Successes

Our Strategic Framework in Action

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The Framework

We published *The Strategic Framework for the Southern Research Station* in 1997. The Strategic Framework enhances our ability to work with other members of the forestry community on a broader scale, across State and local boundaries, to respond to the complex issues challenging natural resource management. It provides a mechanism to leverage our science and resources in an integrated fashion and to assure accountability in our research and development programs. The Strategic Framework supports our commitment to collaborative stewardship by delivering usable information and technology to public and private customers to implement sustainable land and resource management. Sustainability is the concept that brings focus to the SRS research and development program.

The Forest Service is committed to the goal of sustainability, which is defined as the ability of the biophysical resources-or ecosysterns-to meet human needs and wants without degradation. By maintaining forest health, diversity, and productivity, sustainable forest management ensures that the commodity and environmental needs of present and future generations can be met.

The Strategic Framework establishes three emphasis areas for a dynamic system for setting goals, priorities, and making significant accomplishments:

1. measuring and monitoring forest resources;
2. understanding ecosystem structure, function, and processes; and
3. ensuring environmental quality and sustainable productivity.

Achieving sustainability and incorporating human values into our research program requires a multidisciplinary approach and a customer-driven framework for applying that approach. To integrate the efforts of our 25 Research Work Units, six cross-cutting themes (CCTs) were developed that will help bring people together to address the three emphasis areas across the South:

1. Sustainability and Productivity of Southern Pine Ecosystems;
2. Ecology and Management of Forested Wetlands, Bottomland Hardwoods, and Riparian Zones;
3. Southern Appalachian Ecosystem Research and Sustainability;
4. Sustainability and Productivity of the Interior Highlands Ecosystem;
5. Landscape and Regional Integrated Assessment and Modeling;
6. Inventory and Monitoring.

This section provides an update of some of the accomplishments that occurred in FY99 relating to the CCTs. The CCTs provide a thematic focus for much of our research and development program, but they are not mutually exclusive. Accomplishments may relate to more than one theme and the CCTs do not encompass our entire program. Additionally, we produced over 500 publications and other materials in FY99 that are listed in the final section of this report; they are grouped under the most appropriate CCT.

Caring for the Land and Serving People

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The Sustainability and Productivity of Southern Pine Ecosystems Cross-Cutting Theme includes components of the programs of 17 SRS research work units. This CCT embraces a major portion of our research on forest productivity-a primary resource driver of the South's economy. In addition, this CCT includes research and development related to seven criteria that have international agreement for conservation and sustainable management of temperate and boreal forests. This will lead to more holistic and integrated regional and landscape-scale studies, and become the basis for a corporate vision of the important issues and information gaps that surround these ecosystems.

A wide range of research accomplishments by SRS scientists in FY99 ties into this emerging new vision. Some highlights organized around the seven criteria include:

Conservation of biological diversity

Studies of the Louisiana pine snake indicate that it is extremely rare; it is documented on only a small portion of its historic range in eastern Texas and western Louisiana. Consequently the U.S. Department of the Interior, U.S. Fish and Wildlife Service is evaluating the potential listing of the species under the Endangered Species Act. Research is providing information on general ecology, habitat use, and impact of roads on snake populations. This information is being used by the Forest Service, military installations, and private timber companies to manage fire regimes and vehicle use in ways compatible with maintenance of Louisiana snake populations.

The effects of demographic isolation are particularly severe in small, isolated populations of the endangered red-cockaded woodpecker. An operational scale technique has been developed and field-tested to reintroduce pairs of red-cockaded woodpeckers into areas where only small populations are present and into areas where the woodpecker previously existed. The results suggest that reintroduction of pairs of first-year adults in a spatial array dense enough to allow social contact between adjacent pairs and with preexisting resident groups substantially increases the formation of new breeding pairs of woodpeckers. The ability to reintroduce this species to areas where they have been extirpated is a major breakthrough for the management and recovery of this endangered species.

We examined pileated woodpecker damage to red-cockaded woodpecker cavity trees and cavity enlargement on the national forests in eastern Texas in both longleaf pine and loblolly-shortleaf pine habitats. We also examined the effectiveness of restrictor plates in deterring pileated woodpecker

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enlargement of red-cockaded woodpecker cavities. While restrictor plates are useful for protecting red-cockaded woodpecker cavities, they should be used

only in small populations when cavities are in short supply. The pileated woodpecker plays an important role, especially in the longleaf ecosystem, which is a relatively cavity-barren environment, by providing nesting sites for larger secondary cavity users, such as American kestrels, eastern screech-owls, and fox squirrels.

Maintenance of productive capacity of forest ecosystems.

The increasing intensity of forest management in the South has resulted in a great demand for quality southern pine seeds and seedlings. Production of nursery stock is now about 1.5 billion seedlings per year. The greatest problem in seedling production is for longleaf pine, a species that is in great demand because of longleaf pine restoration efforts. Guidelines are now available that allow the production of high quality seeds and seedlings and result in improved reforestation success. Container production is an effective technique for producing longleaf pine planting stock that survives and grows well in the field. Once established, other management approaches such as the use of chemicals or fire must be used to minimize the effect of competition to restore longleaf pine ecosystems. Repeated use of fire reduces the woody understory vegetation and restores the herbaceous plant community that is a unique component of this ecosystem.

Wood volumes generated from 14-year old Piedmont loblolly pine stands and 17-year-old Coastal Plain slash pine stands were dramatically increased when competing vegetation was controlled in the early years of establishment. The effect of this early competition control on the amount of juvenile wood in the 14-year-old loblolly pine stands was pronounced because the increased growth occurred during the first 10 years. In the Piedmont region, scientists found that 12-year-old loblolly pine stands grown on intensively prepared sites had 2.7 times the basal area as similar aged stands on control sites; both volume and height increased with preparation intensity.

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Maintenance of forest ecosystem health and vitality

Pest Plant Alerts for the most invasive alien plants were prepared in cooperation with Forest Health Protection in the Southern Region of the Forest Service. These will be used by Forest Inventory and Analysis teams to perform the first survey of exotic plants in the region. A major book publication, *Forest Plants of the Southeast and Their Wildlife* Uses, that covers both native and nonnative plants was published in cooperation with the Southern Weed Science Society.

During a southern pine beetle outbreak, the impact of natural enemies and competitors was analyzed. The results indicated the natural enemy complex causes increased mortality 1 year after peak southern pine beetle density. This density-dependent delay is probably responsible for the regular cycles observed in southern pine beetle abundance. Two competitors with southern pine beetle, a bluestain fungus and another phloem-destroying insect, appeared to generate direct density-dependence and may affect the amplitude of the cycles in southern pine beetle.

The impacts and monitoring technology of forest access were examined in several studies. Temporary access is one method of reducing impacts from roads. Temporary access is built, used, removed, and the site restored. The total life-cycle sediment loading from temporary low-water fords was quantified over a 2-year period. Alternative sediment-trapping structures for turnout ditches on forest roads were also examined in a long-term study of erosion in forest access. Sediment basins appeared to be the most effective treatment.

Conservation and maintenance of soil and water resources

When southern pine forestsare regenerated, strips of timber are often retained along streams to minimize nonpoint water pollution during and following logging. Within intensively managed forest landscapes, these riparian zones are important to wildlife because they often provide critical habitat features, e.g., mast-producing hardwoods, snags, cavity trees, and large woody debris, that may not be present or abundant in adjacent pine plantations. However, landowners who retain riparian zones typically forego economic returns by not harvest-

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ing the timber within these areas. Research initiated to determine the amount and value of residual timber in nine riparian zones in east Texas shows that landowners sacrifice significant economic returns by retaining these zones; projected values were $66, $319, and $479 per acre for narrow, medium, and wide zones. Research results also suggest that wide riparian zones provide the most benefit to many wildlife species.

The influence of silviculture treatments on physiological responses, including photosynthesis, transpiration, stomal conductance, and xylem pressure potential, and water use continues to be a focus at research sites in Louisiana and North Carolina. The data suggest that early-season shoot expansion, crown growth, foliage production, root initiation, and crown physiology respond to microclimate changes within loblolly pine stands of large trees as a result of silvicultural manipulation. Although fertilization increases leaf area and thus total water use, water relation experiments show that fertilized trees use less water per unit leaf area; thus fertilized trees actually obtain higher water-use efficiency. Global climate change may also influence environmental factors within stands and cause potential stresses on growth and productivity of southern pine forests.

Courtesy Texas Forest Service

Maintenance of forest contribution to global carbon cycles

There has been substantial progress in quantifying the role of southern pine forests in sequestering atmospheric carbon dioxide (CO_2). Fertilization resulted in loblolly pine stands being a sink for atmospheric CO_2 compared to unfertilized stands, that were sources of atmospheric CO_2. This shift in carbon economy was largely due to the higher productivity of fertilized trees. Increases of CO_2 by about 60 percent raised photosynthetic rates through the tree canopies with and without fertilization. Branch and diameter growth increased by about 20 percent. Inclusion of root growth and decomposition studies added valuable insight on belowground impact prediction models. The ability to synthesize research

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results via mathematical modeling has resulted. A product of the effort was the major modeling meeting, "Toward the Application of Process Models to Sustainable Management of Southern Pine Forests."

Maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies

In an evaluation of the effect of five different silvicultural strategies and wood type on mechanical and physical properties of loblolly pine particleboard and fiberboard, it was found that the inner wood can produce particleboard and fiberboard panels with comparable mechanical and physical properties to outer wood. The effect of the silvicultural strategy was minimal for most properties.

Legal, institutional, and economic framework for forest conservation and sustainable management

Conservation Reserve Program (CRP) participants in Alabama were surveyed to determine how their lands would be managed after CRP funds expire without opportunity for renewal. If the CRP lands were planted in trees, 90 percent would remain in trees; if the lands were planted in grasses, 60 percent would be converted to row crops. Therefore, for sustained mitigation of soil loss and reduction of excess production capacity, tree planting as a conservation practice should be advocated and encouraged.

The statutory, administrative, and judicial adjustments in the Federal income tax and in the State income, property, and harvest taxes were monitored in terms of their effect on owners and managers of nonindustrial, private forest land. Forest-related tax law provisions and proposed legislation were interpreted for Agency and external clients. Prototype tax compliance software was developed for private forest land owners through cooperative research with university specialists.

Lead contacts for the Sustainability and Productivity of Southern Pine Ecosystems Cross-Cutting Theme: RWU SRS-4105 at Auburn, AL, and RWU SRS-4111 at Pineville, LA.

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Wetlands, Bottomland Hardwoods, and Streams

Approximately 50 percent of the wetland resource in the United States occurs in the South, and the majority of these wetlands are forested. In addition to jurisdictional wetlands, nonhydric bottomlands and riparian areas occur in a hydrogeomorphic setting similar to wetlands. Sustainable management of these forests, a majority of which are in private hands, provides research challenges addressed by SRS scientists. The Ecology and Management of Forested Wetlands, Bottomland Hardwoods, and Riparian Zones Cross-Cutting Theme involves activities of 13 research work units in the SRS. Two of these research work units are devoted to the issues in this CCT. Our research is organized around seven criteria for sustainable management and conservation of these forest types. Through this work we investigate ways in which the critical ecosystem functions can be maintained effectively in a social and economic context acceptable to those who own, manage, and care about the resources.

Conservation of biological diversity

The importance of wetlands to biodiversity is reflected in the role of critical habitat for both plants and animals. Over 50 percent of threatened and endangered species rely on wetlands for part or all of their life cycle. Wetlands also provide habitats that are critical to diversity at the landscape scale. For example, in the Southeastern United States, wetland ecosystems contain 75 percent of all bird species that use forests. Because approximately 50 percent of the wetlands in the Southeast have been destroyed, wetland restoration is important to the maintenance of biodiversity.

Assessing the effectiveness of forested wetland restoration is difficult because of the long time frame necessary for the development of soils, vegetation, hydrology, and fauna1 communities. To assess the success of forested wetland restoration projects, metrics are being developed that are sensitive to early changes in community development and are predictive of future conditions. These studies are being conducted in the Atlantic Coastal Plain and Mississippi Alluvial Valley; in floodplain, bottomland hardwood, and swamp ecosystems; and in

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sunken wetlands such as Carolina Bays. Carolina Bays are not only poorly understood with respect to hydrology, but have been severely altered by human activity, and are of ecological significance as habitat for several biological communities and rare species. Numerous studies have been initiated to assess differences in the hydrologic regime and other ecosystem functions between altered, restored, and reference ecosystems as a metric for evaluating the success of wetland restoration.

A cornerstone to the restoration work and other biodiversity-related research in this area has been the establishment of reference wetlands in the Atlantic

Coastal Plain and Mississippi Valley. These wetlands provide a baseline for assessing ecosystem structure and function that is critical to the maintenance of biodiversity. Results of one initiative were presented in a symposium as part of the annual meeting of the Society for Wetland Scientists in Norfolk, VA. The symposium was titled "Development of Reference Bottomland Hardwood Ecosystems: The Southern Forested Wetlands Initiative."

Understanding the interaction of land management practices and the use of wetlands by avian and invertebrate species has been constrained by insufficient knowledge. Studies employing experimentally created gaps, timber harvests, and reduction of insect populations determine the relative importance of these factors in bird and invertebrate populations. These studies are being conducted in a variety of wetland types across the South. Silvicultural manipulation can influence wildlife and endangered species habitat and biodiversity; however, there are few long-term studies of the influence of intensive management on these resources. In a continuation of experiments conducted for decades on a paired watershed, vegetation dynamics in a watershed managed for the endangered red-cockaded woodpecker is being compared with vegetation dynamics in a watershed that has been excluded from intensive management. Models are being developed to predict habitat quality for birds on public and private land in the South. Field data from research projects are being used to validate the model and, if necessary, refine it. Refinements may include incorpo-

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ration of quantitative models that employ landscape or vegetation-structural-predictor variables. These models are used to integrate field studies, which are in turn used to parameterize and test the models.2. Maintenance of productive capacity of forest ecosystems

Maintenance of productive capacity of forest ecosystems

Operational planting under the Wetlands Reserve Program has produced few successful plantings of bottomland hardwoods in the Lower Mississippi Alluvial Valley. A recent survey of afforested agricultural land in Mississippi found 90 percent failure, indicating the difficulty of the task of forest restoration in bottomland hardwood systems. While planting seedlings was more successful than direct seeding acorns, only 23 percent of the land planted with bare-root seedlings had at least 100 trees per acre after 3 years. Research reported this year continues our efforts to specify techniques for successfully planting harsh sites. Matching tree species to site conditions (soil characteristics and flood regime) continues to be the most critical factor and mismatching accounts for many problems in operational plantings. Proper handling of planting stock and planting techniques are nearly as important.

Precommercial thinning of water tupelo stands in the Mobile-Tensaw River Delta was investigated. Contrary to results in other parts of the country, survival of water tupelo coppice was very high and the thinning and cleaning treatments did not affect survival. Cleaning Carolina ash and willow from the stands had no positive effect on individual tree- or stand-level variables measured. We concluded that cleaning had no beneficial effect over the 5 years of the study. Thinning, however, significantly increased diameter growth of the water tupelo. Thinning is potentially an effective option in stands with a high density of water tupelo sprouts (approximately 2,000 sprouts per acre over 3 feet tall at age 4 after clearcutting).

Forest soils are the basis of sustainability in resource management. We are focusing on the impacts of forest operations on soils, their physical and bio-

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geochemical responses, and resulting effects on vegetation. Studies of above- and belowground growth and carbon allocation are being conducted in both reference and harvested bottomland hardwood forests, short-rotation woody crop plantations, and in flood tolerance experiments. In addition, the influence of different water level management and cover crop treatments on biomass productivity, retention of nutrients in biomass, carbon sequestration, and their influence on water quality are being quantified using experimental catchments.

Regenerating bottomland hardwood forests following harvest usually depends upon advanced regeneration and/or sprouting of the cut stems. However, the low regeneration success of desirable species illustrates our need to better understand regeneration dynamics in floodplain forests. Studies of the environmental factors that influence survival and growth of advance regeneration is helping to determine whether survival and growth of advance regeneration can be enhanced by preharvest treatments.

Maintenance of forest ecosystem health and vitality

We are evaluating electronic aromascan technology to detect pathogenic microorganisms in absence of visible indicators. These organisms cause economic loss in bottomland hardwood and other forests in the South. We have been able to discriminate pure cultures of wood decay fungi isolated from decayed trees. This technology has potential to identify wood decay fungi, vascular wilt fungi, bacterial wetwood, bacterial leaf scorch, and many microbes capable of causing lumber degrade in wood samples. Another approach is to develop a simple, accurate system to detect wetwood in living oaks and sawn oak lumber using ultrasound. An accurate prediction of site risk factors would allow silvicultural manipulation to reduce incidence of affected trees. We are focusing on characterizing bacterial populations, measuring physical characteristics, and using ultrasound to detect wetwood of oaks on bottomland sites in the Mississippi Delta.

Many wetland ecosystems in the Southeast are dependent on natural fire regimes. We are participating in research with the National Fire Laboratory to de-

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velop prescriptions to apply prescribed fire to organic soil wetlands. That research is considering both fire behavior and the environmental effects on forest ecosystem health.

Southern Research Station scientists participated in an important symposium, "Ecology and Management of Bottomland Hardwood Systems: The State of our Understanding." The meeting brought together a wide array of our clients, including the full range of interests from production forestry in bottomland hardwoods to the protection of wetland forest ecosystems. Papers given at this symposium will be published in 2001.

Conservation and maintenance of soil and water resources

Long-term study of watersheds in the Atlantic Coastal Plain has allowed SRS scientists to evaluate the effects of prescribed fire, hurricane damage, and intensive versus nonintensive forest management on streamflow, water quality, and nutrient cycling. Often these studies involve collaboration with other Federal agencies, forest products industry, and university collaborators. Information from these studies is being used in regional assessments, such as the National Water Quality Assessment Program of the U.S. Geological Survey, and in preparation of wetland management guidebooks using hydrogeomorphic modeling by the Environmental Protection Agency.

A study of Carolina Bays has been initiated to determine the origin of water, establish pathways for net water transformations, determine the role of soil physical properties on water retention within the bays and associated uplands, assess the processes affecting water quality and mineral cycling in the bays, and evaluate the role of restoration on water quality improvements.

Hydrologic modeling is critical for assessing and managing the Nation's water resources. Unlike in the Western United States, there are few models for the Coastal Plain and Piedmont regions. Work is underway on the application of several models. The wetland hydrologic model, FLATWOODS, is being tested by the Southern Global Change Program in South Carolina to increase our understanding of the effects of land management on natural forest processes and the effects on available clean water. The information from this study will be applied to other types of forested wetlands (cypress ponds, Carolina Bays, and bottomlands) in the South. This model has the capability to simulate lateral water movement from upland forests to wetlands and can be used by land managers and planners. Tests are proceeding with a two-dimensional model, WATRCM, to assess water re-

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sources at the landscape level. Future improvements to the models will include the ability to track nutrient concentrations dissolved in the water as they move across the landscape. These hydrologic models are also being used to provide the basis for models on soil carbon and nitrogen cycling in forested wetlands.

Maintenance of forest contribution to global carbon cycles

Following the conventional paradigm, afforestation of former agricultural fields should increase soil organic matter and thus not only improve the long-term, sustainable productivity of the soils, but also contribute to sequestration of atmospheric carbon. Numerous studies of reforestation are underway to test how different restoration techniques, site preparation methods, and silvicultural management practices influence carbon sequestration into soil organic matter.

Peatlands are natural carbon sinks because organic matter decomposition is less than net primary production. Because one-third of the global soil carbon pool is found in boreal peatlands, considerable concern exists over the potential impacts of global change and land management practices on the carbon balance in peatlands. In collaboration with Scandinavian scientists, studies of the changes in soil carbon pools associated with silvicultural practices are underway.

Soil carbon in wetlands is recognized as an important component of global carbon budgets and contributor to future climate scenarios. Until recently, however, little work has been done on modeling soil carbon cycling in these diverse ecosystems. In particular, studies have not addressed how the organic matter decay factor is modified as the soil environment changes, whether from land management activities, human disturbances, or climate change. Recently, a wetland soil carbon mode1 has been developed.

Maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies

Society is increasingly demanding that timber production be conducted in a manner that enables forests to provide other benefits and services, including recreational

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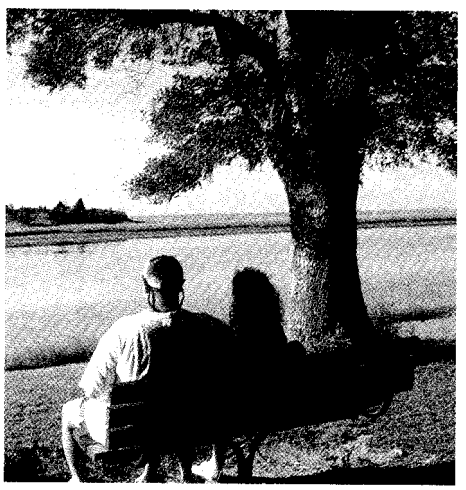
and scenic enjoyment, watershed protection, and wildlife habitat. A model has been developed to integrate economical and ecological perspectives for sustainable forestry. Models of economic



analyses are used to formulate research questions and study plans to develop socioeconomic assessment frameworks of sustainable forestry. In addition, a model is being developed for the simulation of forest stand succession and to predict forest stand attributes for forest ecosystems in landscapes with wetlands.

Legal, institutional, and economic framework for forest conservation and sustainable management

A module for economic analysis with environmental constraints has been developed for use with the model LEEMATH to assess the implications of alternative management strategies to the net profits from timber production and wildlife habitat quality.

Lead contacts for the Ecology and Management of Forested Wetlands, Bottomland Hardwoods, and Riparian Zones Cross-Cutting Theme: RWU SRS-4103 at Charleston, SC, and RWU SRS-4155 at Stoneville, MS.

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The objectives of the Southern Appalachian Ecosystem Research and Sustainability Cross-Cutting Theme are to: (1) identify and test principles and develop ecologically based information applicable to management of Southern Appalachian forest ecosystems, focusing on natural and planned disturbances; (2) increase our knowledge of social and economic influences on forest resource management and the values derived from them; and (3) develop and provide tools to forest managers in a form useful for integrating ecological and socioeconomic information to aid in forest management decision-making.

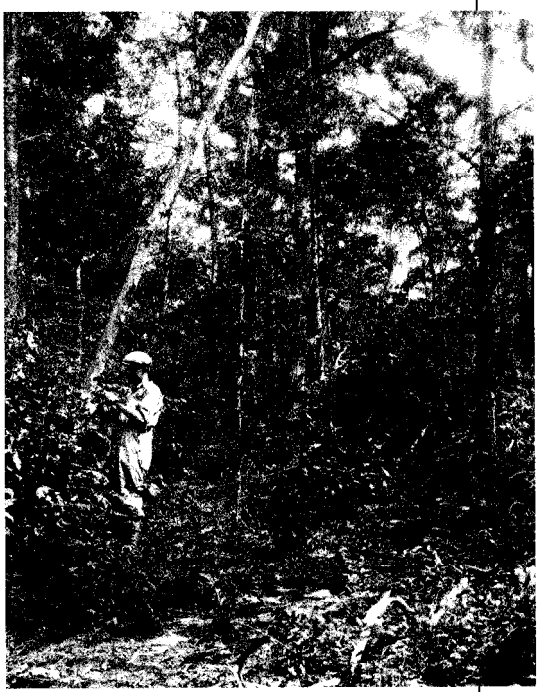
The major questions are straightforward and are not unique to the Southern Appalachians: (1) what are the values people associate with forests, both public and private, and what are the benefits expected from forests, given these values, and (2) what are the capabilities of forested ecosystems to provide these benefits on a sustainable basis?

The overall approach has been both to identify relevant ongoing research efforts and to initiate new efforts that will provide the information needed by forest managers. Much of this work will require interdisciplinary efforts and partnerships. Integration across disciplines and spatial scales will be aided through the development of land management tools such as decision-support systems. Research activities are organized in three broad categories: ecosystem dynamics, structure and function; social and economic influences in forest management; and synthesis and integration of information. Highlights in these categories for FY99 include:

Ecosystem dynamics, structure and function

Analysis of data from an ongoing study of mixed hardwood tree species indicated that site environmental factors related to soil moisture availability was superior to site index for explaining variation in periodic diameter growth of individual trees.

Southern Institute of Forest Genetics scientists developed DNA-based markers to facilitate the restoration of the American chestnut tree to



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eastern forests. The DNA-based markers developed for the host are being used to determine the number of genes that control resistance to chestnut blight fungus; detect additional sources of resistance; determine levels of genetic variation and how it is portioned across the natural range; and identify pure species from putative hybrids. The DNA-based markers developed for the pathogen are being used to study genes that cause a hypovirulent phenotype that may be used to develop a successful control program for the chestnut blight fungus.

Results from a study of the use of stand restoration burning in xeric pine/hardwood ecosystems were published in a series of papers in a special issue of *Forest Ecology and* Management. Studies showed that stand restoration burning is an effective tool for restoring desired species composition and diversity without negative impacts on nutrient cycling, small mammals, or forest floor insects, Studies are continuing that examine the linkages between biodiversity and ecosystem function in the Southern Appalachians. Several papers were published quantifying the significance of individual species' physiological characteristics, e.g., leaf respiration and photosynthesis, in regulating net primary productivity across the landscape. In addition, new studies have been established that examine the role of understory herbs and grasses in regulating forest floor processes. Research is continuing on developing understanding and predictive models of land-use change in the Southern Appalachian region. Concurrent studies of the effects of these changes on terrestrial and aquatic systems provide a linkage between historic, contemporary, and future effects of disturbance on ecosystem structure and function.

Our research on the interrelationships among the endangered Carolina northern flying squirrel, hypogeous mycorrhizal fungi (truffles), and spruce-fir habitat continued. In January 1999, we initiated a collaborative study with scientists from Clemson University, SC and North Carolina Wildlife Resources Commission to determine the seasonal food habits of northern flying squirrels and some of their potential competitors (southern flying squirrels, red squirrels, and chipmunks) in the Balsam Mountains, NC and the Great Smoky Mountains National Park, NC. Results of this study will allow us to determine the relative importance of truffles in the diet of northern flying squirrels as well as determine dietary similarity and the potential for competition among the various squirrel species.

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To gain further information about the habitat relationships of mycorrhizal fungi, we initiated a cooperative study with scientists at Appalachian State University, NC. The objectives of this research are to

test the relationships between mycorrhizal fungal sporocarps and habitat type (spruce-fir versus northern hardwood) as well as to examine the occurrence and abundance of fungi associated with tree roots in the two habitat types. This study is an excellent follow-up to previous work on the occurrence and abundance of truffles in spruce-fir and northern hardwood habitats and will test some of the hypotheses that were generated in earlier descriptive work. This research will also provide more specific information on potential dietary items for northern flying squirrels and the interrelationships between the fungi and dominant tree species in northern flying squirrel habitat.

Natural and artificial regeneration of upland hardwoods has been problematic in national forests and other landownerships in the South. Intensive research continues on long-term studies on hardwood regeneration, specifically northern red oak and white oaks. The research clearly indicates that tree seedlings with high numbers of first-order lateral roots are the most competitive and thus most likely to survive and become established when planted in harvested forest land. Both genetic and nursery selections are needed to secure quality seedlings. Full sunlight has been identified as the most critical requirement for artificial regeneration of these species on good sites in the Southern Appalachians, followed closely by competing vegetation control. Photosynthesis and other physiological studies demonstrate that under low light conditions, as occurs when planting these species beneath an overstory, carbon allocation to roots of these tree species is curtailed in favor of some limited stem growth, resulting in a declining ability of the seedling to compete with other vegetation once the overstory is harvested. These findings provide important technology for artificial regeneration of these oak species and have implications relative to species diversity and mast production for various wildlife species.

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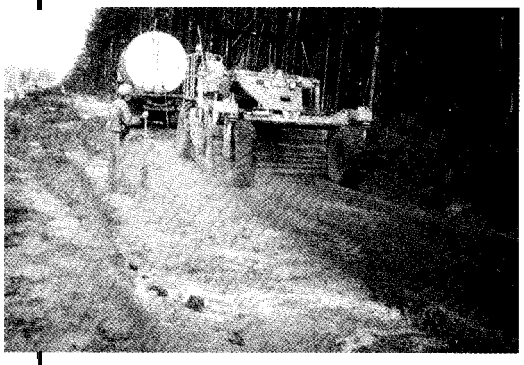
From a large subregional study of acorn production, we found that yearly acorn production varies among species and individual trees vary dramatically in their average production. Determining acorn crop sizes, patterns of production, and potential ways to predict crop size is useful to foresters in oak reproduction, and wildlife managers in assessing acorn availability for food.

Long-term studies of erosion control methods for forest roads are quantifying sediment trapping efficiency of alternative turnout ditch designs, erosion control for various vegetative stabilization treatments of road sideslopes, and life-cycle sediment yields of temporary stream crossings. The results of these studies will be synthesized into guidelines and recommended practices. A new



study has been initiated to examine the impacts of road obliteration practices.

Forest operations in upland sites are being investigated. The effect of removal intensity on productivity and cost for ground-based systems has been reported. A long-term study of manual methods for selection of stump sprouts was initiated. The costs of various methods were determined and the growth of the selected stems is being monitored to assess outcomes. A landscape visualization tool has been developed to depict alternative treatments. The program is being refined for open distribution.

Social and economic influences in forest management

The evaluation of hardwood pallet cants when converted to pallet parts was completed. We determined that cants with > 30 percent unsound wood should be reduced to chips. We also developed a spreadsheet business plan model and economic evaluator to enhance recovery and high-value uses of pallets at landfills. This has developed into a major effort at landfills to recover wood for reuse and recycling.

Understanding how people influence forests is crucial for developing effective ecosystem management plans. A research study evaluated patterns of land uses and development in four large areas of the Southern Appalachians. These studies explain how patterns of land use are determined by topography and by economic conditions. These research findings are incor-

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porated in a land use of forecasting model that predicts where and how land uses and building density may change in the future.

Another key to effective ecosystem management is understanding the values that people place on all of the benefits derived from forests. Three studies developed estimates of the amenity value of forests in the Southern Appalachian Mountains. The first study determined that recreation values in wilderness areas varied by the size of tree, maximum elevation, the amount of running water present and the degree of isolation offered. The second study evaluated the importance of various services provided by National Forests and discovered that people value ecological services (such as the supply of clean water or native ecosystems) more than recreational opportunities, the consumption of fish and game, or the supply of timber. The third study examined the distribution of benefits for protecting a unique forest ecosystem and found that conservation efforts provide equitable benefits to broad segments of the population.

Synthesis and integration of information

The first fully operational version of the NED ecosystem management decision-support system,

NED-l, was completed this year. The Microsoft COM/DCOM interoperability standard was tested and implemented as a generic, software communications standard for the NED family of software products. We were able to connect NED-l with the Forest Service growth and yield standard, forest vegetation simulator (FVS) using COM/DCOM.

Another major accomplishment was the consolidation of the extensive knowledge base of species-specific forest regeneration responses. This knowledge base has been captured in a computer program that simulates the postdisturbance response of forest regeneration in the Southern Appalachian region. The computer program is being distributed to practicing foresters (State forestry agency personnel, consulting foresters, and National Forest System silviculturists) through their participation in recurring silviculture short courses and other ongoing technology transfer activities.

Lead contacts for the Southern Appalachian Ecosystem Research and Sustainability Cross-Cutting Theme: RWU SRS-4101 at Bent Creek, NC, and RWU SRS-4351 at Franklin, NC.

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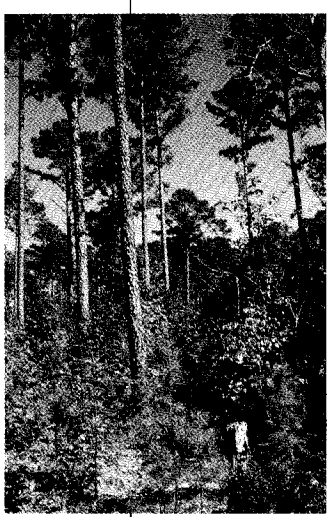
Interior Highlands



Research has an important role to play in the implementation of the Forest Service Natural Resource Agenda. The research conducted under the Sustainability and Productivity of the Interior Highlands Ecosystem Cross-Cutting Theme directly supports two elements of the Natural Resource Agenda-watershed health and restoration, and sustainable forest ecosystem management. The Interior Highlands are among the most important but least intensively studied regions in the mid-South. Four major ecological provinces comprise the Interior Highlands—the Ozark Highlands of southern Missouri and northern Arkansas, the Boston Mountains of north Arkansas, the Arkansas River Valley, and the Ouachita Mountains of western Arkansas and eastern Oklahoma. This CCT is designed to provide the scientific basis and integrating framework to support management of the Interior Highlands forests for public, forest industry, and nonindustrial private forest landowners.

The CCT builds on both the long standing ongoing research in the oak-hickory forest type, and on newer research studies in the shortleaf pine and pine-hardwood forest types, which constitute some of the lesser known of the major forest types in the South. These studies are bound together using interdisciplinary research programs that encompass vegetation, wildlife, aquatic ecology, hydrology, and human dimensions. Within these programs, SRS scientists have developed cooperative studies with scientists from the North Central Forest Experiment Station as well as with university, State and industry cooperators in Arkansas, Oklahoma, Missouri, Texas, Louisiana, Mississippi, and elsewhere.

A major effort contributing to this CCT has been the Ozark-Ouachita Highlands Assessment, an interdisciplinary assessment of conditions in the region coordinated by the National Forest System and the SRS.

This assessment will include the most comprehensive assembly to-date of data that relate to terrestrial and aquatic ecology, hydrology, atmospheric, and social sciences in the Interior Highlands. Of special interest to the research community is the potential of the Ozark-Ouachita Highlands Assessment to

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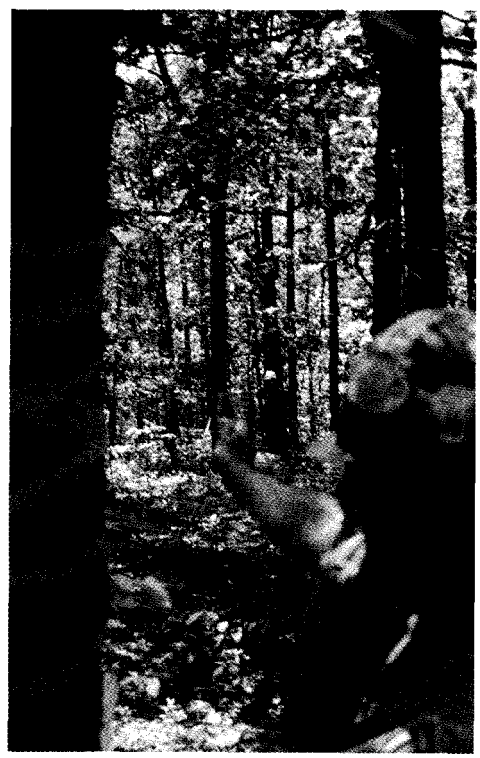
identify prominent gaps in existing knowledge of natural resources in the region, that can be addressed by expansion of existing interdisciplinary research programs.

Progress under this CCT was made in the ongoing measurement and monitoring associated with the Ouachita Mountains Ecosystem Management Research Project-a three-phase comprehensive ecosystem management research and demonstration project in Arkansas and Oklahoma. In FY99, the fifth year of post-treatment data was collected in the 52-stand data base; these data quantify the effects of reproduction cutting alternatives on vegetation, wildlife, arthropods and microbial diversity, logging and economics, visual quality, soils, and water quality. Treatment plans were finalized and implementation of the treatments commenced in the four-watershed landscape study, in which time substitutes for space in large-scale experimental replication of pretreatment conditions. The landscape treatments are being operationally conducted by cooperators in the National Forest System and forest industry. The experimental design, treatment, and monitoring of such broad-scale plot-intensive studies is possible because of cooperation with colleagues in the National Forest System, State agencies, and universities within and near the Interior Highlands. The end of FY99 saw plans in full gear for convening the "Symposium on Ecosystem Management Research in the Ozark and Ouachita Highlands," which is to be held in the first quarter of FYOO. The agenda calls for scientists to present more than 70 papers and posters emphasizing 5-year results



after treatment in the stand-level study, and 5-year baseline conditions in the landscape study, as well as data from other ecosystem management research projects in the Interior Highlands.

Additional studies are in the planning stages to better characterize the vegetation, wildlife, soil, herpetofaunal, and entomological effects of large-scale ecological

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process restoration using prescribed fire on public and private forests; to expand the spectrum of sustainable management alternatives in oak-hickory stands in the Interior Highlands; and to learn more about bat communities in the region.

Key research outcomes accomplished are documented in publications listed in the final section of this report. The publication of research describing landscape patterns of distribution of coarse woody debris in oak-hickory forests

in the Interior Highlands should prove useful in forest health monitoring and in comparisons with other regions. Publication of an even-aged, natural shortleaf pine growth and yield model, and release of the user's guide for the model, gives forest landowners and managers a guide for sustainable management of even-aged stands of shortleaf pine. The model can be used to project stand dynamics under different thinning regimes and also under alternative reproduction cutting methods. The model can be tailored to the specific conditions in a given forest stand. Research was published on the effects of alternative timber harvest activities on southern flying squirrels. The presence of mature forests adjacent to harvested stands, along with retention of unharvested riparian areas, overstory hardwoods, and snags within harvested areas reduced the severity of harvesting impacts on flying squirrels. However, the seed tree regeneration method, particularly where overstory hardwoods were not retained, produces a level of disturbance too severe for flying squirrel persistence. Research results on the quality of residual stands following uneven-aged reproduction cutting in oak-hickory stands in the Boston Mountains of Arkansas provided information on damage that can be expected when alternative reproduction cutting methods are imposed in the region.

Lead contact for the Sustainability and Productivity of the Interior Highlands Ecosystem Cross-Cutting Theme:
RWU SRS-4106 at Monticello, AR.

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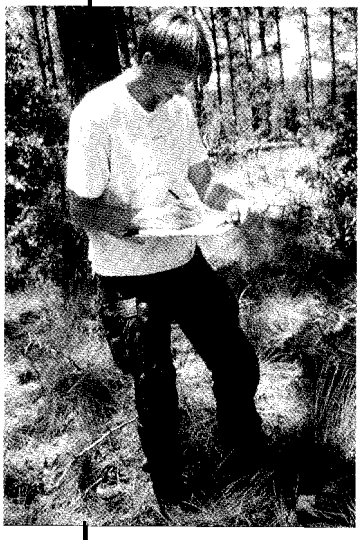
Large Scale Assessment and Modeling

The goal of the Landscape and Regional Integrated (Large-Scale) Assessment and Modeling Cross-Cutting Theme is to understand how biological, climatic, physical, and social sciences operate at large spatial scales under historic, current, and future conditions. Understanding and managing large-scale ecosystems is a complex problem that requires integration of analyses across ecological and social sciences. This integration is fundamental to understanding how these systems might respond to cultural and environmental changes in the future and how policy and management decisions might affect these outcomes. The broad focus of this CCT dictates that the research will cut across and integrate work being done in many disciplines. Developing landscape and regional modeling approaches provides a mechanism for translating field, laboratory, and fine-scale modeling research into a form that has applications to important problems related to large-scale forest ecosystems.



Research under this CCT is contributing to conceptual frameworks for interdisciplinary research to address regional environmental questions in the South. This work is being conducted in two areas. One addresses the issues faced by forest managers by organizing information on forested ecosystems and management responses in decision-support systems. The other, regional assessments, studies social and ecological systems at regional, continental, and global spatial scales and across time scales. The product of this research is improved scientific understanding and a set of assessment models that can be applied to examine regional resource issues.

Decision Support Systems

In the area of decision support, three research efforts have made considerable progress over the past year. An ecosystem management decision-support system has been developed for the Southern Appalachians. The system, named NED, brings together available knowledge on silviculture, wildlife, and water quality to fully inform and aid forest management. In addition to linking forest management to ecological and environmental implications, NED allows managers to design and compare the impacts of alternative management treatments on complex ecosystem management goals.

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Another decision-support system effort is focusing on forest management at a broader scale. A prototype of the decision-support tool, Landscape Evaluation of Effects of Management Activities on Timber and Habitat (LEEMATH), has been completed that simulates timber growth and harvest, and habitat loss and regrowth for birds, reptiles, and amphibians in managed forest landscapes in the Southeastern United States. As an assessment tool of habitat quality at large scales, LEEMATH predicts potential habitat locations and areas of target species for a landscape or region with geographic information system (GIS) data. LEEMATH is being tested with wildlife data from field studies on the properties of the International Paper Company.

A third decision-support system was developed to maintain good water quality at the watershed scale. The GIS Assessment of Transport of Eroded Sediment (GATES) model is based on field research on the Wine Spring Watershed Ecosystem Study in western North Carolina. This GIS-based modeling system predicts where soil erosion will occur within a watershed, given alternative forest management practices. The model is designed to use existing data and to be operated by Forest Service and other land managers, The manager is able to develop alternate management practices, e.g., road construction and harvesting locations and timing, that minimize the amount of soil sediment that moves into a stream. The model is being validated with data collected throughout the Southeastern United States, as well as from collaboration with China that was recently funded by the Forest Service International Program.

Regional Assessment

Several research projects are contributing to our ability to assess historic, current, and future changes in southern forests. This includes work that examines the linkages between social and ecological systems, and linkages between climatic, physical, and biological components of forest ecosystems. Systems for evaluating the impacts of global climate change are being developed at regional and national scales.

In the area of social science, a set of studies has examined factors influencing land-use change in the South at various temporal and spatial scales. The research shows how economic and topographic factors organize patterns of land uses and have led to the development of land-use forecasts. Predictions of land-use changes are being incorporated in national and regional assessments. In the Southern Appalachians, fine-scale land-use forecasts have been used to focus ecological studies along a development gradient and to estimate the long-run ecological implications of land-use changes.

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Large Scale Assessment and Modeling

The SRS also completed a national assessment of recreation supply and demand and continues research on spatially explicit analysis of recreation trends. This research focuses not only on what kind of forest-based recreation is being demanded and where these demands are focused, but also on the broader implications of recreation use for forest ecosystems. These studies provide forest managers with basic data and insights into the recreation and tourism demands on southern forests and highlights where demands may be most intense. In addition, research has investigated the impacts of population growth and dispersion on forest conditions and uses on both private and public lands.

The South now produces twice as much timber as it did in the 1960's and more than 55 percent of all the timber produced in the United States. This has raised concern regarding the sustainability of forests and forestry in the region. To address these concerns, SRS leads a private-public consortium called the Southern Forest Resource Assessment Consortium to improve the assessment of timber supply and inventory in the South. This group, which involves 16 funding entities and 12 universities, has funded more than 25 studies over the past 5 years and continues to develop resource assessment tools for the public and private sectors.

The SRS continues to make progress in developing a modeling framework for evaluating the ecological and social implications of global climate change. This year, SRS scientists developed new techniques for scaling temperatures measured at monitoring sites up to broader spatial scales. Temperature is a key driver of ecosystem processes and is likely to experience increasing variability as a result of global change. Evaluating the potential impacts of an altered atmospheric environment on forested ecosystems requires a combination of predictive tools (models), long-term measurement data, and experimentation. A model was developed to scale air temperatures, a key driver of biological processes such as plant respiration, from small scales to regional scales. This model fills an important knowledge gap for scaling physiologically based hydrology and productivity models from stands and watersheds to regions.

There has been substantial progress in quantifying the role of southern pine forests in sequestering atmospheric carbon dioxide. An analysis of field experimental data indicated that, over 3 years, fertilization resulted in loblolly pine stands being a sink for atmospheric carbon dioxide, compared to unfertilized stands that were sources of atmospheric carbon dioxide. This large shift in carbon

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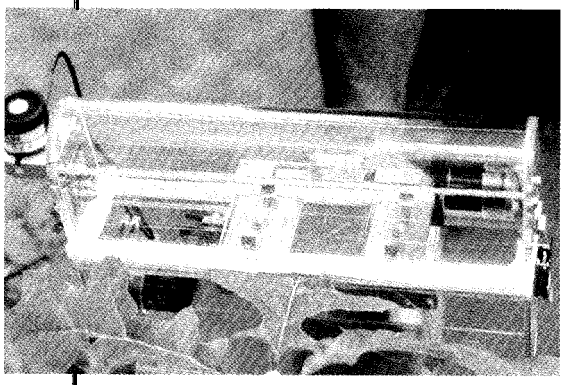
economy was largely due to the higher productivity of fertilized



trees. Elevated carbon dioxide treatments increased photosynthetic rates through the tree canopies with and without fertilization when carbon dioxide was increased by approximately 60 percent. Branch and diameter growth increased by about 20 percent. Work continued to improve our ability to synthesize research results via mathematical modeling. In particular, progress has been made using a simple and effective model called Physiological Processes Predicting Growth (3-PG) in collaboration with Australian scientists. This model has the potential utility for industry as well as for making regional assessments.

The integration of global environmental change effects in regional and national assesments is critical to the development of science-based forest management and policy. In October 1997, the Southern Global Change Program and the Northern Global Change Program began a 5-year National Integrated Ecosystem Modeling Project to better understand how environmental stress influences forest productivity and hydrology across eastern forest ecosystems. Products from this effort are being used to assess regional forest productivity and carbon gain under current and future predicted climate and forest ecoregions. Forest carbon budgets are being developed for the region that will directly contribute to the National Forest Carbon Budget Assessment and research findings are contributing to the U.S. Global Change Research Program National Forest Assessment report to Congress.

Lead contacts for the Landscape and Regional Integrated Assessment and Modeling Cross-Cutting Theme: RWU SRS-4851 at Reseach Triangle Park, NC, and RWU SRS-4852 at Raleigh, NC.

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Inventory and Monitoring

The goal of the Inventory and Monitoring Cross-Cutting Theme (CCT) is to provide current resource information and analysis on forest ecosystem sustainability issues and to improve techniques to inventory, monitor, and evaluate resources. Immediate needs relating to this CCT can be summarized with four key questions:

1. How can strategic inventory and monitoring be implemented to meet timeliness and quality needs across all ownerships of the South?
2. How can social and economic influences be integrated into the strategic inventory and monitoring programs?
3. What are the relevant analytical procedures to address forest ecosystem sustainability questions and what criteria and indicators need to be developed?
4. How can the technology to achieve the necessary inventory and monitoring needs be developed?

In FY99, the Forest Inventory and Analysis Research Work Unit (FIA) hosted several meetings across the South that focused on annual inventories—these were efforts to address the first key question. Several hundred individuals from across the country representing States, universities, industry associations, landowners, and the Forest Service attended. Out of these meetings came the establishment of a Southern Annual Forest Inventory System (SAFIS) Technical Review Committee. This committee met in mid-November 1998 to review SAFIS plans and approaches, and identify future research needs. Another technical review meeting was held in May 1999. With work towards finalization of the national FIA field guide, a meeting was held with State Forester representatives to develop regional additions to the field guide. After development of early drafts, these regional enhancements were mailed out for wide review. Numerous other meetings with clients and collaborators were also held to develop technical and logistic aspects of annual inventories for the South.

Several States are now using their own resources to hire staff for field data collection for the base set of SAFIS plots. During FY99, eight States put an estimated $2,505,000 into the strategic inventory and monitoring program for the South. Funds of $1,170,000 in cost-share dollars were provided by the SRS. In terms of personnel, a total of 91 full-time-equivalents (FTEs) was utilized by the FIA unit with the State Forester organizations contributing another estimated 69 FTEs.

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At the end of FY99, annual inventories were being conducted in five of the eight collaborating States (Georgia, Virginia, Kentucky, Tennessee, and South Carolina), with a final periodic inventory being done in an additional collaborating State (Alabama), and training being conducted for State-employed personnel in the remaining two States (Arkansas and Louisiana). In addition, Federal crews were conducting a periodic inventory in one State (North Carolina).

Nine SRS research work units and the Southern Forest Health Monitoring Program are now identified with the Inventory and Monitoring Cross-Cutting Theme. Initial discussions with representatives from each unit have identified several areas for potential research: recreation supply and demand; tree volume taper function development; economic and ecological models in broad scale assessments; use of FIA plots to develop a southwide data base, linking with other important variables; social/economic impacts on forest sustainability; effects of forestry and environmental laws; and ultrasonic and digital camera technology to assess tree and other resource characteristics.

One important issue that will be the subject of future study deals with the spread of exotic plant species across the South. Exotic plants are a growing threat to native plant and animal species and economically important pine and hardwood trees. The FIA program has recorded the presence and abundance of woody exotic plants as part of past inventories in the Southeastern States, and will continue recording the presence southwide in future inventories. The Southern Global Change Program, in collaboration with FIA, entomologists, and pathologists, is beginning to use past field data to map the distribution and density of exotic plant species across the Southeastern States. This information will be linked with detailed ecological data, such as soils, climate, and native plant communities, to better understand how exotic plants are able to establish and compete with native plants. The goal of this work is to develop management strategies for the control and eradication of exotic plant species.

Future work for the Inventory and Monitoring Cross-Cutting Theme will involve the development of an approach for incorporating all the science issues listed above into a coordinated plan for research.

Lead contact for the Inventory and Monitoring Cross-Cutting Theme: Program Manager for Southern Forest Inventory, Monitoring, and Analysis Program and RWU SRS-4801 at Asheville, NC.

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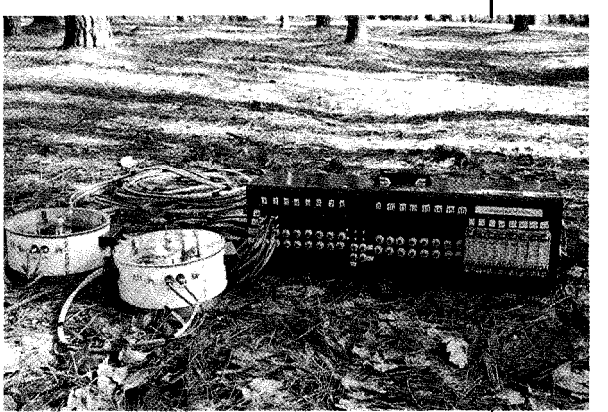
In addition to the work that is related to the individual Cross-Cutting Themes, many studies are continuing under our overall mission that respond to several of the CCTs, to the Natural Resource Agenda, and to meeting other critical information needs. Many result from work that was begun several years, or even decades, before the current Strategic Framework was developed. The following examples show a broad cross section of the technology, information development, and research findings that do not fit just within one CCT.

Sustainable Forest Ecosystem Management

Soil, woody debris, root, and stem respiration measures are essential to understanding ecosystem carbon loss. We are now entering an age where carbon pool management is being legislated and the role soil respiration plays in carbon budgets continues to be refined. The Automated Carbon Efflux System (ACES) is a multiport, dynamic gas sampling system that utilizes an open flow-through design to measure carbon dioxide fluxes from the forest floor or woody tissue with a variety of chamber styles. It is a composite sampling system that switches sequentially through 16 chambers using solenoids; pumps air to and from the sample chamber; measures air flow rates, air and soil temperature in each chamber, and soil moisture; controls the gas analyzer; and records data from all of the output devices. The ACES is fully automatic, requiring only calibration checks twice per week. It provides the following data: time, chamber identification number, molar flow to and from the chamber, and continuous soil moisture reading. Respiration data from the ACES combined with soil moisture and temperature will provide a powerful tool for modeling CO,



efflux from soils. The ACES was designed to be used in remote field locations and runs on DC power. A provisional patent application has been submitted. The ACES will be applied to large-scale, collaborative carbon sequestration research across a variety of sites in the Southeast. The ACES is a tool integral to a newly funded Agenda 2020 project; current collaborators include Virginia Polytechnic Institute and State University, Duke

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University, Auburn University, Brookhaven Labs, Westvaco Corporation, and International Paper Company.

A spreadsheet business plan model and economic evaluator were developed to enhance recovery and high-value uses of pallets at landfills. This has developed into a major effort at landfills to recover wood for reuse and recycling. Recovery is an economical way to reuse pallet materials while reducing the need for trees as a source for new pallets.

New ways to improve the effectiveness of trenches for oak wilt control were examined. Final results for this study indicate that certain water-permeable trench inserts significantly increase the effective longevity of trenches beyond the first 3 years following trench installation. Most disease breakouts from trenches occur during the first 3 years. Biobarrier provided the best defense against trench breakouts due to root transmission of the oak wilt fungus. The epidemiology of potential vectors of the oak wilt fungus in Quercus species is the focus of a study in cooperation with the Texas Forest Service. We are developing probes to test potential insect vectors that may be carrying the oak wilt fungus. We are developing methods to quickly identify the fungi and have 10 species under study.

Recreation

Significant progress was made in understanding public preferences for forest management and ecosystem values. Nonmarket values (estimated using stated preference methods) showed that the public prefers more benign harvest practices on public forest land than on private land, and that an equal mix of areas available for harvesting and protection is preferred on public forest land.

Research assessing the national status and trends in outdoor recreation was completed and published as a book entitled Outdoor Recreation in American Life. This work is the Nation's authoritative source presenting information on trends in current and future supply and demand for outdoor recreation and wilderness. It is being widely used by agency, industry, academic, and nongovernmental organizational interests. Complementary to that recreation work is another book, Integrating Social Sciences with Ecosystem

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Management, that provides insights into the need for and use of social sciences in the management of natural resources including recreation. Other highlights include journal articles on public attitudes regarding wildlife, recreation, ecosystem management, and environmental issues.

Other research includes evaluations of recreation demand for wildland activities focusing on cultural differences for rural participants. The study has found that southern rural blacks and whites differ on nonconsumptive wildland recreation preferences, but are similar regarding consumptive activities like fishing and hunting. A study in Jamaica has demonstrated that ecotourism can be an economically viable method for conserving forests and generating jobs and revenues in a lesser-developed country.

Forest Roads and Watershed Health and Restoration

Unpaved forest roads in the Southern Appalachian Mountains were often located near streams and rivers, thereby contributing storm flow and sediment to the aquatic ecosystem. Practices developed and studied at the Coweeta Hydrologic Laboratory aid landowners and managers in reconstructing these roads to protect water quality. Simple techniques for redesign of storm water drainage structures can provide low-cost alternatives, where the forest floor can absorb and filter runoff from roads. These practices apply not just in the Appalachians, but wherever storms and roads are placing sediment in the stream. Land managers and consultants who assist nonindustrial forest land owners can use the principles for maintenance, reconstruction, or restoration of problem roads.