alternative to planting for the oaks especially on old-field sites. Pecan has also been seeded successfully. On recently harvested sites, openings should be at least 2 acres to prevent depredation of the acorns by rodents (Johnson, 1981). Probability of successful regeneration is higher for planting than direct seeding (Allen, 1990), but the cost of direct seeding is considerably less (Bullard et al., 1992).

Regardless of the method of artificial regeneration it is imperative that the species be matched to the site. A guide developed by Baker and Broadfoot (1979) or the interactive computer version, SITEQUAL, developed by Harrington and Casson (1986) can be used to evaluate site potential for bottomland hardwoods.

Wildlife Habitat Some of the most productive and valuable fish and wildlife habitats in the United States are found in the Bottomland Hardwood Forest. Fertile alluvial soils, abundant water, high-quality food of great variety, relative freedom from fire, usually accessible agricultural fields, and good escape cover all contribute to provide this favorable habitat (Glasgow and Noble, 1971). White-tailed deer, wild turkey, squirrels, rabbits, waterfowl, and many nongame species of birds and mammals abound in the Bottomland Hardwood Forest. Some uncommon or rare species that utilize bottomland forests are the southern black bear, ringed sawback turtle, swallow-tailed kite, and American bald eagle.

Silvicultural practices as discussed earlier for natural stands are highly compatible with maintenance of good habitat for many wildlife species. Some of the most productive deer and wild turkey areas in the South are in forests intensively managed for timber production. Changes in management practices to improve wildlife habitat, if needed at all, have to do with timing and size of cuts.

Mixed bottomland hardwood forests can, and often do, provide an economic return from the wildlife resource (Haygood, 1970; Glasgow and Noble, 1971). Hunting leases of $10 per acre per year are quite common, and some leases exceed $15 per acre per year. Hunting leases not only provide a direct economic return, but they often assist the landowner in providing security and protection for the area and upkeep of the forest roads.

Special Problems in Management Most sites on which mixed bottomland hardwoods, as well as the baldcypress–tupelo and cottonwood–black willow type groups, grow were classified as wetlands by the 1989 delineation manual (Fed. Interagency Comm. for Wetland Delineation, 1989). Although there will probably be site classification changes in the future, it is likely that most bottomland sites will be classified as wetlands. On wetland sites there can be no permanent drainage or discharge of sediments or other material onto the sites. Furthermore, most states in the South have developed "Best Management Practices" for wetlands that specify acceptable silvicultural practices. There is no permit requirement for hardwood management on these sites as long as these practices are followed.

In mixed hardwoods it is not unusual to find 10 to 15 different commercial species in a few acres because sites are so intimately intermixed. Not only do the inherent qualities of each species differ; there is also a wide variation in quality and form of logs and trees within a species. Furthermore, there has been a lack of integrated markets, making it economically impossible to cut most stands properly. As a result, most low-grade material cannot be harvested, and the cost of eliminating this poor material to make way for more desirable growing stock is more than most landowners have been willing to expend. Recently, there has been a marked increase in the demand for hardwoods for pulp and paper production and for mill energy wood. Most species, even of low grade, can be used. Cuttings of this type have a great potential for improving hardwood management in that they are extremely useful for timber-stand improvement and for increasing regeneration potential of the more desirable species.

Most species in this type have a tendency to develop epicormic branches when the stand is opened. The problem is most severe in trees of low vigor, especially those in the lower crown classes. The problem can be largely eliminated by light to moderate thinnings, which favor vigorous trees with good crowns in the dominant and codominant crown classes. The practice of leaving midstory trees, even if not desirable species, has been recommended for reducing epicormic branching (Johnson and Shropshire, 1983).

Susceptibility to Damage Fires do not often occur in bottomland hardwood stands because the bottoms are too wet to burn. However, when fire does occur in very dry periods, it can be very damaging to bottomland hardwoods. It may kill almost all seedlings and small saplings and severely damage poles and many

sawtimber trees. None of the bottomland species is resistant to fire damage. The greatest loss from fire in the poles and sawtimber trees is the result of rot, stain, and entrance of insects in the damaged areas.

Concentrated grazing by cattle can cause severe damage to bottomland hardwoods by eliminating reproduction of many species, deforming small trees that are not killed, and reducing growth by soil compaction and restricted water movement. Browsing of young seedlings and saplings by deer can also be a serious problem at times.

Although detrimental to established stands, disturbances such as fire and grazing have played an important role in the establishment of many stands. They have been very important in determining species composition. Many stands with a high percentage of oaks apparently originate following some disturbance such as fire, grazing, or mowing (Aust et al., 1985). Oaks can withstand these disturbances better than many of their competitors. Although the tops of the oaks are killed or removed, large root systems are allowed to develop. Once the disturbances are controlled, the vigorous sprouts produced by the oaks can outgrow competing woody vegetation.

Numerous insects and diseases infest the different species occurring in bottomland hardwood stands. Trees of low vigor are most susceptible to attack by wood borers and defoliators (Solomon and Swords, 1978). Fortunately they do not normally cause widespread mortality, but do result in defects, decay, and loss of growth. In 1989 and 1990, serious dieback and mortality of sugarberry occurred in Louisiana and Mississippi. This decline of sugarberry apparently resulted from heavy infestation of the leaves by a tiny insect in the family *Psyllidae* (Solomon, 1991). Dutch elm disease and elm phloem necrosis have killed most American elms in the northern and central part of their range. Oak wilt has been a problem in some areas (Lewis, 1981), and oak decline, a disease of unknown etiology, occurs across the southern region (Starkey et al., 1989; McCracken et al., 1991; Nebeker et al., 1992). Diseases of sycamore have become more important, especially in plantations. One disease, variously described as sycamore canker or sycamore dieback, has become very common. The organism(s) causing the lethal bole cankers have not been established, but *Ceratocystis fimbriata* and *Botryodiplodia theobromae* appear to be involved (McCracken and Burkhardt, 1977). Sycamore is also susceptible to anthracnose, which causes defoliation and cankers (Merz, 1965).

Periodic flooding is characteristic of much of the mixed bottomland hardwoods type. The effects of flooding may be either beneficial or detrimental, depending on the time and duration. Flooding during the dormant season causes little harm to any of the species and may, in fact, improve subsequent growth of the trees. Even seedlings of most species can survive extended flooding during the dormant season, and some species even tolerate saturated soil conditions in the summer, but few can withstand complete inundation after foliation (Broadfoot and Williston, 1973). Large trees of most species can tolerate short periods of flooding during the growth season, but few species can survive continuous flooding for the entire growing season. Continuous flooding for 1 to 4 years will kill trees of most bottomland hardwood species (Broadfoot and Williston, 1973). Changes in natural drainage as a result of beaver impoundment, construction of dams, and use of green-tree reservoirs (Karr et al., 1990) have resulted in loss of vigor and growth, tree mortality, and compositional changes in bottomland hardwood stands across the South.

Silviculture of Forests of the Brown Loam Bluffs

Growth Rates Bluff sites are capable of producing quality hardwoods at a rate comparable to any other place in the United States. Well-stocked stands can produce more than 500 board feet per acre per year, and yellow-poplar and a few other species can grow 6 feet in height or more annually during the first 10 to 15 years (Johnson, 1991). Trees of several species, including oaks, ash, and yellow-poplar, often produce three or four quality logs per tree. Diameter growth is exceptionally good, with rates of 0.75 inches or more per year being fairly common for dominant red oaks.

Rotation Age or Size As with bottomland hardwoods, there is generally no fixed rotation age for harvesting stands of trees. Harvest is determined primarily by size, growth rate, and vigor or condition of the more desirable species in the mixture. Trees 26 to 28 inches d.b.h. are generally considered mature, and most sawmills would prefer not to handle trees larger than this. Under good management, trees of this size can be produced on a rotation of about 60 years or less.

Cultural Practices In many respects, Bluff forests are similar to most other upland hardwood forests of the South. Most stands are understocked and have been high-graded to the point that present composition and quality are far less than desirable. Many of the stands need to be regenerated, while others are in need of improvement cuttings.

As previously noted, Bluff forests are very diverse in composition, and cover types are usually indistinct. Silvicultural practices generally are not dictated by a consideration of forest type, nor are they designed to maintain a particular type. Generally they are designed to create and/or maintain a certain species or species mixture on the sites (slope position) most suitable for that species or mixture. Fortunately these highly productive sites support a number of desirable species. Cherrybark oak (Fig. 6-9) and Shumard oak are among the best and are favored on all sites with the possible exception of dry ridges with thin loess, where pine is more suitable. Ash, yellow-poplar, cottonwood, and black walnut do well in coves and bottoms, while sweetgum, ash, and yellow-poplar grow well on lower and middle slopes. White oaks and southern red oak can be managed on upper slopes.

Artificial regeneration of oaks, ash, sweetgum, and yellow-poplar has been successful in the Bluffs, but almost all regeneration is now done by natural means. Regeneration is easily obtained on these sites, but maintaining the desired composition, especially of the oaks, can be a major problem. Past cutting practices, especially single-tree selection, has in many areas promoted the growth of Amer-

Figure 6-9. *Cherrybark oak on colluvium at the base of the slope in the silty uplands (Brown Loam Bluffs) of Mississippi. (From USDA For. Serv.)*

ican hornbeam and eastern hophornbeam. These very shade-tolerant species are widespread in the understory of Bluff forests. They often form a dense canopy both as a midstory and where the overstory trees have been removed. They will have to be cut or deadened to obtain reproduction of more desirable but less tolerant species.

Another problem for natural regeneration of oaks in some areas is the presence of large amounts of yellow-poplar. It is difficult to obtain sufficient advance regeneration of oak seedlings, and then when released they do not compete well with the faster-growing yellow-poplar seedlings.

Even-aged and uneven-aged (group-selection) regeneration methods can be used in the Brown Loam Bluffs, but the desirable species are mostly intolerant or moderately intolerant of shade, so regeneration openings must be large enough to provide sufficient sunlight for the regeneration. The key is providing the necessary environment for the young seedlings, regardless of opening size. The most common method of regeneration, termed clearcutting, is not clearcutting in the classical sense in that the new seedlings come from advance regeneration, sprouts, and seed. Success of the method depends on control of the shade-tolerant understory species and manipulation of stand conditions to favor establishment of advance regeneration before the final harvest, which removes all trees 2 inches d.b.h. and larger. Where yellow-poplar is a potential problem for oak regeneration, one approach might be to cut the yellow-poplar seed trees several years prior to the regeneration cut.

One large industrial landowner uses an uneven-aged system of silviculture, but opening size for regeneration varies from less than $\frac{1}{2}$ acre to several acres in size, depending on stand conditions and the amount and condition of the advanced regeneration. These openings are not recognized as separate stands in future operations. Control of the less desirable, more tolerant competitors is even more critical for this method than for clearcutting.

Susceptibility to Damage Fire and grazing can cause the same type of damage in Bluff forests as in bottomland hardwood forests. However, loss from fires is much more common in the Bluffs than in the bottomlands because of drier conditions and more fuel to support a fire.

Disease and insect problems in Bluff forests are similar to those in Southern Bottomland forests since many tree species occur in both areas. Fortunately, damage to Bluff forests from disease and insects is minor.

A great deal of care is required in logging Bluff forests. Logging roads and skid trails must be located properly to avoid excessive erosion, and the number of trails should be minimized. Tracked vehicles are preferable to rubber-tired vehicles, but off-trail traffic should be avoided where possible. Cable skidding from the ridges can minimize damage to the site.

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