FS-4000-1 (8/76)

USDA-Forest Service	1. NUMBER: SRS-4103	2. STATION: Southern Res. Station
RESEARCH WORK UNIT DESCRIPTION Ref: FSM 4070	3. UNIT LOCATION: Charleston, South Carolina	

4. RESEARCH WORK UNIT TITLE: Center for Forested Wetlands Research: Ecology and Management of Forested Wetland Landscapes

5. PROJECT LEADER (Name and address):
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6. AREA OF RESEARCH APPLICABILITY:	7. ESTIMATED DURATION:
National	5 years

8. MISSION:

To develop, quantify and synthesize ecological information needed to sustainably manage and restore the structure, functions, and productivity of forested wetland landscapes.

This mission is conducted under the basic tenets of forest sustainability, and is intended to provide the information and tools necessary for managing forested wetland landscapes to sustain ecosystem functions, and goods and services to future generations. The relevance of the research program is regional, national, and international, and it is derived primarily from work in the southeastern United States.

9. Justification and Problem Selection
(Starts on page 2)

10. Approach to Problem Solution
(Starts at conclusion of item 9)

Signature	Title	Date
Recommended:	Assistant Director for Research	
	Assistant to Staff Director	
	Staff Director	
Approved:	Station Director	
Concurred:	Deputy Chief for Research	

9. JUSTIFICATION AND PROBLEM SELECTION

Forested wetlands comprise approximately one-half of the remaining 103.3 million acres of wetlands in the United States. Geographically, 82 percent of the total wetland area is distributed among the South (54%), Lake States (19%), and Northeast (9%) regions. The majority of those wetlands are forested. While the ecological and social importance of these forested wetlands are widely acknowledged, they continue to be destroyed at an annual rate of approximately 378 thousand acres, which is 30% greater than the net annual loss of all wetland types in the nation. Development of the information necessary for management, restoration, and conservation of forested wetlands is needed to sustain valued landscape functions.

The ecological role of forested wetlands in the landscape includes alteration of flood flow, maintenance of water quality, habitat diversity for plants and animals, refugia for endangered species, carbon sequestration, and a source, sink and transformer of chemical compounds. The importance of these functions changes according to climate, hydrology, geography, other environmental factors, and scale. At the ecosystem level, wetland functions such as community dynamics, biomass production, and habitat can be important. At the watershed level, water quality, hydrology, organic matter cycling, sustainable productivity and habitat diversity, can be important functions. To illustrate, it is common for wetlands to provide habitat that contributes to the majority of the species diversity within a given watershed while occupying a small area of the watershed. Wetlands are also important at the global scale, especially with respect to biodiversity and biogeochemical cycles. For example, wetlands account for approximately two percent of the terrestrial surface area; however, wetland soils contain approximately 20 percent of the global soil carbon pool, thereby making wetland soils an important terrestrial carbon sink. Wetlands can be particularly sensitive to global change because they commonly exist at the interface between aquatic and upland ecosystems. The riparian landscape position is also important to the health of aquatic ecosystems since wetlands are a major source of energy and nutrients to streams, rivers, and estuaries.

In addition to inherent ecosystem functions, wetlands also provide important economic and social values. Forested wetlands are a significant component of commercial forest lands, particularly in the South and the Lake States. These lands are particularly important because they have the ability to grow wood fiber rapidly, and to provide products that are not otherwise available. For example, some wood products from wetland forests (e.g., bald cypress) are more resistant to decay than products derived from upland species. Accordingly, these wetland-derived products may have longer operational life, and may not require application of costly preservatives. Conversely, other species (e.g., loblolly pine, sweet gum) are responsive to intensive silvicultural practices on hydric soils. In addition to providing wood products, wetland forests provide important values to rural and urban segments of society through activities such as hunting, fishing, nature study, recreation, aesthetics, and gathering of wood, plants, and fruits. The value of the wetland resource is significant by any metric of comparison.

The Southern Research Station (SRS) implements its mission through three central areas of emphasis: (a) measuring, monitoring, and assessment of ecosystems, (b) understanding ecosystem structure, function and processes, and (c) management for sustained and enhanced forest productivity. Six cross-cutting themes (CCT) have been developed as a means to organize and manage SRS's research around

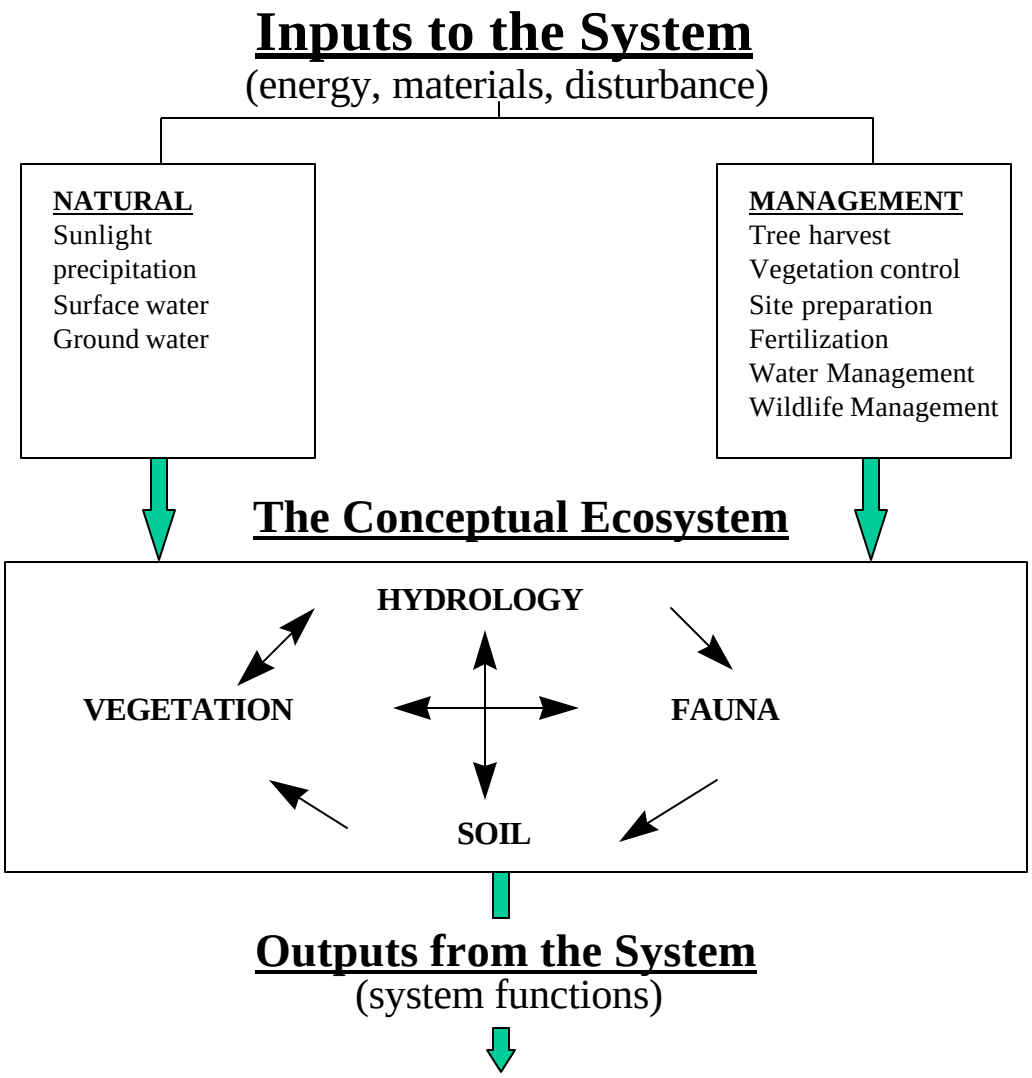
the three central research areas of emphasis. These cross-cutting themes reflect priority forest ecosystem research and technology transfer needs within the southeastern United States.

The Center for Forested Wetland Research (CFWR) will contribute primarily to three CCTs: The Forested Wetlands, Bottomland hardwoods, and Riparian zones CCT, the Large-scale Modeling and Regional Assessment, and the Pine Sustainability and Productivity CCTs.

While the importance of forested wetlands is widely accepted and research over the last decade has greatly advanced the state of knowledge about wetland conditions and processes, both the quality and quantity of the information available to manage the remaining forested wetland resource is inadequate to meet the goals set forth by the concept of *sustainable ecosystem management*. Four Problem Areas were selected to address important knowledge gaps on the basis of (a) important science questions, (b) desired outcomes of the Wetland, Large-scale modeling, and Pine Productivity CCTs, (c) existing capabilities and staff, (d) coordination of expertise and discipline research within the SRS, and (e) discussion with customers.

The four Problem Areas are designed to provide a hierarchical framework for developing and implementing sustainable management and restoration practices. The first Problem Area provides the basis for understanding inherent ecosystem functions, ecosystem processes, and controlling mechanisms in forested wetlands. It provides the foundation for addressing sustainable management (Problem 2) and restoration (Problem 3). Applying information to management and conservation questions across multiple spatial and temporal scales requires the use of the theory and tools developed through landscape ecology (Problem 4). Implicit in each Problem Area are the social and economic factors affect ecosystem processes and dynamics through application of management practices and policy.

Interactions between the vegetation, soil and hydrology in forested wetland ecosystems are governed by complex biotic and abiotic processes that vary depending on geography, geomorphology, and climate. Vegetation is the major biological component of forested wetlands, influencing most aspects of ecosystem structure and function, and sustainable productivity. It is also the primary target of most management activities. The ability to predict responses of forest communities to disturbance and the consequent effects on wetland functions is, therefore, central to developing useful guidelines for management and conservation (Fig. 1). Thus, research is needed to: (a) quantify relevant plant-environment interrelationships, (b) quantify the effects of disturbance or management activities on wetland functions, and (c) develop a predictive model of ecosystem behavior to integrate information gathered under (a) and (b).



Selected ecosystem functions and measures of performance

Wildlife Habitats	Hydrologic Regime	Timber Production
Species occurrence	Quantity	Quantity (yield)
Population levels	depth, timing	commercial tree species
Cover	duration, frequency	product size
Species diversity	Quality	timing
	ion concentration	productivity
	toxicants	
	Sediment loading	

Fig. 1: Generalized systems perspective a forested wetland ecosystem, and selected ecosystem functions.

Past studies of ecological processes and functions of forested wetlands, particularly those related to the myriad of wetland types and conditions, are few compared to the diversity of conditions and information needs. Basic knowledge about physiology of major wetland tree species, structure and dynamics of pure and mixed species communities, soil-plant interactions, hydrology, hydric soils, wildlife habitat, and primary biotic and abiotic functions and their interrelationships in forested wetlands is limited. Existing information is often not in a form that can be applied to ecosystem problems, especially those related to management, restoration or creation of forested wetlands. Accordingly, there is a critical need for research on fundamental biotic and abiotic processes and functions in forested wetland landscapes (Problem 1).

Solution to Problem 1 will provide scientists and resource managers with the basic information to understand how natural processes in wetlands and surrounding forests interact to influence important ecological functions (e.g., sustainable productivity), and how land management practices could affect other wetland functions. Society will benefit from work on this problem area because it will provide new information that will (1) help ensure sustainability of unmanaged and intensively managed forests, and (2) enhance wise use and conservation of wetland resources. The results of the Problem 1 research will also be the foundation for research in the other three Problem Areas. The probability of achieving this comprehensive goal within the next five year period is estimated to be 60% because of the long time frames needed to develop the data bases necessary for the comprehensive assessment and ecosystem modeling. However, within a year period, sufficient data bases on critical processes (e.g. hydrology, soil-plant interactions, biogeochemistry, and water equality) will be developed to allow initial syntheses and modeling efforts. Five years with 2.0 full time scientists supported by work unit or sponsored funds at an average annual budget of $400K will be required to address this Problem. Approximately 0.5 scientist FTE is dependent on sponsored funds; if those funds are not available progress on this Problem will be moderately impacted.

The concept of sustainable management provides for managing forests for both "goods" (e.g., timber, food, forage) and "services" (e.g., wildlife habitat, biogeochemical cycling, hydrological cycles) in such a way as to maintain the ecological integrity and productivity of the resource. Implementation of sustainable management practices requires not only a basic understanding of ecological processes of the resource (described in Problem 1), but knowledge of the effects of management prescriptions on those processes as well. A primary function of forests is carbon sequestration, and hence the production of wood products. Other important functions include providing habitat for plants and animals, refuge for sensitive species, and maintenance of freshwater resources.

The level and type of management is dictated by land owner objectives and capacities of the resource. Silvicultural systems on wetlands includes a variety of harvesting (e.g., selective, clear-cut), regeneration (e.g., natural and artificial), site preparation (e.g., disking, raking, bedding), fertilization, stand tending, and water management practices. Although silvicultural practices are known to modify vegetation, hydrology, soil properties, and nutrient cycles, the effects of these practices on wetland functions and values across the diverse biotic and physiographic settings of the southeastern US and other regions are

poorly understood. Managing complex wetland landscapes requires a detailed understanding of the functional linkages between management practices and ecosystem processes (Problem 2).

The solution to this problem is needed by both public and private forest land managers. As forest industry and other landowners extend both intensive and extensive management to more acres to meet rising demand for forest products and other landowner values, ways of accommodating that demand while sustaining integrity of the resource and the values derived from the lands must be addressed. Research will furnish needed information on effects to ecological functions (e.g., hydrologic, biogeochemical, vegetative, and wildlife habitat) from different management practices. That information will enable reliable decisions to be made on the suitability or desirability of management alternatives on different wetland sites and landscape positions. The results from this Problem Area will also be important components to landscape models (Problem 4). The net benefit to society resulting from this problem solution will be a system of silvicultural prescriptions that ensures an adequate supply of needed forest products and the maintenance of vital ecological functions. There is a 70 percent probability of Problem solution, because management alternatives continue to change and, more importantly, longer time periods are often needed to assess the consequences of land management practices on the resource. Five to ten years with 2.0 full time scientists supported by work unit or sponsored funds at an average annual budget of $400K will be required to address this Problem. Approximately 0.5 scientist FTE is dependent on sponsored funds; if those funds are not available progress on this Problem will be moderately impacted.

The ability to restore or create wetlands is essential to mitigate wetland loss and rehabilitate degraded sites (e.g., prior-converted agricultural lands, or lands following natural catastrophes or anthropogenic disturbances). Restoration involves the re-establishment of wetland conditions, processes, and vegetation on a site in such way as to provide the environment for a self-sustaining hydrophytic vegetative community. In contrast, wetland creation involves the development of a wetland ecosystem in an area that was previously an upland. Wetland restoration and creation are commonly performed by private industry and government agencies for mitigation, the USDA Wetland Reserve Program, mitigation banking, and conservation projects. Restoration of forested wetlands is the predominant approach in freshwater systems. Development of standards, guidelines, and indicators for restoration is important for successful, cost effective, project design. Accordingly, there is a tremendous need to develop quantitative measures of wetland structure, composition, and process that can be used to plan and assess whether a restored wetland will develop in such a way as to meet the desired restoration objectives.

Two major issues associated with wetland restoration are: (1) restoration technologies and (2) assessment of the effectiveness or sustainability of the restoration. Major technological and biological issues in forested wetland restoration include specifications for site conditions, species-site suitability requirements, role of cover crops in tree establishment, optimum hydrologic regime for site colonization, and the role of seed banks in community dynamics. Knowledge of these factors is limited, consequently, protocols for the development of regeneration and restoration prescriptions are not well defined or uniform among managers in the field. Following the initial restoration effort, evaluating a project's success in terms of restoring forest health is difficult because the mandated assessment period is usually short (e.g., 1 - 3 years), and indicators

of desired wetland conditions or processes have not been developed. The concept of establishing reference sites for purposes of comparison has been advocated for both natural and restored wetlands. This approach provides a framework for assessing the deviation of ecological functions in disturbed or restored wetlands from reference conditions. Being able to assess the dynamics of reference wetlands is fundamental to both the development of indicators for assessing forested wetland health, and the development of objective criteria to evaluate the efficacy of the restoration projects. Accordingly, wetland and riparian zone restoration requires both new technologies and indicators of ecosystem health (Problem 3).

The solution to Problem 3 will provide land managers and agencies responsible for the regeneration and restoration of forested wetlands with guidelines for the selection of prescriptions, regeneration methods, site amelioration techniques, suitable species, and indicators of success. The net benefit to society will be a basic means for achieving the goal of no net loss of the nation's wetlands and, in addition, assurance of long term sustainable productivity of those wetlands. The likelihood of advancing restoration technologies to the point of recommending establishment procedures is good given the initiation of several recent experiments and ongoing collaboration with other RWUs and cooperating agencies. The development of an assessment framework is a long-term goal; however, within 5 years draft assessment criteria can be developed and tested. Five to ten years with 2 full time scientists supported by work unit or cooperative funds or grants at an average annual budget of $400K will be required to address this Problem. Sponsored funds support 1.25 scientist FTE for this Problem; if those funds are not sustained progress on this Problem will be significantly impacted.

Managing forested landscapes to sustain "goods" and "services" is a fundamental objective of land stewardship. Sustainability of the goods and services provided by forested landscapes defines forest health. Many forest health-related issues are spatial and large-scale in nature, such as habitat fragmentation, ecosystem productivity, spread of disturbances (e.g., fire and pests), water quality, and soil erosion and sedimentation. Thus, assessment of forest health should be done at large scales, and in a timely fashion. Landscape ecology provides a framework and the tools to address forest health issues; it emphasizes ecological effects of the spatial patterning of ecosystems on large areas. Landscape analyses can be used as the basis for economic, sociological, and ecological studies to determine how to manage lands at large scales to sustain inherent landscape functions and forest products.

Landscapes are mosaics of ecosystems and land uses with forested wetland landscapes being characterized by interacting uplands, wetlands, riparian, and aquatic communities. Thus, managing forested landscapes typically involves the use of a variety of silvicultural regimes that depend upon land-use, management objectives, regulatory restrictions, ownership, and stewardship. Understanding how the spatial and temporal arrangement of ecosystems within the landscape affects the vegetation, wildlife habitats, biogeochemical cycles, and water quality is essential to understanding how landscape functions are governed and, perhaps more importantly, to understanding how landscapes should be managed to ensure the sustainability of inherent functions, especially productivity, habitat, water resources, and wood products. However, there are no commonly agreed upon criteria and methodology to assess forest health at the landscape level. In addition, for landscape indices to be useful, we must be able to show relationships between specific landscape metrics or indices and specific ecosystem functions (e.g.,

habitat suitability indices). New approaches and integrated assessment tools need to be developed for analyses that incorporate science, land use, policy options, and government regulations into assessments of sustainability of forest health and resources on landscape scales (Problem 4).

The solution to Problem 4 will provide land managers, policy makers, and regulators with tools needed to realize the goal of sustainable management -- management of ecosystems to sustain desired landscape functions. The net benefit to society will be a system of decision support tools that can be used to evaluate alternative management strategies for sustainable timber production and ecosystem functions in forested wetlands. The theoretical framework and analytical tools have been sufficiently developed in the discipline of landscape ecology such that, when coupled with strong empirical data base on wetland ecology at the Center, significant advances in the study of forested wetland landscapes can be made. Five to ten years with 2.0 full time scientists supported by the work unit and cooperative funds or grants at an average annual budget of $400K will be required to address this problem. Sponsored funds support 0.75 scientist FTE for this Problem; if those funds are not sustained progress on this Problem will be significantly impacted.

10. APPROACH TO PROBLEM SOLUTION

Problem 1. There is a critical need for research on fundamental biotic and abiotic processes and functions in forested wetland landscapes.

Research in this Problem Area will address critical knowledge gaps in plant biology, community dynamics, ecology and hydrology in wetlands by conducting field and greenhouse studies. Research addressing those needs will initially depend on ongoing field studies, including those on the Santee Experimental Forest, the Coosawhatchie Bottomland Ecosystem Study, the ACE Basin Research Site, the Pee Dee Basin and the Savannah River Site. Studies of basic physiological, ecophysiological, ecological and physical processes, such as root adaptation to hypoxia, gas exchange, nutrient uptake, carbon allocation, above- and below-ground production and turnover, nutrient cycling, and decomposition, will be conducted in fields, greenhouses, and the hydro-edaphytron.

Accomplishments planned for the next 5 years:

1. Establish reference forested wetlands where complete ecological profiles will be quantified. Reference wetlands are needed for comparison in determining the influence of land management activities on ecosystem functioning (Problem 2) and assessment of restoration success (Problem 3). Ecological profiles will be developed for selected forested wetland communities (i.e., bottomland hardwoods, mixed pine hardwoods, pine flats, Carolina Bays, pocosins) on different physiographic positions. These profiles will include vegetation, soil, water, and habitat information that are useful to forest land managers. Planned studies include:

- A study to characterize the structure and function of blackwater bottomland hardwood systems using biotic and abiotic assessments based on field research.

2. Water is the driving force in wetland ecosystem processes, yet wetland hydrology remains poorly understood. Research in planned to determine the hydrologic function of the major wetland types, and to

link hydrologic information to process-level studies on vegetation dynamics, nutrient cycling, carbon sequestration, and habitat. Special consideration will be given to the transport functions, considering the linkages between uplands, wetlands and aquatic communities. Specific studies planned include:

- Characterization of the hydrology in riverine and depressional wetlands.
- Development of a hydrological model for small forested coastal plain watersheds using the research watersheds on the Santee Experimental Forest.
- Development of hydrologic simulation models for depressional wetlands and dendritic drainage systems.
- A study to evaluate material transport in hardwood forest riparian zones and buffer zone processes important in riparian zone management.
- A study to quantify carbon and nitrogen export from managed forests and their relationships to buffer zone processes.

3. Wetlands are important carbon sinks. Research is planned to determine the mechanisms controlling carbon sequestration in wetlands. Rates of organic matter accumulation will be studied using stable isotope technology. The combined information will be used assess potential impacts of global and regional stressors on soil carbon sequestration. Specific studies will include:

- Determination of the interactions of temperature and redox on organic matter turnover.
- A study on the influence of fire on C sequestration in wet mineral and organic soils.
- Determine the primary sources of organic matter to the soil organic matter pool.
- Develop a soil carbon model for wetland soils.

The modeling work is dependent on sponsored funds, accordingly progress will be determined by available funds.

4. Evaluate functions of below ground processes in forest health in wetlands and document contributions of root production to forest productivity. Below ground process are critical to nutrient and water availability, biodiversity, soil chemical and physical properties, and forest productivity. These processes will be documented for hardwood and conifer wetland forests. Root properties related to root functioning (phenology of growth, length, surface area, growth rate, production and mortality), mycorrhizae, and root interactions will be quantified and compared with aboveground growth parameters in forested wetland communities. Planned studies include:

- A study of controlled experiments in the hydro-edaphytron to quantify influences of hydrologic and soil conditions on root morphology, turnover, and physiological responses of the principal wetland tree species.
- A study of root dynamics in bottomland hardwood forests.
- A study of factors that control root decomposition.

The root turnover study in the hydro-edaphytron is dependent on sponsored funds, accordingly progress will be determined by available funds.

5. Determine how environmental factors (hydrology, light quantity and quality, seed and propagule availability, and competitive interactions) and land use (past agricultural activity, logging history, changes in

hydrology, and restoration practices employed) contribute to community composition and dynamics in unmanaged forests of the coastal plain (e.g., mixed species bottomland hardwoods, mixed pine-hardwoods, and wet pine site-types). Forest community structure will be related to hydrology, soil parameters, canopy gap size, and land use and restoration practice in bottomland hardwood and swamp forests. Studies of seed bank composition and woody plant regeneration will be conducted. Finally, a model will be developed to predict growth responses of major wetland forest tree species to competition and environmental factors. Planned studies include:

- An analysis of gap dynamics and regeneration in bottomland hardwood forests.

6. Identify physiological processes that contribute to waterlogging tolerance in woody species. This task will be accomplished in studies to be conducted in the hydro-edaphytron that relate to physiological processes such as root respiration, shoot gas exchange, nutrient uptake, and biomass partitioning to productivity. The facility will also be used to test for indicators that can be used in evaluating genetic controls of flooding tolerance. Planned studies include:

- A study to determine physiological adaptations of the principal wetland tree species to soil waterlogging.

This work is dependent on sponsored funds, accordingly progress will be determined by available funds.

7. Develop approaches for evaluating non-commodity values of forested wetlands. Planned studies include:

- A study to develop valuation procedures for non-commodity resources.

This work is dependent on sponsored funds, accordingly progress will be determined by available funds.

8. Develop indicators of forest health based on the above accomplishments. The indicators will be based on field studies, experiments, and published literature and linked to process models. Planned studies include:

- A synthesis of ecological processes, structure and functions of bottomland hardwood forests.
- Development of a successional model for bottomland forests.

Environmental considerations: Most of the studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." Where environmental concerns exist regarding particular studies (e.g., research involving the use of herbicides), environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs. For research involving possible conflict with permitted activities in the areas under Section 404 of the Clean Water Act of 1977, environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by appropriate staffs of the Forest Service or permitting agencies. If any of these studies have the potential to affect a plant or animal species that is Federally listed as endangered or threatened or proposed for such listing, the RWU will consult with the US Fish and Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended.

Problem 2. Managing complex wetland landscapes requires a detailed understanding of the functional linkages between management practices and ecosystem processes.

The research approach will use knowledge of stand development processes of forested wetlands to devise and test ecologically sound methods for harvesting, regeneration, and intermediate stand tending practices to meet landowner management objectives. The premise for this approach is that the biological and ecological principles that govern natural and planted stand development must be taken into account to develop silvicultural techniques that will maintain ecosystem structure and function. Successful research will enable formulation of sustainable silvicultural prescriptions that optimize tree growth and stand yield, and allow harvest of quality timber and simultaneously provide for non-consumptive uses of the forest resources and sustainability of ecosystem functions. Studies of silvicultural systems will use an interdisciplinary approach to enable the assessment of forest production, environmental quality, and sustainability questions.

Accomplishments planned for the next 5 years:

1. Design and install long-term studies to test new approaches to silviculture of coastal plain conifer and hardwood wetlands. These studies will be based on biological and ecological principles of stand establishment, growth, and development, and will be designed to quantify responses of vegetation, wildlife, soil, and water to treatments applied in bottomland hardwood stands, conifer and hardwood plantations, mixed pine-hardwood stands, and swamps and fens. Approaches will consider both intensive management regimes designed to increase yield per unit area, and management involving natural regeneration and stand tending. The principal factors of sustainability to be considered will include nutrition, organic matter, hydrology, soil physical properties, and physiology and genetics. Planned studies include:

- A watershed-scale assessment of ecosystem dynamics in an agrading lower coastal plain forest -- a paired watershed study on the Santee Experimental Forest.
- A study of sustainability of short-rotation woody crop plantations -- considerations on soil productivity and water resources.
- A study of silvicultural impacts on sustainability of hydric soils.
- A study to evaluate the effects of different regeneration methods on the structure and function of bottomland hardwood forests.
- A study on the recovery of soil C pools following harvesting and plantation establishment.

2. Use the data obtained from the field studies to evaluate the suitability of existing growth and biogeochemical models for predicting responses in productivity and nutrient cycling to silvicultural prescriptions (e.g., NuCM, TWIGS, BYPS, SWAMP, FORFLOW, PTAEDA). Select the appropriate model(s) and modify and calibrate it to provide a prediction system for use in coastal plain forested landscapes. Planned studies include:

- A study to evaluate and customize growth and development models for use in southeastern forested landscapes.

This work is dependent on sponsored funds, accordingly progress will be determined by available funds.

3. Publish practical guidelines for silvicultural prescriptions for use in bottomland stands and mixed pine-hardwood stands. Guidelines will address productivity, water resources and wildlife habitat, and economics. Planned studies include:

- An update of the hardwood regeneration guide.
- A synthesis of harvesting and site preparation impacts on forested hydric soils.

4. Develop and evaluate buffer zone management systems for water quality, non-point source runoff into wetlands and aquatic ecosystems. Planned studies include:

- A study of the effectiveness of buffer zone configurations for managed forest stands.

This work is partially dependent on sponsored funds, accordingly progress will be determined by available funds.

5. Characterize the sustainability of avifauna and herpetofauna habitat in association with wetland silviculture. Planned studies include:

- A study of avifauna use of managed bottomland hardwood forests.
- Testing of the BIRDHAB model applicability for site assessment and management.
- Development of habitat attribute models for wildlife in forested landscapes of the southeastern US.

The wildlife work is dependent on sponsored funds, accordingly progress will be determined by available funds.

Environmental considerations: Most of the studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." Where environmental concerns exist regarding particular studies (e.g., research involving the use of herbicides), environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs. For research involving possible conflict with permitted activities in the areas under Section 404 of the Clean Water Act of 1977, environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by appropriate staffs of the Forest Service or permitting agencies. If any of these studies have the potential to affect a plant or animal species that is Federally listed as endangered or threatened or proposed for such listing, the RWU will consult with the US Fish and Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended.

Problem 3. Restoration of wetlands and riparian zones requires both new technologies and indicators of ecosystem health.

Research in this problem area will address two issues of wetlands restoration. First, experiments will be conducted to determine site requirements for establishment of wetland species, including (a) site preparation

and disturbance amelioration, and (b) interactions among target species, competition, and cover crops. Protocols for site assessment will be developed to provide the land manager with sufficient information to determine what functions a restored site should be able to perform within the constraints of the site location and hydrology. Ongoing research at the Center and new collaborative efforts with other RWUs and agencies will be used to meet this objective. Second, an assessment framework will be developed that consists of indicators or indices of ecosystem health to signify the success of the restoration project. This research will be based on a recently developed conceptual framework and will be refined by studying new and recently restored sites, and agrading forested wetland communities. A major component of this work will be conducted at the Savannah River Site in collaboration with the Savannah River Forest Station and Westinghouse Savannah River Technology Center.

Accomplishments planned for the next 5 years:

1. Determine biotic and abiotic conditions and interactions that are necessary for successful survival of planted trees on wetland sites. Responses of species, especially seedlings, to the interactions of hydrology, fertility, and competition on various sites will be studied. Planned studies include:

- A study of differential responses of species to competition from both herbaceous understory and woody overstory and to site hydrology in terms of seasonal timing and duration of flooding, depth of flooding, and cycles of drought and flooding.
- A study of differential responses of seedlings to fertility in terms of sediment source (red versus black rivers), mineral deficiencies and toxicities, mineral soils versus histic soils, hydrogeomorphic properties, and the presence or absence of soil fungi and microbes.
- A study of the role of mycorrhizae in seedling establishment.
- A study of the effect of herbivory and the use of cover crops on survival and establishment of hardwood tree species.

This work is dependent on sponsored funds, accordingly progress will be determined by available funds.

2. Develop guidelines for re-establishing trees on wetland sites and for amelioration of soil damages. Planned studies include:

- A study of competition control such as herbicide application, prescribed fire, and site water manipulations.
- A study of regeneration techniques--natural versus artificial regeneration and seeding versus planting seedlings.
- A study of appropriate spacing and pre-plant seedling treatments such as inoculation with mycorrhizal fungi, root pruning, and shoot clipping.

This work is dependent on sponsored funds, accordingly progress will be determined by available funds.

4. Develop and test an assessment framework that can be used to determine the effectiveness of wetland restoration projects. Research in this area will identify key features of wetlands that are indicative of its current function and future persistence and functionality on the landscape. Indicators that show up in the short-term will be more valuable than those showing up after 15 or 20 years. Also the timing of assessments in terms of seasonality may be important. Planned studies include:

- A study of the effectiveness of restoration projects in bottomland forests.
- Development of methods for restoring Carolina Bays.

- A study of functional linkages between aquatic ecosystems and restored riparian zones.
- Development of indicators and indices of ecosystem health that can provide a means of quantifying restoration success.

Environmental considerations: Most of the studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." Where environmental concerns exist regarding particular studies (e.g., research involving the use of herbicides), environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs. For research involving possible conflict with permitted activities in the areas under Section 404 of the Clean Water Act of 1977, environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by appropriate staffs of the Forest Service or permitting agencies. If any of these studies have the potential to affect a plant or animal species that is Federally listed as endangered or threatened or proposed for such listing, the RWU will consult with the US Fish and Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended.

Problem 4: New approaches and integrated assessment tools need to be developed for analyses that incorporate science, land use, policy options, and government regulations into assessments of sustainability of forest health and resources on landscape scales.

This Problem Area will develop spatially explicit models that can quantify the functional linkages among ecosystems in the landscape and be used to evaluate economic and ecological effects of forest management at the landscape level. Given the increasing demands being placed on a limited land base, we must be able to address the question: How can we manage landscapes to obtain maximum benefits while ensuring the integrity of the nature resources on which these benefits are based. We will also address research topics that have both theoretical and practical implications, such as how to assess forest health and measure habitat suitability at the landscape level. The landscape research initiative at the Center will be based on long-term data sets from the experimental forest, remotely sensed data bases, ongoing large-scale field experiments, the Center's process-oriented studies, and support of and collaboration with private industry and other agencies.

Accomplishments planned for the next 5 years:

1. Develop criteria and methodology of forest health assessment with the help of spatial landscape models. This accomplishment defines the general direction of the Center's landscape initiative. Information about ecological processes of forested wetlands (Problem 1), ecologically sound silvicultural prescriptions (Problem 2), and regeneration and restoration of forested wetlands (Problem 3) will be needed for the model development and testing. Thus, the landscape research will integrate research activities from the other three Problem Areas of the Center. Planned studies include:

- A synthesis of studies on ecosystem functions and processes, silviculture, and restoration of forested wetlands to address large-scale issues about sustainability of natural resources.

This work is partially dependent on sponsored funds, accordingly progress will be determined by available funds.

2. Develop a generic, GIS-based model that can be used to evaluate economic and ecological effects of forest management on wildlife habitats at the landscape level. This landscape model has four major components (Fig. 2): (a) a stand model to predict tree growth, (b) a habitat attribute model at both the stand and landscape scales to estimate habitat attributes of each stand and of the landscape, (c) a habitat suitability model at the landscape scale to calculate habitat suitability indices for functional groups of species, and (d) a landscape spatial information system to combine the above models in space and time. Planned studies include:

- Development of a model for landscape evaluation of effects of management activities on timber and habitat (LEEMATH).

3. Develop models to predict changes in habitat attributes at multiple scales during the course of stand development in pine plantations, mixed pine hardwoods, and bottomland hardwoods. Habitat attribute dynamics is essential to assessment of effects of forest management on wildlife at the landscape level, and habitat attribute models are key to linking stand growth information to wildlife habitat quality. Planned studies include:

- Development of expert systems of habitat attribute dynamics that may consist of either a large tabulated data base or a set of empirical models relating habitat attributes (e.g., canopy closure, density, understory, favorable edge) to stand characteristics (e.g., age, type, density, silviculture treatment history).
- Development of integrated and process-based models of habitat attributes at within-stand, stand, and landscape scales.

This work is partially dependent on sponsored funds, accordingly progress will be determined by available funds.

4. Design landscape measures of habitat suitability and establish their relationships to actual habitat requirements of some target species. Landscape indices of habitat suitability need to be developed to reflect spatial configuration of the landscape (e.g., juxtaposition, edge, nearest neighbor distance, patch size) and evaluated for their effectiveness with respect to ecosystem processes. Planned studies include:

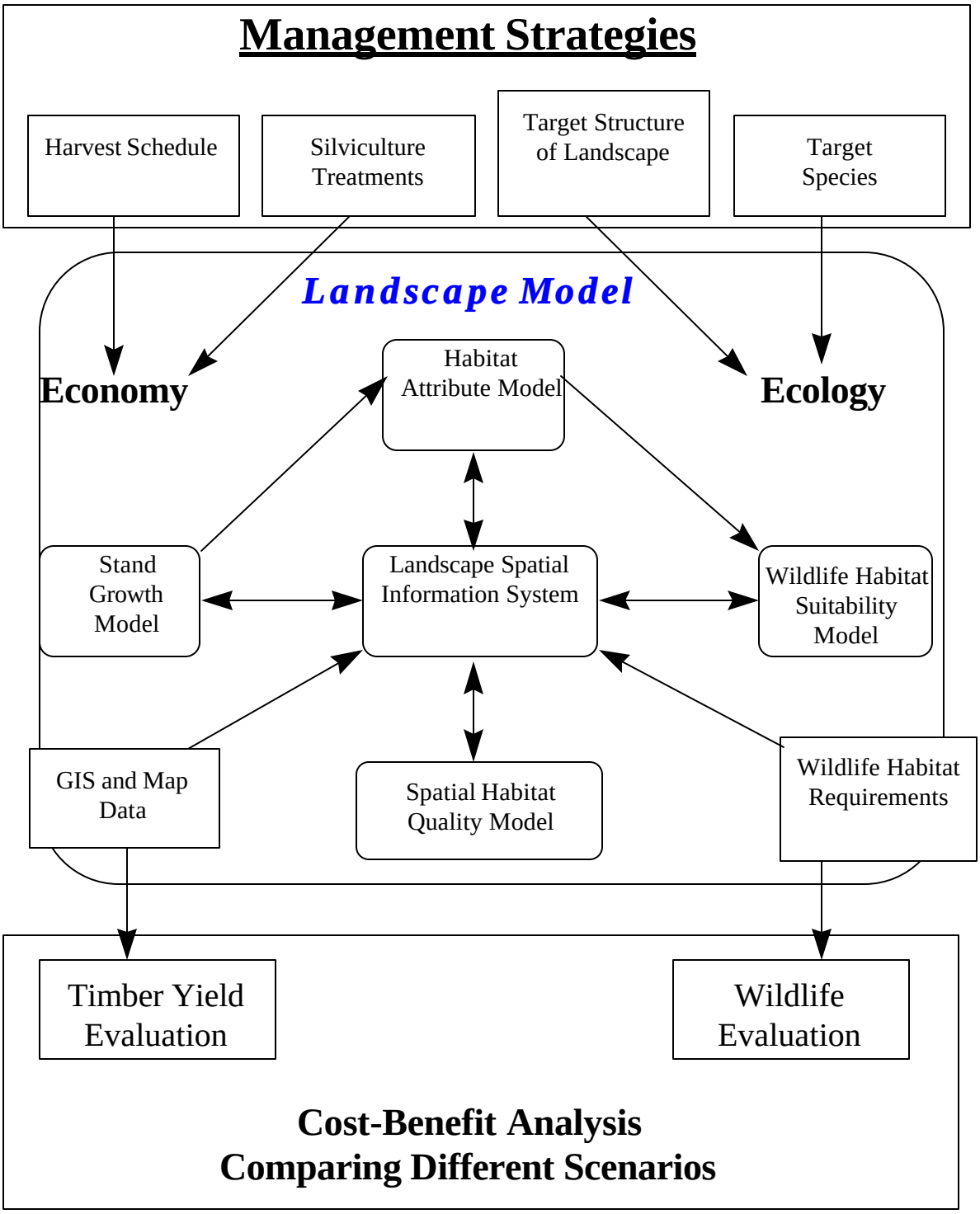


Fig. 2: The conceptual design of LEEMATH, a landscape model for assessing ecological and economic sustainability of land management practices.

- Evaluation and design of landscape metrics of habitat suitability that reflect the habitat requirements of target species.

5. Develop models similar to LEEMATH that can be used to address other aspects of natural resource management (e.g., water quality, recreational values). Such models may consist of modules of stand growth, soil, hydrology, sedimentation, and biogeochemistry. Planned studies include:

- Development of a model that can be used to evaluate economic and ecological effects of forest management on water quality at the landscape level.

Environmental considerations: Most of the studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." Where environmental concerns exist regarding particular studies (e.g., research involving the use of herbicides), environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs. For research involving possible conflict with permitted activities in the areas under Section 404 of the Clean Water Act of 1977, environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by appropriate staffs of the Forest Service or permitting agencies. If any of these studies have the potential to affect a plant or animal species that is Federally listed as endangered or threatened or proposed for such listing, the RWU will consult with the US Fish and Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended.

11. COOPERATION

The Center is staffed to lead research within the four Problem Areas. However, the research questions often necessitate expertise, capabilities, or staffing levels that are beyond that which is available at the Center. Those deficiencies are alleviated through joint research programs with scientists at other Forest Service Research Work Units, universities, federal and state agencies, and private industry (see Table 1).

Collaboration is organized in two forms. The first is Forest Service-lead projects where cooperators satisfy specific discipline or staffing needs. This approach is commonly needed to assemble interdisciplinary teams. Scientists in the disciplines of wildlife biology, economics, social sciences, ecology, and hydrology are frequently used. The second form is where Center staff participate in a research team on projects that are lead by cooperators. In this case, staff are contributing expertise to a project that has relevant outcomes to the Center's mission and the Station's cross-cutting themes.

Table 1. Cooperators with the Center for Forested Wetlands Research effective January 1997.

Cooperators	Location
US Forest Service	
Center for Bottomland Hardwood Research	Stoneville, MS
Fire Behavior Laboratory	Missoula, MT
Soil & Water Management Laboratory	Boise, ID
Savannah River Forest Station	Aiken, SC
Croatan National Forest	Croatan, NC
Francis Marion National Forest	Columbia, SC
Forest Soil Productivity	Research Triangle Park, NC
Southern Global Change	Raleigh, NC
Other Federal Agencies	
Biological Resource Div., USGS	Lafayette, LA; Nacogdoches, TX
Corps. of Engineers	Vicksburg, MS
Water Resource Div., USGS	Columbia, SC; Reston, VA
Oak Ridge National Laboratory	Oak Ridge, TN
Environmental Protection Agency	Atlanta, GA
Savannah River Ecology Laboratory	Aiken, SC
Universities	
Auburn Univ.	Auburn, AL
Clemson Univ.	Clemson, SC
College of Charleston	Charleston, SC
Florida A&M	Tallahassee, FL
Medical University of South Carolina	Charleston, SC
Michigan Technological Univ.	Houghton, MI
North Carolina State Univ.	Raleigh, NC
University of Delaware	Newark, DE
University of Florida	Gainesville, FL
University of Georgia	Athens, GA
University of Idaho	Boise, ID
University of South Carolina	Columbia & Aiken, SC
University of Tennessee	Knoxville, TN
Virginia Tech. Univ.	Blacksburg, VA
Industry	
Westvaco	Summerville, SC
Union Camp	Savannah, GA
International Paper	Bainbridge, GA
Westinghouse Savannah River Technology	Aiken, SC

Center	
Non-Government Organizations	
Tall Timbers	Tallahassee, FL
Audubon	Summerville, SC

12. STAFFING

This research program requires an average of 8 scientists per year, although additional staffing is warranted. Distribution of scientist FTE's through the next 5-year term is as follows:

Problem Area	Scientist Years per Year				
	1	**2**	**3**	**4**	**5**
1	2.0	2.0	2.0	2.0	2.0
2	2.0	2.0	2.0	2.0	2.0
3	2.0	2.0	2.0	2.0	2.0
4	2.0	2.0	2.0	2.0	2.0
Totals	8.0	8.0	8.0	8.0	8.0

Five permanent full-time scientists, one of whom is project leader, are presently supported in the basic RWU budget. The balance of the scientists positions are realized through term or post-doc appointments, or additional permanent staff if program funding is increased. The FY97 scientist staffing plan included 7 scientists (5 permanent, 2 post-docs).

Permanent support staff at the Center include 4 professional, 2.5 technical, 1.5 administrative and 1 facility FTEs. The Center also employs term professional and technical support staff, student assistants and graduate students to augment overall program staffing needs; those positions are supported entirely on sponsored research funds. Those staffing levels average 5 technical / professional support positions, 5 student assistants, and 5 graduate students. The Center also uses three part-time positions through the Department of Labor's Senior Citizen Program.

13. ECONOMIC ANALYSIS

The projected base funding required for this research program are approximately $1.6 million per year. The FY96 base appropriations to the Center were approximately $900K with an additional $200 of Ecosystem Management funds. This amount is approximately the same as in FY94 and FY95. In FY96 agency appropriations supported approximately 70% of the Center's research program. Accordingly, sponsored funds are required to sustain the research program. Increased competition for smaller pools of sponsored research funds promises to be an ongoing challenge for the Center's

scientists. The program as planned and budgeted is tenable given the track record of the scientists, and opportunities afforded by current research program and facilities. However, sustained Forest Service appropriations at FY97 levels are essential as a de-minimus to leverage research programs, and increased funding is highly recommended to ensure attainment of both the goals of the Center and the Station's CCTs.

Estimated annual costs (thousands of dollars) for the Center during the five year period (cost basis is $200K per scientist-year plus 2% inflation each subsequent year). This budget reflects effectively constant funding levels with only 2% inflation increase in appropriated funds. Differences between estimated annual costs and Appropriated Funds would be covered by funding from outside sponsors.

Problem Area	Year				
	FY98	**FY99**	**FY00**	**FY01**	**FY02**
1	400	412	424	437	450
2	400	412	424	437	450
3	400	412	424	437	450
4	400	412	424	437	450
Totals	1,600	1,648	1,696	1,748	1,800
Appropriated Funding Plan	1,115	1,145	1,168	1,191	1,215

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