SILVICULTURE OF SOUTHERN BOTTOMLAND HARDWOODS: 25 YEARS OF CHANGE

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ABSTRACT ,

This paper describes changes that have occurred in the silviculture of southern bottomland hardwood forests over the past 25 years, particularly in terms of modifications to existing silvicultural practices, abandonment of unsuitable practices, and development of new practices. Changes in the focus and objectives of hardwood silviculture and the emergence of new concerns to hardwood silviculturists are also discussed. Speculations on the future character of hardwood silviculture in southern bottomlands, as well as recommendations for future silvicultural research, are presented.

INTRODUCTION

Silviculture of southern bottomland hardwood forests has evolved considerably over the past 25 years. Many existing silvicultural practices have been modified to be more successful and to be more ecologically sound. Some silvicultural practices common 25 years ago have simply been abandoned. New silvicultural practices have been developed through research and have been implemented on the ground. In many instances, the focus and objectives of southern bottomland hardwood silviculture have changed. Many new and challenging issues have affected the way silviculturists manage southern bottomland hardwood forests. All of these changes and developments have altered the character of hardwood silviculture over the past 25 years and will continue to shape the character of hardwood silviculture for many years to come.

This paper will (1) describe changes in the silviculture of southern bottomland hardwood forests that have occurred over the past 25 years, (2) speculate on the future character of hardwood silviculture in southern bottomland forests as it will develop over the next 25 years, and (3) present recommendations for future research in the silviculture of southern bottomland hardwood forests.

OVERVIEW OF SOUTHERN BOTTOMLAND HARDWOOD FORESTS

To adequately understand and appreciate the changes in silviculture of southern bottomland hardwood forests that have occurred over the past 25 years, it is necessary to be familiar with the southern bottomland hardwood resource itself-the extent of the resource, the physiography of the sites, and the major cover types that are found in these diverse forests.

Extent of the Resource

Currently, there are about 30 million acres of bottomland hardwood forests in the South (Hodges, 1994). The loss of these valuable forests, primarily as a result of conversion to agriculture and other uses, has slowed in the

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recent past. For example, there were 40 million acres of bottomland hardwood forests in the South in 1952, but only 32 million acres in 1977 (USDA Forest Service, 1988). The current estimate of 30 million acres represents a loss of 25 percent of the acreage since 1952, but a loss of only 6 percent since 1977.

More than 90 percent of the bottomland hardwood forests across the South are privately owned. Non-industrial private landowners account for about 66 percent of these lands, while forest industries own about 25 percent of the total (Saucier and Cost 1988; McWilliams and Faulkner 1991). Public ownership accounts for only about 9 percent of the bottomland hardwood forests in the South, but this proportion may be increasing as a result of mitigation purchases by the federal government (Hodges, 1994). This great diversity of owners creates a wide range of management objectives that present many challenges to hardwood silviculturists as they seek to fulfill those objectives through silvicultural prescriptions.

Hodges (1994) summarized the most recent USDA Forest Service inventories and reported that southern bottomland hardwood forests contain about 45 billion cubic feet of growing stock, of which approximately 160 billion board feet (International 1/4-inch scale) are in sawtimber. Based on these figures, hardwood sawtimber volume averages between 5300 and 5400 board feet per acre across most southern bottomland forests.

Although growth exceeds removal by a ratio of 1.4: 1 .0, McWilliams and Faulkner (1991) reported that many southern bottomland hardwood stands are greatly understocked. For example, 60 percent of the area supports stands of less than 5000 board feet per acre; 37 percent of these stands carry less than 1500 board feet per acre. Net annual growth across the region averages less than 50 cubic feet per acre per year, a growth rate of only about 3.3 percent per acre per year. Recent decreases in the volume of high-quality hardwood sawtimber, especially in Mississippi, may lead to future shortages in this valuable resource (Beltz et al. 1990).

Physiography

Two types of river systems are generally recognized within the southern bottomland hardwood forest resource: major riverbottoms and minor streambottoms. Major riverbottoms are associated with large streams, and are formed from alluvium of regional origin. Soils are highly diverse, but most are generally high in expanding clays. Flooding in major riverbottoms is usually frequent and of long duration, leaving the sites inundated for as much as several months each year. Major riverbottoms support about 8 million acres of bottomland hardwood forests across the South. In contrast, minor streambottoms are typically associated with smaller streams, and are formed from alluvium of local origin. Soils are generally sandy because the alluvium originated from the coarse-textured deposits of the lower Coastal Plain. Flooding is usually of short duration, but many sites may flood several times during the winter and spring months each year. Minor streambottoms support about 17 million acres of southern bottomland hardwood forests. Bottomland soils in the South differ widely in physical and chemical properties, especially texture, structure, drainage, and water-holding capacity, but most bottomland soils in both types of river systems are relatively young and are characterized by indistinct profile development.

Within a bottomland, minor variations in topography, generally of less than a few feet, lead to greatly different site conditions. The normal pattern of deposition during a flooding event, in which coarse materials (sands) are deposited immediately adjacent to the stream and progressively finer sediments are deposited in sequence away from the river, coupled with these minor variations in topography, lead to the formation of distinct site types that vary greatly in soil texture, drainage, water-holding capacity, and wetness. As a result, wide ranges in productivity and species composition are found across these basic site types within a bottomland. Floodplain formation is described in mote detail by Putnam (195 1).

Six basic site types are found in most bottomlands (Hodges and Switzer, 1979). A ***bar*** is new land constantly formed by the river as erosion occurs on one bank and the resulting sediment is deposited downstream on the

opposite bank. **The *front*** is the natural levee alongside the river, and is generally the highest point in the floodplain. ***Flats*** form the general terrain between the ridges within a **floodplain.** Flats typically account for the greatest proportion of land **area** within most floodplains. Ridges are the fronts of **former** stream channels and may rise up to 10 feet higher than the adjoining flats. A ***slough*** is a narrow, meandering, shallow depression that typically remains wet well into the growing season. Most sloughs are either drainages that seasonally carry standing water or **are** the remnants of old stream channels. A ***swamp*** is a much broader, distinct depression with standing water throughout the year, except during periods of extreme drought. Soil properties, as well as flooding depth and duration, vary widely among these six basic site types, and have a profound influence on species composition and productivity.

Major Cover Types

This great **diversity in** both species composition and site characteristics produces a complex ecosystem. However, species composition within a southern bottomland hardwood forest can be categorized into seven major cover types, as **described** in detail by Johnson (1981) and by Meadows and **Stanturf** (1997).

Cottonwood-willow. Eastern cottonwood and black willow are pioneer species that occur on bars, or "new land." Cottonwood generally occurs on welldrained, coarse-textured sediments, while willow is usually limited to the poorly drained, fine-textured sediments. Both species are very intolerant of shade and do not succeed themselves naturally.

Ebn-sycamore-pecan-sugarberry. This species association is also commonly referred to as riverfront hardwoods. It typically occurs on fronts and high ridges near the stream. These sites are well-drained and relatively dry. They are very productive and generally support a wide diversity of species.

Elm-ash-sugarberry. This species association commonly occurs on the wide flats within the bottomland. Consequently, it is one of the most common and widespread species associations in southern bottomland hardwood forests. In comparison to the fronts and high ridges, these wide flats are generally wetter, less productive, and tend to support a narrower range of species.

Overcup oak-bitterpecan. **Overcup** oak and bitter pecan generally occur only on low flats or in sloughs within southern bottomlands. These wet sites are not very productive and tend to support only a few species that can tolerate the adverse conditions.

Sweetgum-red oak. The sweetgum-red oak cover type occurs primarily on ridges within major riverbottoms and on the higher sites within minor streambottoms. These very productive sites yield much of the high-quality oak sawtimber grown in southern bottomland hardwood forests. Successionally, the sweetgum-red oak type is transitory and its perpetuation requires silvicultural **treatment.** Clatterbuck and Meadows (1993) presented specific silvicultural guidelines to successfully regenerate sweetgum-red oak stands.

Red oak-white oak. This species association contains a wide variety of species, but is generally dominated **by** both red oaks and white oaks. It occurs on ridges within older, infrequently flooded bottomlauds. Hickories, rather than sweetgum, are the most common non-oak species. This cover type represents a later sere within the succession of southern bottomland hardwood forests.

Cypress-tupelo. Baldcypress and water tupelo typically occur in varying mixtures in true swamps that are more or less permanently flooded. Because other species cannot tolerate the semi-permanently flooded conditions,, the cypress-tupelo association represents an arrested stage of succession that may persist for hundreds of years.

Hodges (1997) provided an in-depth discussion of the formation, **development,** and **ecology** of the major site types within southern bottomland hardwood forests and the species mixtures **associated** with each. Successful silvicultural manipulation of southern bottomland hardwood **forests** requires a thorough understanding of these critical species-site relationships.

The remainder of this paper will address **three** questions, as they pertain to southern bottomland hardwood forests:

1. How has hardwood silviculture changed over the past 25 years?

2. What will be the character of hardwood silviculture during the next 25 years?

3. What are the future **research** needs in hardwood **silviculture?**

CHANGES IN HARDWOOD SILVICULTURE

Silviculture and management of southern bottomland hardwood forests **25 years** ago were heavily influenced by John Putnam, former Director of the USDA Forest Service's Southern Hardwoods Laboratory that has been in operation in Stoneville, Mississippi since 1940. Putnam devoted over 40 years to the study of southern bottomland hardwood forests. During that time, he provided one of the first comprehensive descriptions of the forests of the region (Putnam and Bull **1932),** and formulated the first practical guidelines for their management (Putnam **1951),** which were later refined (Putnam et al. 1960).

In the southern bottomland hardwood forests of the early **1970s,** the typical objective of management was the production of high-quality sawtimber. Because there were few, if any, hardwood pulpwood markets across the South, the emphasis in most stands was on growing large trees at least 40 inches d.b.h. To achieve these objectives, Putnam recommended uneven-aged management, using both single-tree and group selection, for most cover types except for pure, even-aged stands of cottonwood and willow. To maintain well-stocked stands, Putnam recommended relatively light partial harvests on a **10-year** cutting cycle. Marking rules were based on a tree classification system devised by Putnam to evaluate critical characteristics of individual **trees** in the stand. These frequent, light cuts were most often accomplished through shortwood logging, an operation in which harvested logs **are** bucked into short lengths in the woods prior to skidding them to a landing. Shortwood logging resulted in much less damage to residual trees and thereby reduced the impacts of these frequent entries into the woods.

By the early **1970s,** however, clearcutting and other even-aged management systems were increasing in use among managers of southern bottomland **hardwood** forests. These even-aged systems were less complicated and less costly to implement than were **the** uneven-aged systems advocated by Putnam. Artificial regeneration of southern bottomland hardwoods was also becoming mom common during the early 1970s. Managers viewed artificial regeneration primarily as a tool to incorporate gains from hardwood tree improvement programs, such as the one that produced superior clones of eastern cottonwood **(Mohn** et al. 1970).

Modifications to Existing Silvicultural Practices

Silviculture of southern bottomland hardwood forests has not been drastically overhauled during the past 25 years. Rather, progress has been made through both major and minor modifications to existing silvicultural practices that have stood the test of time. Important modifications have been made in three critical areas of silvicultural activity: (1) natural **regeneration,** (2) artificial **regeneration,** and (3) intermediate stand management.

Natural regeneration. One important development in natural regeneration of southern bottomland hardwoods has been the recognition that adequate advance reproduction must be present in the stand prior to harvest to successfully regenerate most species, particularly bottomland oaks. If adequate advance reproduction is present in the stand, a complete **clearcut** is the recommended prescription for even-aged management (Clatterbuck and Meadows 1993). However, if advance reproduction is not present in sufficient quantity, Hodges (1987) recommended a modified shelterwood method be used to obtain advance reproduction. The key to successful use of this modified shelterwood is to provide enough sunlight to the forest floor to maintain the growth and development of advance reproduction. In most southern bottomland hardwood stands, control of less desirable species in the dense mid-story and understory is also necessary to allow adequate sunlight to reach the forest floor (**Janzen** and Hodges 1985). Once adequate advance reproduction is established, all remaining shelterwood trees should be removed to release the developing reproduction. Recognition of the importance of advance reproduction and the development of this modified shelterwood with mid-story and understory control have been extremely critical advances in successful natural regeneration of many southern bottomland hardwood species.

Another important modification in natural regeneration of southern bottomland hardwoods has been in the size and character of **clearcuts.** Most clearcuts today are complete clearcuts, in which all stems larger than seedlings are cut or deadened, rather than commercial clearcuts, where only the merchantable stems are cut. This complete removal of-stems from the previous stand provides full sunlight to the forest floor and enables the new regeneration to successfully compete in the new stand (Meadows and **Stanturf** 1997). The size of clearcuts in southern bottomland hardwood forests has also changed over the past 25 years. In response to public concerns over clearcutting, most managers today employ smaller clearcuts of about **10-15** acres or less.

Clearcuts of only l-3 acres in size actually resemble large group selection cuts, and create patches of even-aged regeneration that are-too small to be managed as individual stands. This combination of even-aged silviculture and uneven-aged management, called patch cutting, is becoming increasingly common in bottomland hardwood forests throughout the South. This new technique essentially produces an uneven-aged stand that consists of many small, irregularly shaped, even-aged groups. It allows for the even-aged development of small groups within an uneven-aged forest matrix (Meadows and **Stanturf** 1997). Because it combines the biological advantages of clearcutting with the aesthetic and wildlife advantages of group selection, patch cutting has become very attractive to many landowners across the South.

Artificial regeneration. **Numerous** changes and modifications to artificial regeneration practices have also occurred. The interest in artificial regeneration of southern bottomland hardwoods has fluctuated greatly over the past 25 years. For example, there was a great deal of interest in the development of successful artificial **regen**eration techniques during the late 1960s and **1970s,** primarily as a tool for the introduction of genetically improved stock into southern bottomland hardwood forests. Interest weakened during the **1980s,** however, as the emphasis of management shifted to natural regeneration. More recently, interest in artificial regeneration has strengthened once again, as reforestation of abandoned agricultural land has become a priority concern both for forest managers and policy-makers.

One of the biggest changes in artificial regeneration of southern bottomland hardwoods has been the development of successful direct-seeding techniques for oaks and other heavy-seeded species such as pecan (**Johnson** and Krinard 1987). Since oak direct-seeding methods were first developed in the **1960s,** there have been many improvements in seed collection, storage, handling, and sowing techniques, as well as advances in plantation establishment and weed control practices. Practical guidelines for successful direct-seeding of southern **bottom**land hardwoods, particularly oaks, are given by Allen and Kennedy (1989) and Kennedy (1993).

Another important development in artificial regeneration of southern bottomland hardwoods has been the increasing popularity of mixed-species plantations. Successful establishment of mixed-species plantations is now possible because our basic understanding of species-site relationships, interspecific competitive relationships, and patterns of natural stand development has greatly increased over the past 25 years. New research is currently underway to examine the feasibility of various species mixtures, such as water oak-green ash-Nuttall oak (Goelz 1995a) and cottonwood-red oak (Schweitzer et al. 1997). Many wildlife managers are currently planting mixtures of red oak and pecan on an operational scale on wildlife refuges across the South.

Intermediate stand management. Intermediate management of southern bottomland hardwood forests has intensified over the past 25 years. As in the past, the emphasis for most managers continues to be on the 'production of highquality hardwood sawtimber.' However, pulpwood production in hardwood stands has increased dramatically in recent years and has become the primary objective for a few industrial owners and is an important secondary objective for others.

The renewed interest in thinnings and other partial cuttings is at least partly due to the expanding hardwood pulpwood market that provides an important commercial outlet for the smaller, low-quality stems removed in partial cutting operations. However, the focus of these partial cuttings has changed over the past 25 years. In the past, the initial partial cut in southern bottomland hardwood stands was an improvement cutting designed to improve species composition and stand quality (Putnam and Bull 1940). Subsequent cuts were performed to regulate stand structure and density in basically uneven-aged stands, with emphasis on stand-level prescriptions (McKnight 1958). Today, the initial partial cut in southern bottomland hardwood stands is still an improvement cutting, but the objective for all partial cuts is primarily to promote the growth and development of individual trees with good potential for high-quality sawtimber in even-aged stands (Meadows 1996). So, over the last 25 years, the focus of partial cuttings in southern bottomland hardwood forests has shifted from stand-level prescriptions in uneven-aged stands to individual-tree-level prescriptions in even-aged stands.

One of the most valuable tools available for the management of southern bottomland hardwood forests is the tree classification scheme developed by John Putnam (Putnam 1951, Putnam et al. 1960). Putnam created this classification system to serve as a basis for planning partial cuttings and for developing rules for marking hardwood timber. The tree classes help the timber marker identify the types of trees that should be left in the residual stand and the types of trees that should be removed in some type of partial cutting. In this way, the tree classes are a form of cutting priority. The definitions and criteria for these tree classes have been modified and refined over the past 25 years, but the basic concepts advanced by Putnam are still widely used by silviculturists in the management of southern bottomland hardwood forests today. Meadows (19%) defined specific criteria for the four hardwood tree classes currently recognized-preferred growing stock, reserve growing stock, cutting stock, and cull stock.

One of the big problems associated with any partial cutting in hardwoods is the possible production of epicormic branches along the boles of residual trees. Consequently, along with the renewed interest in partial cutting has come a renewed interest in the phenomenon of epicormic branching in southern bottomland hardwood forests. Epicormic branches produce small knots on the lumber cut from hardwood logs. These knots are critical defects that may drastically reduce both lumber grade and value, thus creating a serious problem in the management of hardwood stands for the production of high-quality lumber. In fact, Meadows and Burkhardt (in press) reported a 13 percent reduction in the value of willow oak lumber as a result of defects caused by epicormic branches.

To minimize the production of epicormic branches on the boles of residual trees following partial cutting and reduce their subsequent impacts on lumber value, it is essential to understand the factors that affect epicormic branching. In the past, most hardwood silviculturists believed that epicormic branches developed solely as a result of sudden exposure of the bole to direct sunlight, usually following some type of partial cutting. However, evidence has mounted over the past 25 years that tree vigor plays a major role in determining the likelihood that an individual tree will produceepicormic branches (Brown and Kormanik 1970, Erdmann et al. 1985, Meadows 1993). In fact, Meadows (1995) theorized that the propensity of hardwood trees to produce epicormic branches is controlled at a gross scale by species and at an individual-tree level by stress, or tree vigor, such that low-vigor trees of susceptible species are much more likely to produce epicormic branches than are high-vigor trees of resistant species, when the buds that produce epicormic branches are stimulated by sudden exposure to direct sunlight. Meadows (1995) categorized southern bottomland hardwood species based on their known or suspected susceptibility to epicormic branching, and presented some general guidelines to reduce the risk of epicormic branching in southern bottomland hardwood forests.

Abandoned Silvicultural Practices

In addition to these modifications to existing silvicultural practices, there are a few practices in southern bottomland hardwood forests that have been abandoned, or at least are no longer recommended. These include (1) high-grading and (2) single-tree selection.

High-grading. **High-grading,** which also includes diameter-limit cutting, is a practice in which the most valuable stems are removed in a commercial harvest operation and the less valuable stems are retained. It removes the best and leaves the worst. Repeated high-grading ultimately produces an under-stocked stand of low-value species and low-quality trees. In many cases, the resulting stand exhibits low productivity and is not a good indicator of potential site quality. Unfortunately, many managers of previously high-graded stands mistakenly interpret the existing poor stand conditions to be a reflection of poor site quality, rather than a result of past cutting practices and mismanagement, and fail to recognize the true productive potential of the site. In severely high-graded stands, often the only option is to initiate regeneration procedures to create a new stand that more fully utilizes the inherent site quality. Unfortunately, there are still many high-graded stands of southern bottomland hardwoods. These stands present major challenges to hardwood silviculturists. But, research and landowner education programs, over the past 25 years, have drastically reduced the incidence of this management practice.

Single-tree selection. Another silvicultural practice that is no longer recommended in southern bottomland hardwood forests is single-tree selection. In the 1950s and 1960s, Putnam advocated the selection system and uneven-aged management of southern bottomland hardwoods; he was not a believer in even-aged management, except for certain species in specific situations. Putnam recommended the selection system as the best way to ensure good development of immature trees in mixed-species stands. Because differences among species in inherent growth rate and tolerance to shade produce stands consisting of many size classes, the diameter distributions Putnam observed in these mixed-species stands resembled those classically associated with uneven-aged stands. Consequently, Putnam mistakenly classified most southern bottomland hardwood forests at that time as many-aged, even though most were actually even-aged. As a result of this erroneous assumption, Putnam discounted even-aged management because conversion to even-aged stands would require uneconomic harvest of large volumes of immature timber and other promising growing stock. Putnam also doubted that even-aged stand structure could even be attained or maintained in mixed-species stands. Uniform regeneration of desirable species over large areas would be very difficult to achieve. Consequently, Putnam argued that the selection system was the most desirable way to economically manage southern bottomland hardwood forests (Putnam et al. 1960).

However, Putnam failed to recognize the long-term consequences of single-tree selection in mixed-species stands, such as those found in most southern bottomlands. Because the openings created through removal of individual trees are small, single-tree selection actually favors the development of shade-tolerant species. In fact, when used repeatedly, single-tree selection results in a shift in species composition away from high-value intolerant species to lower-value tokrant species (Meadows and Stanturf 1997). Because there are very few commercially valuable shade-tolerant species in southern bottomland hardwood forests, single-tree selection is not an effective regeneration alternative in most stands. The single-tree selection method of regeneration is especially not recommended for southern bottomland oaks (Toliver and Jackson 1989, Clatterbuck and Meadows 1993, Meadows and Stanturf 1997). The opening size is simply too small to provide adequate sunlight to the forest floor to allow successful growth and development of oak reproduction (Johnson and Krinard 1989).

New Sllvlcultural Practices

There have been several new developments in the practice of silviculture in southern bottomland hardwood forests over the past 25 years. These include (1) a better understanding of the basic ecology of these systems, (2) development of new stand evaluation and management tools, (3) development of alternative management systems, and (4) other new developments.

Better understanding of basic ecology. Recent research has given us a much better understanding of the basic ecology of southern bottomland hardwood forests, particularly in terms of the complex species-site relationships that operate in these systems (Hodges and Switzer 1979, Hodges 1994, Hodges 1997). Knowledge and understanding of the great diversity in both species composition and site characteristics, and the manner in which these two components interact, greatly improve our ability and capability to manage southern bottomland hardwood forests. More accurate silvicultural prescriptions can now be made that reflect this increased understanding of the basic ecology of southern bottomlands.

Recent research has also greatly increased our understanding of the patterns of stand development in southern bottomland hardwood forests-how stands develop and mature over time. This increased knowledge allows hardwood silviculturists to make more effective prescriptions and to more accurately predict the effects of those prescriptions in mixed-species stands of southern bottomland hardwoods.

For example, in a study reported by Johnson and Krinard (1976, 1983, 1988), two sweetgum-red oak stands in southeastern Arkansas were harvested in the winter of 1956-57, and the growth and development of the new stands were monitored over time. Through the first 9 years of development on one of the sites, the new stand was dominated, both in number and size of stems, by sweetgum, river birch, and American hornbeam. However, between the ages of 9 and 29 years, mortality of river birch was high, and the species essentially dropped out of the stand. Density of American hornbeam remained high, but it lost its early dominance, and was relegated to an understory position in the developing stand. During the same time period, sweetgum was able to maintain its relatively high density and its dominance within the stand. However, recent measurements at age 37 years[1] indicated that sweetgum mortality had increased significantly and that dominance of the stand by sweetgum had declined dramatically. In contrast, red oaks (primarily cherrybark, water and willow oaks) were far less numerous than the other three initially dominant species and were inconspicuous during the early years of stand development. However, the oaks gradually developed into an increasingly greater component of the stand and, by age 37 years, it was apparent[1] that the red oaks will eventually dominate the stand. The important point is that bottomland red oaks, though greatly outnumbered and quite inconspicuous in many young, even-aged stands, can gradually out-compete the initially dominant pioneer species and eventually dominate the mature stand. A thorough understanding of this pattern of development in sweetgum-red oak stands allows the silvicuhurist to make more reliable prescriptions and to more effectively manage these stands.

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[1]Meadows, J.S. and J.C. Goelz. 1993. Unpublished data. On file with: USDA Forest Service, Southern Hardwoods Laboratory, Stoneville, MS.

New stand evaluation tools. Several new stand evaluation tools have been **developed** over the past.25 years to aid in the management of southern bottomland hardwood forests. For example, Baker and Broadfoot (1979) provided a site evaluation guide for 14 commercially important southern hardwood species. The field guide incorporates an evaluation of the physical condition, moisture availability, nutrient availability, and aeration of a soil into a site quality rating that serves as an estimate of site index. This guide has been and continues to be widely used by silviculturists to assess the suitability of any given site for the growth of these 14 species.

Johnson (1980) proposed a method to evaluate regeneration potential in southern bottomland hardwood forests. The easy-to-use technique is a numerical evaluation of **regeneration** potential that emphasizes the size and number of advance reproduction as well as the stump sprout potential of trees to be harvested; The method has since been tested on **an operational** scale and has been modified specificallyfor bottomland oaks and ash (Johnson and Deen 1993, Hart **et al.** 1995).

More recently, Manuel and others (1993) developed a stand evaluation model designed to assist managers of southern bottomland hardwood forests in making preliminary management decisions. In most previously unmanaged or mismanaged stands, the initial decision to be made is whether to manage the existing stand or initiate regeneration procedures. The expert-knowledge model developed by Manuel and others (1993) helps managers in making this difficult decision. The model is gaining widespread acceptance among hardwood silviculturists across the South.

Another important stand evaluation tool developed recently is the stocking guide for southern bottomland hardwoods generated by Goelz **(1995b)** from hypothetical values for stand densities before and after partial cutting in even-aged stands, **as** recommended by Putnam and others (1960). The guide incorporates estimates of **trees** per acre and basal area per acre into an estimate of percent stocking, a more accurate representation of stand density than either of the other two measures taken separately. Goelz (1995b) interpreted stand density before partial cutting to represent 100 percent stocking and stand density after partial cutting to reflect B-line stocking. Our current recommendations are (1) to thin stands in which stocking is greater than 100 percent, and (2) to reduce residual stocking to the B-line. Because Putnam's recommendations were based on years of experience rather than on actual research results, we recently initiated a series of thinning studies in sweetgum-red oak stands to test the suitability of Putnam's B-line and two other constant levels of residual stocking, in an effort to determine the optimum level of residual stocking following partial cutting in stands of southern bottomland hardwoods (Meadows and Goelz, in press).

Alternative management systems. Several new "alternative management systems'* for southern bottomland hardwood forest have been developed over the past 25 years. These systems are designed to simultaneously produce commodities and maintain or improve environmental values. Desired management objectives can be achieved with minimal environmental impact.

One of these new management systems is deferment cutting, a possible regeneration alternative to clearcutting, in which a stand near rotation age is cut heavily (to **10-25** square feet of basal area per acre) and an underwood of natural regeneration is allowed to develop. The older residual trees from the previous stand and the younger-regeneration from the new stand are then allowed to develop together as a two-aged stand (Beck 1987). This alternative regeneration method is attractive to landowners because it maintains at least some high forest cover continuously on the site, while allowing the development of a new even-aged stand. As such, deferment cutting provides the silvicultural benefits of clearcutting, but reduces some of its negative attributes. Deferment cutting appears to be a viable regeneration alternative to clearcutting in Appalachian hardwood stands (Miller and Schuler 1995, Miller **1996),** but has only recently received research attention in southern bottomland hardwood forests (Meadows, in press).

Another alternative management system developed over the past 25 years is crop-tree management. This system focuses on selecting and releasing individual crop trees that will yield multiple benefits to the landowner; including highquality hardwood timber, improved fish and wildlife habitat, enhanced aesthetics, and improved water quality. Management decisions are centered on these pre-selected crop trees while the remainder of the stand is essentially ignored. Crop-tree management was originally designed as an alternative system to fulfill multiple stewardship goals on private, non-industrial forests of Appalachian hardwoods (Perkey et al. 1994), but has recently been expanded to southern hardwoods (Houston et al. 1995).

Other new developments *There* have been other new developments in the management of southern bottomland hardwood forests over the past 25 years. For example, prescribed burning has been proposed as a tool to enhance oak regeneration on better sites (Van Lear and Watt 1993). Historically, fire played a dominant role in the establishment of many oak-dominated stands, but the possible use of fire as a way to perpetuate the oak component in new stands has not been adequately addressed by researchers. The tentative guidelines proposed by Van Lear and Watt (1993) are based on the role of fire in the ecology of oak regeneration, specifically on (1) the biological adaptation7 of oak to fire, (2) the ecological functions of fire in oak regeneration, and (3) the history of fire in oak-dominated ecosystems. Their guidelines suggest that prescribed burning can be used (1) to promote oak advance reproduction prior to harvest, and (2) to increase the quality and numbers of oak stems after clearcutting. ,

The increased use of mechanized harvesting has been another important development affecting the management of southern bottomland hardwood forests. Mechanized harvesting has not only made partial cutting in southern bottomland hardwood stands mote attractive to managers, but has also made the practice of complete clearcutting more economical As a result, it is now more feasible and more economical to apply the appropriate silvicultural treatment at the appropriate time in managed stands of southern bottomland hardwoods.

Changing Focus and Objectives

The focus and objectives of silviculture and management in southern bottomland hardwood forests have broadened over the past 25 years, primarily to include (1) the rapidly expanding hardwood pulpwood market, (2) integrated timber/wildlife management, and (3) new government programs designed to increase reforestation of marginal agricultural land.

Development of hardwood pulpwood market. *One* of the biggest changes in the management of southern bottomland hardwood forests over the past 25 years has been the development of a sound hardwood pulpwood market. This rapidly expanding market has provided an economic outlet for low-value species and low-quality trees that otherwise would be regarded as permanent liabilities in most stands. The stability of this new market has prompted more mixed-product management (for both sawtimber and pulpwood) in many stands of southern bottomland hardwoods. In most cases, the emphasis of management is still on the production of high-quality hardwood sawtimber. However, many hardwood lumber companies are now cutting and marketing large volumes of pulpwood during their partial cutting operations, and many paper companies are now growing high-quality hardwood sawtimber, where appropriate, while still harvesting enough pulpwood to supply the needs of their mills. The development of a strong hardwood pulpwood market provides additional management options for landowners and thus improves our silvicuhural capabilities in the management of southern bottomland hardwood forests.

Integrated timber/wildlife management. Another change affecting the management of southern bottomland hardwood forests has been the increased emphasis on integrated timber and wildlife management. An increasing number of both public and private owners are interested in managing individual stands for the production of both timber and wildlife. In many cases, managers are concerned not only with **conservation of** game **species,** but also with the creation and maintenance of suitable habitat for non-game species, particularly neotropical migratory birds and small mammals. In fact, forest industry has assumed the lead role in promoting integrated timber/wildlife management of bottomland hardwood forest in the Lower Mississippi Alluvial Valley (Bullock 1994, Staten 1994). Techniques required to inventory and monitor populations of neotropical migratory birds have recently been developed **(Hamel** et al. 19%). These guidelines will allow land managers to determine the extent of existing bird populations on their lands, and will assist them in managing their forests both for the production of hardwood timber and for the maintenance of viable **populations of** neotropical migratory birds.

New ***government programs.*** We have also recently seen the creation of new government programs designed to **increase reforestation** of marginal agricultural lands. The Conservation Reserve Program was initiated to subsidize **establishment of** permanent vegetative cover on erodible **cropland** (Stanturf and Shepard **1995),** and has gained widespread acceptance among private landowners across the South. The more restrictive Wetland Reserve Program was created to preserve wetland sites primarily for wildlife habitat. Both of these federal programs have resulted in **the** restoration of many thousands of acres of former **cropland** to bottomland hardwood forests.

New Concerns ,

Many new and challenging issues have emerged over the past 25 years that affect the way silviculturists manage southern bottomland hardwood forests. Perhaps the most far-reaching concerns that directly affect management have been environmental issues and regulations. Since the late **1960s,** the general public has taken a much more active interest in the management of both public and private forestland. Concerns over a variety of issues, such as endangered species, clean water, wildlife conservation and preservation, forest fragmentation, wetlands conservation and preservation, wilderness preservation, aesthetics, and biological diversity have resulted in many modifications to management practices in southern bottomlands. For example, concerns over environmental issues have prompted the development of ecologically sensitive Best Management Practices and their voluntary implementation by most land managers in southern bottomland hardwood forests. Unfortunately, environmental concerns have also led to an ever-increasing number of federal regulations that restrict the management and use of this valuable resource. Concerns over environmental issues such as these, more than any other single factor over the past 25 years, have shaped the changing character of hardwood forestry across the South into what it is today.

FUTURE CHARACTER OF HARDWOOD SILVICULTURE

The character of hardwood silviculture in southern bottomland forests will continue to evolve during the next 25 years. Concerns over environmental issues will likely continue and will lead to greater involvement by the public in the decision-making processes that affect management, even on private lands. **One** result of this greater involvement will be increased regulatory activity in southern bottomlands. Environmental concerns will also likely result in greater emphasis on alternative management systems, as silviculturists develop new practices that are more environmentally friendly and more acceptable to critics. Maintenance of site productivity and protection of biological diversity and integrity will be critical components of these alternative management systems.

Silviculture and management of southern bottomland hardwood forests will continue to diversify during the next 25 years. Greater emphasis will be placed on integrated management of individual stands for multiple **objectives,** particularly timber, wildlife, and recreation. Silviculturists will, by necessity, become more creative in **prescribing management** regimes to fulfill these objectives.

As land bases continue to shrink, management of individual stands will become more intensive. There will be greater emphasis on the growth and development of individual trees and on management of smaller stands. Mixed-product management and greater utilization of the raw material will likely become more widespread as silviculturists try to meet society's demands for the efficient use of the southern bottomland hardwood resource.

RESEARCH NEEDS IN HARDWOOD SILVICULTURE

Hardwood silviculturists today are much better equipped to manage southern bottomland hardwood forests than they were 25 years ago. Research has provided much valuable information that has led to many beneficial changes in the practice of silviculture in these systems. However, today's silviculturists will be poorly equipped to successfully manage these same forests 25 years from now unless research continues to address the current and future problems to be faced by managers of this resource. To ensure effective management of southern bottomland hardwood forests in the future, we believe that research should focus on the following specific areas:

Basic biology and ecology. We need to increase our understanding of the basic biology and ecology of individual hardwood species and how they interact with one another in mixed-species stands. Patterns of stand development for a variety of species mixtures across a variety of sites need to be identified and quantified. Greater understanding of ecological functions and processes within southern bottomland hardwood forests is essential to the development of environmentally friendly management practices.

Quantitative tools. As management becomes more intensive, quantitative tools must become more reliable and sophisticated. There is a critical need for growth and yield models that accurately describe the nature of southern bottomland hardwood stands and reliably predict the effects of various management regimes on future stand conditions. Refinement of existing site and stand evaluation models and development of additional decision-making models are also critically needed for effective management of southern bottomland hardwood forests.

Regenemtion. Improved techniques, for both natural and artificial regeneration, are needed to successfully perpetuate stands composed of desired species. Increased understanding of basic seed biology and the development of better seed and seedling handling techniques are also needed.

Management of existing stands. Under more intensive management regimes, silvicultural treatment of immature stands becomes more important. Improved management of existing stands of southern bottomland hardwoods will require better marking rules, increased understanding of the phenomenon of epicormic branching, and improved harvesting techniques.

Alternative management systems. To address the issues that will shape hardwood silviculture during the next 25 years, research must develop additional alternative management systems that will simultaneously provide for the production of desired commodities and the maintenance of critical environmental values in southern bottomland hardwood forests.

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