
Research Challenges And Opportunities To Enhance Ecological Functions In Forested Wetlands

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INTRODUCTION

Protecting wetland values and functions are important goals for forest managers. Value and function are easy terms to confuse, but they are not interchangeable. Societal values are directly and indirectly associated with ecological functions. For example, forested wetlands may suppress flooding downstream, which is a value. Floodplain forests store water, impede flows, and dampen flood peaks which are the underlying functions that create the conditions (flood suppression) that society values.

The best way to enhance values in forested wetlands is to maintain or restore ecological functions. Although we have little quantitative understanding of ecosystem functions in forested wetlands, we can be certain that good management of existing forests, rehabilitation of degraded forests, and restoration of forests on cleared agricultural land are ways to enhance ecological functions in forested wetlands.

In this paper, we will discuss current trends in research on forested wetlands, primarily from a southern perspective, within a context of sustainable forestry. We will then use a conceptual model, the self-renewal — rehabilitation — restoration continuum (Maini 1992), to discuss research needs in southern bottomland hardwood forests.

SUSTAINABLE FORESTRY, THE NEW POLICY PARADIGM

Much of the research agenda today is set by policy debates, especially in federal agencies that have embraced “ecosystem management”. Long-term site productivity and sustainable development are two other concepts featured in policy debates, and these three concepts can be related in an hierarchical fashion. Long-term site productivity is a critical component in the decision matrix for ecosystem management, itself a necessary component of sustainable forestry (Briggs et al. 1995).

Long-term site productivity (subsumed by the emerging concept of soil quality) is concerned with maintenance of the productive capacity of forest sites. In its simplest form, it comprises a site’s inherent fertility, aeration, stability, moisture, and microclimate. These characteristics are not fixed quantities, however, and that’s where the complexity arises. Exogenous influences and other perturbations can enhance or degrade site productivity. Some influences are under a manager’s control, such as fertilization and irrigation. Many influences are not, such as flooding, air pollution, and global climate change. Historically, much of our research has concentrated at this level of site and stand, on defining productivity in terms of timber

and wildlife values. Recently, the focus of this research has shifted toward defining site productive capacity in broader terms and over longer time horizons. Intensively cultured pine and eucalyptus systems have shortened rotation lengths to the point where we can compare productivity over several rotations, and there are concerns that some practices lower site productivity (Powers et al. 1990). The lack of such concerns in intensively cultured cottonwood, however, is probably due to much higher inherent soil fertility (Francis 1985, Nelson et al. 1987).

Ecosystem management (EM) has been embraced by several federal agencies, led by the USDA Forest Service. Although there remains much confusion and contention over exactly what Ecosystem Management is (Grumbine 1994) or how to apply it in practice, Irland (1994) listed the primary issues of concern to EM: 1) long-term site productivity, in its broadest sense, 2) biological diversity, and 3) landscape pattern.

Much of the writing on EM is concerned more with the process of managing in an ecosystem context, and less with measurable outcomes. Public input and cross-ownership coordination are topics that have received much attention (Irland 1994). Two contentious issues, we believe, form the basis for differing views on what ecosystem management means: who gets to decide, and what are acceptable levels of human intervention (management) of ecosystems? These questions are operationalized as what levels of product flows (goods and services) will managers try to sustain? These questions are inextricably linked to ownership patterns (the relative mix of public and private land) and social attitudes toward private property rights, and to landowner obligations to provide social values without compensation.

Sustainable forestry, in our view, is the emerging policy paradigm that will redefine debate over these issues. Sustainable forestry subsumes the concerns of long-term site productivity, biological diversity, landscape pattern, and ecosystem integrity (Briggs et al. 1995). It directly addresses the issues of who gets to decide how much intervention is allowed into natural systems, by incorporating into the policy framework economic efficiency, intergenerational equity, and global patterns of resource utilization (Briggs et al. 1995, Bowyer 1992).

Sustainable forestry has three major elements: silvicultural/ecological sustainability; economic sustainability; and social sustainability. Simply put, to be sustainable a forest management system must be technically feasible, economically viable, and socially acceptable (Briggs et al. 1995). Sustainable forestry is an offshoot of sustainable development, which has

been defined as economic development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Holdgate 1993). Sustainable development, and by extension sustainable forestry, puts human needs squarely into the picture. Sustainability is not synonymous with maintenance of long-term site productivity, as some earlier literature suggested (e.g. Perry 1988).

SELF-RENEWAL — REHABILITATION — RESTORATION CONTINUUM

We find it helpful to view research needs within the conceptual model advanced by Maini (1992), where the state of the forest ecosystem can range from “natural” to “degraded” (Figure 1). Across this continuum, the state of the ecosystem is affected by changes — natural disturbances, management interventions, and anthropogenic impacts. The changes produced by these perturbations range from reversible to irreversible, depending on the state of the forest ecosystem and

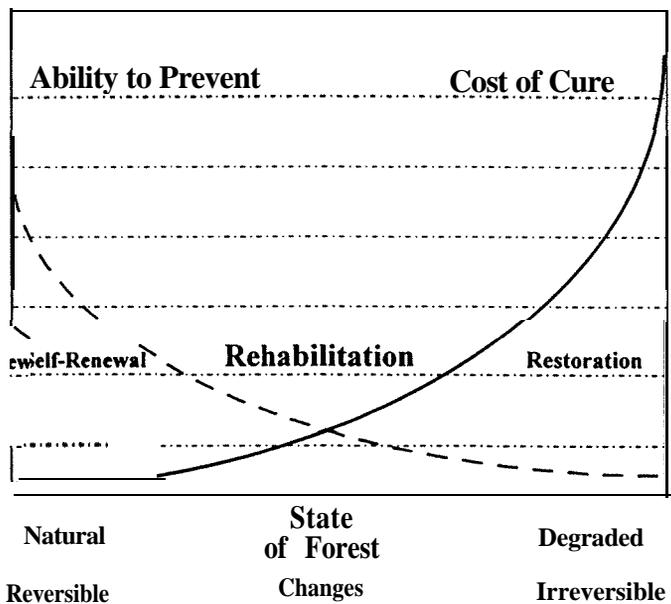


Figure 1. The Self-renewal-Rehabilitation--Restoration continuum described by Maini (1992), where the “state of the forest” is affected by reversible or irreversible changes. As the forest moves from a natural to a degraded state, the ability of the manager to prevent irreversible changes decreases and the cost of intervention increases.

whether or not managers can effectively intervene. As the forest moves from a natural to a degraded state, the manager’s ability to prevent irreversible change decreases logarithmically and the cost of restoring the health of the system rises exponentially.

Conceptually, research can be directed at the “natural” forest where self-renewing processes maintain ecosystem functions. Most research in hardwoods on natural stand management fits at this end of the continuum. Many of our hardwood stands, however, have been high-graded in the past

and some have been burned or grazed. These degraded stands are in need of rehabilitation, which can be accomplished through appropriate silvicultural treatments. Other stands, however, have been so degraded that natural renewal processes are overwhelmed and more drastic, and costly, interventions are necessary. Restoration presumes a loss of ecosystem function, for example by clearing of the forest and conversion to agriculture, or by impoundment of surface and groundwater by highway construction resulting in permanent waterlogging (Stanturf et al. in press).

In each area of the research continuum, we face exciting research challenges in southern bottomland hardwoods. Many of these challenges, furthermore, apply throughout the hardwood biome. Although it is beyond the scope of this paper to discuss each challenge in detail, we will describe some on-going research in each area.

RESEARCH CHALLENGES IN NATURAL STAND MANAGEMENT

We see five distinct research challenges in natural stand management: 1) renewal/regeneration, 2) biodiversity, 3) understanding functions, 4) effects of management on functions, and (5) linkages with aquatic systems.

Renewal/Regeneration

Throughout eastern hardwood forests, there has been a concern with lack of adequate oak regeneration. A recent symposium was devoted to this topic (Loftis and McGee 1993) and it is difficult to generalize about the problem or the research underway to address it. In southern bottomland hardwoods, we have made progress on understanding how to predict regeneration potential in natural stands, based upon a technique developed by Johnson (1980). The technique is similar to regeneration prediction models developed for other hardwood types in that it emphasizes size and number of stems of advance reproduction, and sprouting potential of species in the existing stand (Johnson 1977, Loftis 1990, Marquis and Bjorkbaum 1982, Sander et al. 1976, Stanturf and Meadows 1994). We have tested and modified Johnson’s model (Johnson and Deen 1993, Hart et al. in press), but important questions remain. How many regeneration plots must be stocked to provide a reasonable assurance that regeneration to desirable species will be successful? What will be the species composition of the next stand given the regeneration stocking at different times after harvest? The method is only applicable for complete overstory removal; is it robust enough to apply to other regeneration methods that result in less than complete overstory removal?

Economics dictate that we will continue to rely on natural regeneration in bottomland hardwoods, and silvics dictate that regeneration cuts must be large enough to allow full sunlight to reach advance reproduction of desirable shade-intolerant species. Clear-cutting favors these commercially preferred moderately

intolerant to intolerant species (Meadows and Stanturf in press), but social pressures dictate that we develop **alternatives** to **clear-cutting**. Clear-cutting with reserves has been utilized to try to overcome some of the aesthetic problems associated with commercial and silvicultural clear-cuts. In clear-cutting with reserves, varying numbers of trees are retained to achieve goals other than regeneration, such as den trees for wildlife management. In another variation on clear-cutting, termed a deferment cut, up to 2.5 sq. ft. of basal area per acre, consisting of vigorous, large pole to small **sawlog** trees of desirable species, is retained and carried through the next rotation. Because these reserved trees are left for aesthetic rather than regeneration purposes, the deferment cut is not a variation of the seed-tree method. We do not know yet whether these reserved trees will adversely affect regeneration, or whether the public will view a deferment cut any more favorably than a clear-cut. While deferment cuts may be a viable even-aged regeneration alternative to clear-cutting, this hypothesis must be tested experimentally and operationally.

The most **difficult** aspect of natural regeneration in bottomland hardwood stands is maintenance of a viable oak component. If there is oak in the overstory but oak advance reproduction is lacking in size or number, a manager can promote development of adequate oak advance reproduction through understory deadening or partial overstory removal (Clatterbuck and Meadows 1993). The objective of classical shelterwood techniques is to increase light to the forest floor so that seedlings can establish and grow before the over-story is removed. Once seedlings are established, further cuts are needed to maintain their survival and growth.

Heavy shelterwood removals will favor fast-growing intolerants other than oaks, and light cuts may favor less desirable tolerant species. Experience has shown that classical shelter-wood methods are not reliable enough to regenerate bottomland oaks in one or two partial cuts. Future research should be directed toward quantifying the light conditions on the forest floor necessary at different stages of seedling development and on establishing relationships between light levels and amounts of overstory and **midstory** leaf area. Understanding these relationships will allow us, to develop guidelines for cutting intensity, numbers of cuts and intervals between them, and the degree of competition control necessary. Stands with dense understories and midstories of tolerant species will require deadening or removal of undesirable, lower canopy stems to allow sufficient light to reach the forest floor (Janzen and Hodges 1987).

Biodiversity

Bottomland hardwood forests provide habitat for numerous species (Wharton et al. 1982; Taylor et al. 1990). Mature bottomland forests in particular (Dickson 1988) provide habitat during the breeding and over-wintering seasons for many

species of neotropical migratory birds (**NTMB**) which appear to be declining North America (Whitcomb et al. 1981, **Robbins** et al. 1989, Maurer and **Haygood** 1993). The majority of NTMB with declining populations are interior-dwelling species (Whitcomb et al. 1981, **Robbins** et al. 1989) that may be sensitive to the fragmentation of large, contiguous areas of mature forest into smaller, dispersed patches (Saunders et al. 1991, Pashley and Barrow 1992).

Most of our knowledge of fragmentation effects, however, have come from studies of forest patches within agricultural or urban matrices. The transition between stands of mature and regeneration forest is not as abrupt as that between forests and non-forests, and the edge habitat within forests is dynamic. With time, the regeneration stand will grow and develop vertical structure. There is little information, however, on the effects of fragmentation of any kind in bottomland hardwoods and we need to know what impact, if any, regeneration method, size of opening, or timing of cutting has on **NTMB**. There are three related questions that need to be answered to enable us to design regeneration treatments that avoid detrimental impacts on reproductive success of NTMB. In general, at what size does an opening in the overstory become detrimental to NTMB reproductive success? Are **"edges"** between mature and regeneration stands different, from the bird's perspective, than forest and non-forest edge? Does this difference change as the surrounding landscape differs, or put differently, how important is landscape context?

Understanding Functions

Federal agency approaches to land management are undergoing a shift from parcel-specific concerns toward a more holistic, ecosystem management approach. Much of our knowledge of bottomland hardwood ecosystems comes **from** anecdotal information. Although we have a conceptual understanding of these systems (**Mitsch** and Gosselink 1993), our present knowledge base is fragmented and lacks **sufficient** detail to manage on an ecosystem basis. Our lack of knowledge also makes it difficult to monitor forest health or to restore degraded forests. While we are increasingly aware of the dramatic rate of disappearance of these important resources through the 1980s (MacDonald et al. 1979, Turner et al. 1981, Tansey and Cost 1990, **Hefner** et al. 1993, 1994), we have little quantitative information on their chemical, physical or biological functions (Harms and **Stanturf** 1994).

The Bottomland Hardwood Ecosystem Management Project of the USDA Forest Service is part of an interagency initiative to provide information that will form the scientific basis for holistic management of these systems (Harms and **Stanturf** 1994, **Stanturf** et al. 1995). An interdisciplinary team of researchers from several federal agencies, universities and forest industry have begun an integrated regional study of the structure and function of bottomland hardwood forests in minor

stream bottoms of the Atlantic Coastal Plain and within the Lower Mississippi Alluvial Valley. The objectives are to 1) quantify the physical, biological and chemical functions summarized in Table 1; and 2) document and evaluate the effects of silvicultural manipulation on key functional capacities. The project is being conducted in two phases. Phase I, now underway, addresses the first objective by selecting four representative systems and monitoring them over a 4-year characterization period. During Phase II, **silvicultural** treatments will be imposed to directly examine the effects of manipulation on ecological processes and functions (Harms and **Stanturf** 1994; **Stanturf** et al. 1995).

Stand	Ecosystem	Landscape
	<i>Physical Functions</i>	
Climate	Hydroperiod	Flow paths
Sedimentation		Hydrologic Linkages Mass Balance
	<i>Biological Functions</i>	
Productivity	Biodiversity	Genetic Diversity
Decomposition	NTMBS	Landscape Context
Composition	Mammals	Landscape History
Structure		
Woody Debris		
Snag Production		
Herpetofauna		
Microbial Ecology		
Arthropods		
	<i>Chemical Functions</i>	
Nutrient Cycling	Biogeochemical	Water Duality
Sediment	Transfers	
Soil		
Sheetflow		
Carbon Cycling		

Table 1. Functions to be measured on primary sites.

Concurrent with the characterization effort, we are taking an adaptive management approach to developing Consensus Expert Judgment models of important relationships (Bliss et al. in press). Social science techniques (networking and Delphi) are being used to define cause and effect relationships among natural processes operating in bottomland hardwood ecosystems and to describe how management activities directly and indirectly **affect** natural processes in these dynamic systems. A second goal of this adaptive management component is to identify, through consensus, all factors that should be evaluated in comparing different management systems.

Effects of Management on Functions

Timber harvesting has occurred in southern bottomland forests for over 200 years, but only recently have we examined the impacts of this management technique on ecological functions in bottomlands. Hydrology is the driving function in

these systems (**Mitsch** and Gosselink 93, Lugo et al. 1990), but we know little quantitatively about hydrology, its effects on productivity and **other** functions, or how disturbances impact hydrology. Bottomland hardwood forests contribute to the important role of floodplains in regional hydrologic cycles; hence impacts of logging and other management activities on water quality are of paramount importance. Studies of **long-term** ecosystem response will require large-scale, multidisciplinary studies on several reference sites such as the Bottomland Hardwood Ecosystem Management Project (Stanturf et al. 1995), but definitive results are many years away.

Fortunately, short-term results from several studies are now available (Stanturf 1994, Lockaby and **Stanturf** in press). We are aware of no study that shows a long-term effect of vegetation removal alone on hydroperiod, as long as **BMPs** are followed. Road construction may affect hydroperiod and water quality (Runner et al. in press), but this is an area that requires further research. While it is common for watertables to remain high during several growing seasons after clearcutting, this effect generally disappears as sites revegetate (Aust and Lea 1992, Perison et al. 1993).

Bottomland hardwood forests can serve as sources or sinks for nutrients (Brinson 1993). Silvicultural manipulations conceivably could stimulate decomposition to such a degree that manipulated stands could become sources of non-point source pollutants (sediment, nitrate, etc.). Most studies have shown the magnitude of such effects to be negligible and any effects to be short-term (Shepard 1994). In fact, regeneration stands may trap more sediment than older stands (Zaebst et al. in press).

Partial cutting has been practiced to improve overstory composition and to control density, and may be prescribed more frequently in the future to develop advance reproduction. Although partial cutting has the benefit of increasing growth of residual trees, it can also stimulate epicormic branching and cause damage to residual stems. While some logging damage is unavoidable, the potential impact on future stand value can be excessive (Meadows 1993).

The **greatest** need for additional research is a better understanding of hydrology, both as it drives ecological processes that affect functions, such as primary productivity and biogeochemical transformations, but also as management actions affect hydroperiod. Methods are needed to quantify sheetflow across floodplains, and for examining any interaction of floodwaters with groundwater.

Linkages with Aquatic Systems

We need to consider hydrology in a broader context, at the landscape scale. Linkages with aquatic ecosystems need to be considered in a management context, particularly for bottomland systems subject to annual overflow flooding. As many as 100 species of fish are dependent on bottomland

hardwood wetlands at some stage of their life-cycle (Killgore et al. 1994). Buffalo, gar, minnows, shiners, and darters are species that require shallow water sites within infrequently flooded bottomland stands to deposit their eggs. An understanding of these relationships and the linkages between bottomland hardwood ecosystems and aquatic systems is seriously lacking.

Research Challenges In Rehabilitating Degraded Stands

In many stands, the manager is faced with a legacy of high-grading, cattle-grazing, and fire. Low-quality, low-vigor, poorly-stocked stands clearly need to be regenerated. On the other hand, a fully-stocked stand of mostly desirable species presents many opportunities to apply classical silvicultural systems for its management and improvement over time. A middleground exists, however, where the decision to manage or regenerate is very difficult to make. Fortunately, a decision model is available (Manuel et al. 1993) that provides assistance, based upon the expert judgment of experienced hardwood foresters. The model is driven by three variables that describe each tree's potential contribution to stocking: dbh, tree class (preferred or reserve, sensu Putnam et al. 1960), and a quality score based on species, crown class, merchantable height, butt log grade, and vigor.

The worst possible scenario for the manager to face is a stand that needs to be regenerated because it is composed of low-vigor, low-quality stems of shade-tolerant species. The lack of value in the stand and the need to regenerate precludes manipulations to favor development of advance reproduction of desirable species. The lack of desirable over-story species that could provide a seed source, especially for oak, leaves the manager few options except to supplement natural regeneration through artificial means.

If the stand can be carried for a few years, it may be possible to establish advance reproduction prior to overstory removal by underplanting seedlings or direct-seeding acorns. Although this has been done successfully with upland oaks, we know of no experimental success with bottomland species. Nevertheless, this seems a fruitful avenue for research. In principle, the prescription is simple: control undesirable **midstory** and **understory** competitors, create a shelterwood, plant large stock, and remove the shelterwood (Johnson et al. 1986; McConnell 1993). In practice, we lack the ability to even consistently apply shelterwood methods to obtain natural regeneration.

Some attempts have been made to supplement natural regeneration after overstory removal by planting seedlings or direct-seeding acorns after clearcutting (McConnell 1993). Promising areas of research are to test the feasibility of these approaches, to determine under what conditions they work (e.g., with or without competition control), and to compare the economics of supplemental planting after clearcutting versus underplanting prior to shelterwood treatments.

Research Challenges In Ecosystem Restoration

While the literature on bottomland hardwood restoration is substantial (Haynes et al. 1988, 1995), much needs to be done (Clewell and Lea 1990, Sharitz 1992). Major research emphases today are on 1) characterizing reference sites to guide restoration efforts, 2) developing new reforestation techniques, such as intercropping, 3) developing methods to establish mixed-species stands, and 4) identifying the effects of restoration at the landscape level (Kennedy 1993, Stanturf and Shepard 1995).

Reference Sites

Sharitz (1992) stressed the need to compare functions of natural and restored forests, because it has not been scientifically established that reforestation necessarily restores all functions. A first step in achieving restoration is to identify the functions that characterize undisturbed sites. These undisturbed sites must be identified and characterized in order to develop criteria for measuring the success of restoration projects. This should be one outcome of the Bottomland Hardwood Ecosystem Management Project (Stanturf et al. 1995). Results from this study will contribute to the understanding of functions of bottomland hardwood forests needed to guide restoration efforts and allow for evaluation of their success, but the range of community types needs to be broadened.

Intercropping

The forest products industry, the US Fish and Wildlife Service, and the USDA Forest Service Southern Hardwoods Laboratory are implementing a large-scale study of reforestation techniques (Stanturf and Shepard 1995). Four treatments will be compared that differ in intensity, in rapidity of reforestation, and in **future** opportunities for income **from** timber. Treatments consist of direct-seeding **Nuttall oak acorns**, planting **Nuttall oak seedlings**, intercropping cottonwood with **Nuttall oak**, and a control **treatment** that will be allowed to revegetate naturally. Each treatment will be evaluated using **20-acre** plots in three replicate blocks. These relatively large plots will be valuable for demonstration purposes and will be large enough to accommodate future research needs, such as comparisons of wildlife use among treatments.

Intercropping cottonwood **with Nuttall oak is a technique** designed by James River Timber Corporation, and is currently being used in the company's private landowner reforestation assistance program. The rationale for this novel technique is to use cottonwood as a nurse crop that improves the conditions for oak survival and growth. This treatment was explicitly designed to provide early income **from** timber as an economic incentive to encourage private landowners to reforest degraded wetlands. The nurse crop concept is well-known in **silviculture** (Matthews 1989) and has been recommended for reforestation of abandoned agricultural fields (McKevlin 1992). However, no data are available to compare it to other more commonly used reforestation methods.

Cottonwood cuttings are planted at 12 by 12 foot spacing, with herbicide application and disking during the first two growing seasons to control competition. In the spring before the third growing season, **Nuttall** oak seedlings are planted in between every other row of cottonwood.

Cottonwood can grow 65 feet in height and yield 30 cords per acre at age 10 on the heavy clay Sharkey soils typical of millions of acres of the Mississippi Delta (Krinard and Kennedy 1983a, 1983b). Yields for other species are lower than for cottonwood. Green ash at age 10 on Sharkey soils has been shown to range from 27 ft to 30 ft, **sweetgum** ranged from 18 ft to 21 ft, and sycamore from 26 ft to 31 ft (Krinard and Kennedy 1983b). Thus, cottonwood growth is approximately double that of other species. Volume growth followed similar trends.

At age 10, the cottonwood is harvested and the oak released. If the cottonwood is harvested in the dormant season, sprouting occurs and a second, 10-year pulpwood rotation is obtained. Previous research, however, indicates that the yields in the second rotation will be lower. After the second cottonwood rotation is harvested, the **18-year-old** oak forest is released. Alternatively, selected cottonwood stems can be retained after either, or both, cottonwood harvests to increase diversity and structure in the stand. The rapid establishment of a forest canopy by cottonwood may accelerate natural succession by attracting the birds and small mammals that are vectors for dispersal of heavy seeds. Cottonwood may also be used to rapidly create vertical structure, cavities for nesting, and downed woody debris.

Mixed-Species Stands

A major research challenge today is restoring **mixed**-species stands that quickly acquire the kind of structure found in natural stands. Restoration efforts in the past have concentrated on establishing single-species plantations. The appearance of a plantation can be avoided by altering the pattern of planting, for example by planting in wavy lines rather than straight rows. Mixed-species stands, however, are necessary to establish canopy structures that maximize avian diversity (Stanturf 1995).

Multispecies plantations can be established in several types of mixtures (Goelz 1995, in press). Intercropping mixtures (single species rows) and mixed monotypes (species in block plantings) produce an overall mixture, but species are clumped in a way that does not mimic natural conditions.

Methods for establishing true mixtures will require basic information on how species compete with each other during early stand development, especially after crown closure. This line of research is illustrated by a systematic spacing study at Lake George, MS (Goelz 1991). This rather complicated study is investigating two spacings between individual stems (6 ft and 9 ft), the proportions of green ash, **Nuttall** oak, and water oak, and the relationship between size, distance, and species of neighbor and individual-tree growth. Because early growth of

some species may be quite slow, they can be overtopped by competitors. In addition to inherent growth rates, competitive ability is affected by environmental conditions such as soil properties and flooding frequency and duration (McKnight et al. 1981). Therefore, the Lake George spacing study is replicated on two contrasting soil types.

Landscape pattern

Most reforestation work occurs in small patches, except for a few large public projects. Many researchers have discussed the effects of fragmentation on wildlife, particularly **area**-sensitive, interior-dwelling neotropical migratory birds (Robbins et al. 1989, Wilcove and Robinson 1990). Few, however, have examined the benefits of reforesting in large blocks, particularly when existing large patches are to be connected by corridors. The Lake George Restoration site (Stanturf et al. In press) provides an opportunity to evaluate this hypothesis. The restoration site connects two of the largest blocks of natural and restored bottomland hardwood forests in the Lower Mississippi Alluvial Valley, the Panther Swamp National Wildlife Refuge and the Delta National Forest. Wildlife use of the area prior to, and following, restoration is being evaluated.

CONCLUDING THOUGHTS

It is our impression that we could be doing a better job of using what we already know about managing, rehabilitating and restoring bottomland hardwoods. If we're correct, then the linkage between research and application, commonly termed technology transfer, needs more attention from both scientists and managers. Meetings such as this one are useful, but cannot provide managers with the specific information and advice needed everyday on the job. Thus, we'll make a plea for expending some effort and resources to develop and acquire innovative technology transfer products. Here are two ideas that we think will help transfer silvicultural understanding.

Demonstration Forests

Nothing gets an idea across like a good example, and new techniques validated by research need to be demonstrated on an operational scale. Such was the motivation behind the **20-acre** treatment plots in the study of **cottonwood-Nuttall** oak interplanting (Stanturf and Shepard 1995).

Decision-Support Systems

Site-specific silvicultural prescriptions should be the norm in forest management but too **often** there are countervailing pressures to find simple, universally applicable treatments to achieve desired stand conditions (Stanturf et al. 1993). As **Marquis** and **Twery** (1993, pp. 157) pointed out regarding oak regeneration "success will depend upon the careful prescription of treatments tailored to each individual situation." Decision-support **systems**, expert systems, or artificial intelligence are terms to describe

various decision-aids, available now or in development, that aim to assist landmanagers in making **silvicultural** prescriptions based upon conditions or **characteristics of the** stand in question (Marquis and Twery 1993).

One of the oldest decision-support systems is the guide to evaluating reforestation potential on a site, developed by Baker and Broadfoot (1979). A simple model for guiding decisions as to adequacy of advance reproduction was developed by Johnson (1980), tested by Johnson and Deen (1993) and revised for some species by Hart et al. (in press). We've already mentioned the guide to making the "manage or regenerate" decision (Manuel et al. 1993), which is available for personal computers. Clatterbuck and Meadows (1993) published a simple prescription model for regenerating bottomland oaks, and McKevlin (1992) published a generalized prescription model for bottomland hardwoods.

Decision-support systems cannot, and should not, replace an experienced forest manager. Decision-support systems should not be used to regulate forest practices because they cannot produce a single "correct" answer to all management questions. They should not be used to blindly second-guess decisions made by managers on the ground. So what good are decision-support systems? They are invaluable in training new managers (especially re-training experienced foresters from other biomes). They can be used effectively to transfer new research results, by changing decision criteria or otherwise modifying the model in light of new understanding. Most importantly, decision-support systems can be used interactively by a land manager to improve **his/her** decision making abilities. Development of a decision-support system will require developing a stand-growth simulator robust enough to describe the myriad communities, site-types, and stand conditions in the bottomland hardwood ecosystem.

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