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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 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 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 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 (Large-Scale) Assessment and Modeling; 6) Inventory and Monitoring. The CCTs incorporate and address national concerns, and position us to be responsive with research direction to study those concerns.

This section highlights many of the accomplishments of our scientists that occurred in FY00 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. We produced nearly 600 publications and other materials in FY00 that are listed in the final section of this report; they are grouped under the most appropriate CCT.

Interest in collaboration in any of the CCTs is encouraged and welcomed. The research work units with the lead contacts for each CCT are listed at the end of the following CCT highlight sections. The research work unit addresses and telephone numbers may be found in Section Four.

The Strategic Framework is on our Web site at: http://www.srs.fs.fed.us/about/framework.htm

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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 driver of the South's economy. In the fall of 2000, we published a booklet describing this CCT's objectives, research questions, and collaborative opportunities. It is on the SRS Web site, at http://www.srs.fs.fed.us/about/PineCCT_book.pdf and is available in hard copy from SRS headquarters in Asheville.

Establishment and Management of Southern Pine Ecosystems

Expansion of southern pine plantation forests has become the best hope of meeting the increasing demand for forest products in the United States. The productivity and sustainability of these forests must be maintained, and increased, if we are to continue to meet society's needs. Restoration of the longleaf pine ecosystem has become a high priority for public land managers in the South. Keys to accomplishing these tasks include improving reforestation efficiencies, increasing early stand development, and maximizing long-term forest productivity.

Southern pine forests play key role in meeting the Nation's demand for wood products.

We continue to expand our knowledge of reforestation-related issues such as improving production of quality seeds and seedlings, particularly for longleaf pine. We can now increase establishment of longleaf pine plantings by using container

stock and applying improved bareroot nursery technology. Understanding pine plantation responses to seasonal burning regimes helps stand establishment and increases the biological diversity in these plantations. Evaluation of seasonal prescribed fire regimes is providing data to the National Forest System on managing longleaf pine forests to achieve restoration of the ecosystem. The results of the seasonal burning programs are being used to manage the Kisatchie National Forest in a way that enhances biological diversity.

Results from long-term soil productivity installations provide guidance for enhancing sustainability of pine plantations by using management practices that minimize nutrient losses, or that use recommended

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fertilization regimes. Other long-term studies are providing a better basic understanding of how plantations can be manipulated to compensate for potential changes in global climate and are the basis for improving predictive models of stand growth and development.

Technology and techniques to evaluate seedling cold hardiness have been transferred to about 15 nurseries. This information is being used to modify seedling lifting schedules with major savings by those nurseries. Guidelines for container production of longleaf pine seedlings are now being used across the South in about 30 nurseries. This technology has dramatically improved plantation establishment of longleaf pine. The data on seed and seedling production of longleaf pine is the basis for expanded reforestation and restoration efforts in the longleaf pine ecosystem. The national nursery consultation effort has resulted in lower nursery production costs and enhanced seedling establishment in Federal, State, and private nurseries.

Information on the ecophysiological effects of management of loblolly pine stands is being presented to teachers through the Temperate Forestry Foundation Summer Education Program. This information has become the basis of modifying teacher plans, and gaining an appreciation of the value of our forests to the nation and region and an understanding of the benefits of management of these forests.

Re-establishment of the Annual Crossett Forestry Field Day

For over 65 years, the Crossett Experimental Forest has served as an outdoor classroom for private landowners, university students, and visiting foresters seeking to learn more about natural stand management, especially selection silviculture. Several of the demonstration stands are among the oldest continuously-active silviculture studies in the nation. The Forestry Field Day was an annual tradition from 1983 to 1996. Scientists and staff presented the 15th Crossett Forestry Field Day on May 3, 2000 with the theme: "Welcome Back to the Crossett Experimental Forest."

Crossett Experimental Forest provides outdoor classroom for small forest property landowners.

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The event featured updates on several long-term demonstration studies, including the Good Farm Forestry Forty, the Reynolds Natural Area, the Block and Strip Clearcut Demonstration, the Stand Rehabilitation Study, and the Competition Control Study. Staff of the Arkansas Land and Farm Development Corporation gave a presentation on opportunities for improving management on minority-owned forestland in the Arkansas Delta.

Since 1983, the 15 Forestry Field Days sponsored by the Monticello/ Crossett research work unit have attracted more than 3,500 foresters and private nonindustrial landowners who are interested in low-cost stand management techniques for perpetuating their forest investments. These techniques demonstrate success in management of native pine forest types using an array of management tactics other than clear-cutting and planting. The study and application of management alternatives is of keen interest to managers of public lands, industry foresters for application to company forestlands in sensitive areas, and nonindustrial private forest landowners who seek a diversity of products and values from small forest properties.

The Field Day attracted visitors from Florida, Georgia, Louisiana, Mississippi, Oklahoma, Texas, and Arkansas. Visitors were able to select reprints of SRS publications, tour historic buildings (including several that are listed on the National Register of Historic Places), and view historic photographs of the Experimental Forest.

Mechanical Treatments for Midstory Reduction

Fire is an important natural element that shapes the structure of many forest types. Periodic natural fires open stands, reduce the numbers of trees, and promote recycling of nutrients in the ecosystem. The exclusion of fire, however, has led to an increasingly dense midstory component of shrubs and young trees. Dense midstories can adversely affect forest health and wildife habitat and increase fire risk. Resource managers attempting to return these stands to a more natural condition need a tool to reduce the midstory component. Mechanical treatments such as cutting or mulching the material are options that can be used to either replace natural fire, or to open stands up for prescribed fire management. Most of the mechanical treatments are adapted from right-of-way clearing equipment with little experience in broad-scale forest management prescriptions. Managers need information to guide the selection and application of mechanical treatments, including productivity and cost information as well as the expected results.

Machines tested for removing dense midstory growth.

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A South-wide study of mechanical treatments was initiated to examine the performance of mechanical treatments in a variety of applications. In New Bern, NC, tests of two types of machines were conducted in the urban interface as an example of fire replacement. On the Kisatchie National Forest in Louisiana, two types of machines were tested for strip thinning of dense pine reproduction as well as midstory removal in mature pine stands. These studies have led to an understanding of site factors that affect the production and cost of these operations. In addition, performance differences were identified that affect the resulting fuel composition. Estimates of production costs are now available for some treatments. The initial findings led to an expanded, continuing examination of midstory reduction treatments. The results of this research will be of value to contractors performing mechanical treatments and to resource managers as they plan for healthier forest ecosystems.

Developing Tools for Precision Forestry

Forest management is becoming more complex as we learn to consider the broader ecosystem in management prescriptions. Managing for wildlife, water quality, soil properties, commodity production, and maintenance of ecological functions requires more information about sites, stands, and the impacts of operations. New technology is available to help acquire and manage detailed information for resource management. An innovative system has been developed to track forest equipment as it operates. Electronic sensors on machines can measure tire slip, tree cutting, travel speeds and many other variables. The information collected in these advanced systems can be used to generate useful information for resource management.

Electronic monitoring of harvesting equipment aids in site remediation.

For example, the resource manager can develop detailed maps of plans for treatments including unit boundaries, restricted areas, locations of landings, and other features. The plan can also detail expected cutting patterns such as density of the residual stand. The electronic system can then monitor the operation, provide real-time direction to

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equipment operators on position and performance, and produce an updated map of the resulting stand after the treatment is complete. The post-treatment mapped information can be used to target site remediation activities such as seeding exposed soil or ripping heavily trafficked areas.

This research project has developed and demonstrated a prototype system which tracks machines and records operational functions. Trafficking maps have been generated from the data and are being evaluated for application in targeted site preparation prescriptions. Summaries of operational data have been created for performance monitoring by the contractors. New technology offers the potential to redefine forest management for the future. This research will define opportunities, costs and benefits, and requirements for further developments.

In Vitro Processes for Pine Host Fusiform Rust Pathogen Challenge Using Single Genotypes of the Fungus Versus Pine Somatic Embryos

The ability to easily produce fusiform rust cultures from single basidiospores and the ability to produce somatic pine embryos over a longer period will permit us to challenge the monogenic somatic embryos in the laboratory to study gene-for-gene interactions in the commercially important pine:fusiform rust pathosystem. We are now able to simply and directly produce cultures of the fusiform rust fungus from single basidiospores as opposed to the common use of several thousand spores to develop a colony of this difficult-to-grow pathogen on laboratory media.

New method to culture fusiform rust fungus expedites genetic investigation.

Because the expression of resistance is a function of the genetics of the host, the genetics of the pathogen, the environment, and their interaction, it is necessary to control these factors under experimental conditions in order to understand the system. The long-term goal is to develop efficient systems for genotyping host resistance loci and pathogen cultures at their complementary avirulence loci. This information will give breeders a way to monitor pathogen avirulence allele frequencies in potential planting areas, and then to select the appropriate families for planting. It will serve as a model for investigating the genetics of other complex, coevolved host:pathogen systems.

Research involves developing and maintaining individual clonal isolates of the fungus with varying levels of pathogenicity, and in challenging individual clones of pines as somatic emblings via tissue culture in vitro, with these fungal isolates in an artificial inoculation system.

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A Proactive Approach to Increasing Below-ground Carbon Sequestration

Below-ground carbon is critical for both nutrient and water cycling. Below-ground carbon typically is of greater quantity than that found above-ground. Soil scientists often assess the impacts of forest management activities on below-ground carbon pools. In 1997, a collaborative study with forest industry was implemented in Washington County, North Carolina in an attempt to proactively increase below-ground carbon pools by incorporating forest slash below-ground as a site preparation treatment. A second study was inititated at Savannah River in 2000.

Increasing soil carbon leads to improved long-term sustainability in forest plantations.

Initial results are positive as both short-term and long-term soil carbon fractions have increased with treatment. Soil carbon has increased while tree growth has been as high, or higher, than traditional site preparation treatments. The experiments will continue to be assessed over time.

This approach may prove useful in proactively increasing below-ground carbon in forest plantations to both increase carbon sequestration and to improve soil quality and thus long-term sustainabilty.

A Bark-shaving Technique to Prevent Rat Snake Predation on Red-cockaded Woodpecker Cavities

Red-cockaded woodpeckers (*Picoides borealis*) nest in living pines in the Southeastern United States. Rat snakes (*Elaphe* spp.) are known to prey on nestlings of this endangered woodpecker. Antipredator behavior exhibited by red-cockaded woodpeckers includes pecking off the loose bark on their cavity trees to create a smooth bole. They also excavate small wounds (termed resin wells) around their cavity entrance that produce a sustained flow of sticky resin that flows down the tree's bole, creating a barrier against rat snakes. In most cases rat snakes cannot climb over the barrier of sticky pine resin because it interferes with the movement of their scales. Rat snakes attempt to climb red-cockaded woodpecker cavity trees significantly more often than other pines in the forest and climbing occurs exclusively during the breeding season, when rat snakes appear to be actively seeking woodpecker nests. Predation attempts are only successful when an inadequate resin barrier is present on the cavity tree.

New method protects red-cockaded woodpecker nestlings.

Researchers at the SRS Wildlife Habitat and Silviculture Lab in Nacogdoches, TX, developed a bark-shaving technique to deter rat snakes from climbing red-cockaded woodpecker trees that is aestheti-

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cally pleasing, more cost effective, and a safer alternative to other snake excluder devices currently available for cavity trees. A drawknife is used to carefully shave the bark in a one meter high band around the circumference to eliminate any furrows or rough surfaces without cutting into the cambium. Shaved barriers should be placed near breast height to facilitate installation, which can be performed by one person in less than five minutes. A very sharp drawknife must be used because a dull knife may pull the bark from the trees, exposing the pine's cambium. When compared to unshaved pines the method was nearly 100 percent effective in preventing rat snakes from climbing, whereas control trees were successfully climbed on every attempt. The bark-shaving technique retains its effectiveness for about 4 months after which tree growth causes an increase in the roughness of the bark, permitting snakes to breach the barrier. The technique is most effective when applied immediately prior to the nesting season so it can protect the nesting effort through the entire woodpecker breeding season.

Reintroduction of red-cockaded woodpeckers generally requires that the birds be placed into a new artificial cavity. Initially, this creates a situation where the woodpeckers are forced to use a roost tree lacking both a smooth bole and a resin barrier for protection from rat snakes. The bark-shaving technique can provide an initial defense against snake predation, and can also be used on nest trees known to have low resin production. The bark-shaving technique developed by the Nacogdoches lab has been incorporated into red-cockaded woodpecker management practices Southwide.

Impacts of Roads and Vehicular Traffic on Snake Populations

The impact of roads on vertebrate species has been primarily investigated for large mammal species. There is a need to assess impacts on other groups of vertebrates. Our research has resulted in significant advances in understanding the impacts of roads and associated vehicular traffic on populations of rare snakes and snake populations in general. Initial research demonstrated that the timber rattlesnake, which is listed by the State as threatened, was most likely eliminated from significant portions of its eastern Texas distribution by road traffic. Similarly, a primary cause of mortality for the Louisiana pine snake, a species under consideration for listing under the Endangered Species Act, was vehicle related. These results motivated a general assessment of the impact of road traffic on snake populations. The preliminary results demonstrate that the impact

Populations of endangered or threatened snake species are adversely affected by roads.

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is very substantial, affecting large portions of the landscape due to the nearly ubiquitous road network. Significant impacts on snake populations in forested habitats were documented for hundreds of yards from road rights-of-way.

These data should allow more detailed assessments of the proportion of landscapes that are ecologically affected by roads, a type of assessment just beginning to be attempted by researchers. These data are being used to make status and management decisions for these species, especially by the USDI Fish and Wildlife Service in the case of the Louisiana pine snake. Results of this research have led to significant modifications of the management of off-road vehicle use on the Angelina National Forest. In addition, the approach taken in this research is being implemented in research currently in progress on the Federally-listed endangered eastern indigo snake. This research should be of interest to conservation biologists, resource managers, agency personnel responsible for regulation of resource issues, and others working to conserve biodiversity and ecosystem functions.

Understanding the Role of Predators in the Population Cycles of Southern Pine Beetle

In economic terms, southern pine beetles are the most significant insect in southern forests. These bark beetles must kill their tree host to reproduce (most pine species are acceptable hosts in an outbreak) and can cause millions of dollars of losses. In 1999 alone it was estimated that southern pine beetles destroyed over $34 million of timber. However, this insect cycles between being incredibly abundant and very damaging and being barely noticeable and colonizing mainly lightning struck trees. Suggested factors which affect these extreme fluctuations in the numbers of beetles have included environment, tree nutrition, and fungal associates and natural enemies of the beetle. However, little has been done to quantify the relative contributions of these factors to southern pine beetle population cycles. In collaboration with the University of Connecticut we have been studying the role of predator beetles that eat southern pine beetles.

Predatory beetles affect population fluctuations of the damaging southern pine beetle.

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It appears that the population fluctuations in the southern pine beetle may be largely due to their interactions with predators. Specifically, mortality of southern pine beetles caused by predation affects their population dynamics in a delayed density dependent manner. In other words, predation by a natural enemy is a factor that significantly contributes to the fluctuations we see in southern pine beetle populations. This knowledge may help us devise biological control strategies and may help us create computer models that can predict when and where southern pine beetles will become epidemic next.

When models are developed, forest managers will benefit by being better able to predict when they will need to plan for southern pine beetle activity. The scientific community will benefit from a better understanding of the ecology and biology of this complex system, as well as from insights into the way in which insects interact with their natural enemies. The public will benefit from new, safer control methods for protecting their trees.

Longleaf Pine Characteristics Influence Prey Available for Red-cockaded Woodpeckers

The red-cockaded woodpecker is an endangered species occurring throughout the Southern United States where it is most often found in association with longleaf pine. Longleaf pine forests have declined from an estimated 24 million hectares to less than 1.3 million hectares today. This loss of habitat is thought to be one of the major reasons for the woodpecker's decline. The majority of the remaining woodpeckers occur on national forests and these forests are expected to support 80 percent of the woodpeckers in the future. Because of this dependence on national forests it is important that we understand what the woodpeckers need and how stand conditions and management practices might affect the species and the arthropods (insects, spiders, centipedes, etc.) they depend on for food.

The red-cockaded woodpecker spends most of its time looking for food on the boles of living pine trees. We conducted a study to see how tree characteristics (age, diameter, bark thickness) and stand conditions (tree density, site quality, and understory plant community) affected the numbers and biomass in dried weight of arthropods that crawl onto trees where they are available as food for the woodpeckers.

Food availability for woodpeckers correlates with tree size.

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We looked at over 50,000 arthropods in 470 genera. The results show that the number and biomass of arthropods increased with increasing tree age up to about 65-70 years. After that arthropod biomass changed little on 70-90 year old trees. Arthropod biomass was correlated with bark thickness and tree diameter in a similar way. However, when we estimated the biomass of arthropods in stands of trees, we found that stands of younger trees had more biomass per hectare than stands of older trees. We did not see relationships of arthropod biomass with the quality of the sites or the condition of the understory plant community.

These results show old trees (more than 70 years old) do not have more arthropods crawling onto them and available for red-cockaded woodpeckers, and that the understory plant community is not critical in supporting arthropods that crawl onto tree boles. In addition, since arthropod biomass on trees was correlated with tree diameter and bark thickness, land managers might be able to provide optimum foraging habitat for red-cockaded woodpeckers sooner than 65-70 years by growing trees faster. These results should benefit public and private land managers charged with managing and improving habitat for this endangered woodpecker.

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 setting similar to wetlands. Sustainable management of these forests, a majority of which are in private hands, provides research challenges addressed by SRS scientists. Our work in the Ecology and Management of Forested Wetlands, Bottomland Hardwoods, and Riparian Zones Cross-Cutting Theme investigates 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.

A workshop, "Research on Wetlands, Bottomland Hardwoods, and Riparian Areas in the Southern United States: Status and Frontiers" was held in conjunction with the Association for Southeastern Biologists in April in Chattanooga, TN. The workshop was a forum to help plan future research priorities for this CCT. Panelists representing the following interests and disciplines presented their view of research needs: silviculture, biodiversity, restoration, riparian area management, water quality, and noncommodity interests.

Contrasting Nutrient Dynamics in Two Bottomland Hardwood Ecosystems

Mainly due to a difference in watershed size, brownwater rivers, blackwater rivers, and low-order streams carry very different sediment and nutrient loads. To date, comparisons have been made between the former two stream types, but nowhere have nutrient dynamics in floodplains of blackwater rivers and low order streams been compared. We hypothesized that the floodplain forests of these systems would differ markedly in both their nutrient capital and the way nutrients were cycled. To test this, net primary productivity (NPP) and nutrient dynamics were contrasted in four forest community types along flooding gradients in each of two neighboring blackwater and low-order streams.

Understanding nutrient cycling difference in ecosystem types will improve restoration efforts.

The blackwater site proved to be nutrient rich, nutrient balanced, and productive, and the low-order stream quite nutrient poor, nutrient imbalanced, and unproductive. Given the greater and more balanced

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nutrient availability and relatively high NPP on the blackwater site, we hypothesized that NPP on the low-order site would respond to microsite fertilization with nitrogen (N), because, based on soil N mineralization and foliar analyses, N was determined to be the most deficient nutrient on that site. To test whether nitrogen or other nutrients might limit NPP at either study site, an experiment employing soil cores fertilized with calcium (Ca), potassium (K), phosphorus (P), or N, was used to assay ecosystem response to nutrient rich microsites.

Although N was highly available on the blackwater site, NPP on that site responded more dramatically to enhanced microsite N availability than any other nutrient. Also, the N-response on the blackwater site was substantially greater than that on the nutrient-poor low-order site. These results suggest that 1) N limited NPP more than Ca, K, or P on the blackwater site, 2) forests on the blackwater site are more vigorous and thus better able to respond to nutrient-rich microsites than those in the nutrient-poor floodplain of the low-order stream, 3) N assimilation and NPP at the nutrient poor site may not be limited by N availability, and 4) external (to the trees) nutrient cycling is more important at the blackwater site than at the low-order stream site, suggesting turnover of both nutrients and biomass is greater and more rapid on more fertile bottomland hardwood sites.

This work is fundamental to sustainable management of bottomland hardwood forests in the Southeastern United States. It also provides a critical foundation for wetland restoration programs. Without reference wetland systems, there is little basis for knowing how effective the restoration effort has been.

Restoration of a Severely Impacted Riparian Wetland System

The Savannah River Swamp is a 3020 hectare (ha) forested wetland on the floodplain of the Savannah River at the Department of Energy's site near Aiken, SC. Historically the swamp consisted of approximately 50 percent bald cypress-water tupelo stands, 40 percent mixed bottomland hardwood stands, and 10 percent shrub, marsh, and open water. Major impacts to the swamp hydrology and vegetation occurred with the completion of nuclear production reactors at the site in the early 1950s. Water was pumped from the Savannah River, through secondary heat exchangers of the reactors, and discharged into tributary streams that flowed into the swamp. From 1954 to 1988, high temperature effluents in excess of 65 ˚C were discharged into one of the tributaries, Pen Branch, at rates often 20 to 40 times greater than normal flow. The sustained increases in water volume resulted in overflow

Success in restoring part of DOE Savannah River site provides valuable information for future wetland restoration.

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of the stream banks, erosion of the original stream corridor, and deposition of a deep silt layer in a newly formed river delta. The nearly continuous flooding of the swamp,

the thermal load of the water, and the heavy silting resulted in complete mortality of the original vegetation in large areas of the floodplain.

Once the pumping was reduced, natural reestablishment of herb, grass, and shrub species occurred in the affected areas; however, few volunteer seedlings of bottomland hardwoods or bald cypress were evident. Given these circumstances, a research program was established by the Savannah River Institute, in cooperation with the Westinghouse Savannah River Technology Center and the SRS Center for Forested Wetlands Research to determine methods for reintroducing forested wetland tree species into this drastically disturbed area. From 1993 to 1995, the Forest Service planted approximately 75 percent of the affected Pen Branch floodplain area in desirable bottomland hardwood tree species, while the remaining area (25 percent) was kept unplanted for experimental purposes. Three restoration strategies were formulated to address the differing conditions of the impacted floodplain. Approximately 8700 seedlings were planted in the lower corridor (15 ha) without any site preparation. The upper corridor (24 ha) was planted after the application of a wetland-approved herbicide and a prescribed burn. The delta (12 ha) was planted after herbicide application in the absence of burning. Herbicide application and prescribed burning were performed to control a dense black willow overstory and to clear brush and vines from the planting area. Tree species included in the plantings were overcup oak, swamp chestnut oak, nuttall oak, willow oak, cherry bark oak, water hickory, persimmon, green ash, sycamore, swamp black gum, water tupelo, and bald cypress.

The research program developed was intended not only to answer questions pertaining to vegetation reestablishment, but also to document ecosystem response and to evaluate whether or not the restored system is following a path toward recovery. The impact of disturbance and its effect on restoration and ecosystem health were evaluated through studies that examined the following parameters: stream hydrology, seedling survival and competition, aquatic insect community dynamics, fish ecology and

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stream habitat, organic matter decomposition and nutrient transport, and animal community distribution. In most of these studies, measurements were made in both the restored system and in one or more minimally disturbed reference systems, and/or control systems, which experienced a thermal impact similar to that of Pen Branch, but were hydrologically restored at an earlier date.

Tree seedling studies indicated that many site preparation techniques (burning, herbicides, thinning) did not significantly impact growth and/or survival. However, tree shelters and root pruning were effective silvicultural techniques that enhanced survivability in areas prone to stress from herbivory and competition. A seedling survey performed in 1997 showed that water tupelo, green ash, sycamore, and persimmon had the highest percent survival in the upper corridor, while bald cypress exhibited the best survival in the wetter lower corridor and delta areas. The restored floodplain contained many of the functional capabilities exhibited by an undisturbed wetland with respect to animal life, however certain species were dominant in Pen Branch when compared to later successional wetlands. Fish populations, for instance, exhibited a higher density in Pen Branch compared to that observed in the undisturbed reference wetlands. Preliminary results also indicated that density of insects in Pen Branch was significantly higher than those observed in reference systems. Results from terrestrial vertebrate studies indicated that birds, small mammal, reptile, and amphibian communities are well established in Pen Branch. For some animal communities, it appears that Pen Branch is providing a greater opportunity for establishment and survival than the later successional systems. Although species abundance and in some cases diversity are higher in Pen Branch than in the reference systems, structural differences with respect to animal communities and key energy sources such as soil carbon and nutrients revealed that the Pen Branch floodplain remains an immature, early successional system, but it is moving toward recovery.

Information from the above studies is being utilized to develop a quantitative assessment method for evaluating riparian wetland restoration success. It is evident from the research that Pen Branch is currently functioning as a viable wetland. The

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degree of function and level of recovery, however, is subject to debate. By utilizing biotic and abiotic metrics obtained from research in hydrology, soils, vegetation, carbon and nutrient cycling, and animal communities, predictions of wetland function in response to the restoration activity can be ascertained. As succession proceeds and research continues in the restored and the relatively unimpacted reference sites, information is being accumulated to validate our predictions and further contribute to the development of our assessment procedure. As a consequence, these efforts will serve as a template for future wetland restorations.

Ecology and Reproductive Biology of Pondberry

Pondberry (*Lindera melissifolia* [Walt] Blume) is an endangered shrub of the Southern United States that grows in seasonally flooded wetlands and on the edges of sinks and ponds. Thirty-six populations are known in several Southern States. Many of the existing pondberry colonies are small and occupy only a portion of the apparently suitable habitat. The species has been affected by habitat destruction and alteration, especially timber harvest, clearing of land, and drainage or flooding of wetlands. In addition stem dieback is a problem and sexual reproduction is sparse in some populations.

Endangered shrub may recover with human intervention.

Pondberry is a shrub that grows to a maximum of 2 meters in height with small yellow flowers that bloom in spring. Pondberry has always been a rare species, and knowledge of its ecology and reproductive biology is lacking. Male plants outnumber females by a ratio of 7:1; female clones are smaller than male clones, and are often absent from stands. Seed production is erratic, and as in many other clonal species, few seedlings occur even when seed production is high.

We have studied pondberry populations in Mississippi and Arkansas and visited populations in several other States. The most vigorous pondberry populations we observed occurred in locations with abundant light. Stem dieback appears to be widespread in populations. We have isolated three fungal pathogens from stems. Six insect species were found in association with pondberry, but do not appear to be limiting factors for the plant.

The hydrology of the pondberry habitat has changed, so areas that were suitable in the past are now less than ideal and some populations are not thriving. However, potted plants in the greenhouse are flourishing, indicating that the plant grows well under the proper conditions. Many populations occur in small wooded areas that have not been cut and planted with crops only because they are slightly

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lower in elevation than the surrounding agricultural land, thus the plant's ability to spread or to migrate to more favorable habitats is limited. Because of the conditions in which it occurs, the survival of this species may depend on human intervention.

Work to establish new populations in protected locations across the species' range should bring about its downgrade from endangered species to threatened and eventually lead to delisting as a threatened species.

Recalcitrant Seeds

The majority of seeds from temperate forest species can be dried to a moisture content of less than 12 percent without damage. Seeds that are sensitive to drying are called recalcitrant seed. Sensitivity to drying makes it difficult to store seed for any useful period. Examples of recalcitrant seeds include many tropical species and acorns of commercially important oaks. Their incapacity for long-term storage presents many problems in producing seedlings for afforestation and reforestation, and for conservation of genetic diversity. If we can determine the causes of the loss of seed viability during drying, we may be able to devise treatments or storage conditions that counteract recalcitrant behavior. Successful storage of seed from species such as the oaks would allow collection during years of heavy seed production (mast years), providing for adequate supplies of seed in other years.

The physiological basis of recalcitrant behavior is not fully understood. One possibility is that recalcitrant seed behavior is based on aberrant metabolism of the seed as water is lost during storage. The role played by carbohydrates such as sucrose in this process is complex, and results reported in the literature are conflicting. The result of an experiment examining the carbohydrates in acorns showed a significant increase in sucrose content of white oak *(Quercus alba)* acorns as seeds slowly desiccated for 9 days. However, we could not be certain whether the increase in sucrose content was due to the drying process, or to the initiation of germination.

We conducted further experiments and found that the drying acorns had higher levels of sucrose than the wet acorns in both the embryo and cotyledon tissue throughout the 9-day experiment. Sucrose contents of the cotyledon and embryo tissue were initially much the same but as the experiment progressed, the

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sucrose content of the embryo tissue became significantly greater than that of the cotyledon tissue in both the wet and dry acorns. The results show a clear effect of desiccation on the sucrose levels in embryos and cotyledons of white oak acorns. The overall higher sucrose contents in dry acorns indicate that this is not due to germination alone. Even as the embryos developed, the drop in sucrose in dry acorns was less than that in wet acorns. A surge in sucrose levels in day 7 dry embryos was more than twice that in wet embryos, suggesting that sucrose transported to the embryo is no longer being used for growth and development but may be preventing cellular collapse as moisture stress increases.

Successful storage of sensitive seeds will broaden opportunities for planting of important species.

Further evidence supporting sucrose as a "glycoprotectant" is found in electron micrographs of desiccating tissues of white oak acorns. Despite the stress imposed by falling moisture contents, cell membranes of white oak tissues remain intact. In contrast, water oak (*Q. nigra)* seeds have a high lipid content and little fluctuation in the cotyledon carbohydrate content during desiccation. In these acorns, membranes may be damaged after only 3 days of drying.

Importing sucrose to the drying embryos of white oak may begin as a germination response, but the continued increase suggests a protective mechanism. Since no evidence of membrane damage was found in the acorn tissues, the combination of high sucrose and a fairly high axis moisture content (26 percent after 10 days) may protect cell membranes; but the mechanism is obviously not successful in preserving viability, which drops rapidly after day 5. Thus while membranes are kept intact in desiccating seeds, perhaps by the protective increase in sucrose content, some as-yet undiscovered metabolic failure must be responsible for the recalcitrant nature of white oak acorns.

This information puts us one step closer to determining the causes of deterioration in recalcitrant seeds. Ultimately, this information will be of great benefit to seed companies and nursery operators who at this time have to rely on current-year seed crops from species that produce recalcitrant seeds.

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The Iatt Creek Ecosystem Study

In the Southern United States, forested wetlands occupy less than half their original 12.5 million acres. To manage, maintain, or restore ecosystems, the initial need is to identify important functions that characterize undisturbed or stable communities or landscapes. The 320-ha Iatt Creek Study area, located on the Kisatchie National Forest in central Louisiana, occupies a segment of a braided stream bottom dominated by Iatt Creek. The 195 km^2 upstream watershed, typical of the Coastal Plain, is primarily forest and pasture. The study area varies in width from 550 to 1000 m with an overall length of 5000 m and is occupied by a mature sweetgum (*Liquidambar styraciflua*) and sweetgum-cherrybark oak (*Quercus falcata* var. *pagodaefolia*) overstory forest. The initial objective of the study was to quantify the physical, chemical, and biological functions of a mature bottomland forest community. We located our study in a minor alluvial bottom to represent the 60 percent of the remaining bottomland forest acreage in this bottomland type.

Initial analyses have shown the forest is mature (66 to 75 years old), tall (33 m), multi-sized, and dominated by large diameter sweetgum, cherrybark oak, and water oak (*Quercus nigra*). Basal area averages 35 m^2 per hectare, with some 73 species appearing in the woody vegetation layers and an additional 80 species in the herbaceous layer. Aboveground net primary productivity averages approximately 14,100 kg/ha/yr, placing the study area among the highest reported for Southeast wetland forests. As expected in a mature forest, approximately 70 percent of net primary productivity is in litterfall (predominantly leaf and branch).

Decomposition studies have shown that the decay and nutrient turnover of fine litterfall is very rapid, suggesting a close linkage between the detrital pathways and plant growth. Evaluation of nutrient and carbon storage within the study area is ongoing.

Increased understanding of a mature bottomland forest will enhance sustainable management.

Repeated winter and summer avian counts have revealed more than 75 bird species. Of these species, 23 were neotropical migrants and 17 were north temperate or short distance migrants. Use of the bottom by nesting and migrating wood ducks is common.

Flooding regime, soils, fluvial geomorphology, and landscape environment of minor bottomlands vary

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dramatically from major bottomlands and from deepwater cypress swamps. The mature minor bottom hardwood forest is a botanically very diverse community that is responsive to site characteristics and reflective of the turn of the century harvesting that led to its development. The mature forest is changing in species composition due to mortality and plant recruitment associated with canopy gap formation. The area supports a biologically very productive mature plant community with much of its net primary productivity associated with leaf production rather than wood or stem production. Leaf production is indicative of the high leaf area, multilayered canopy, that the mesic bottomland supports and illustrates the important role that litter decomposition must play in the rapid return of nutrients to the soil for continued sustained production.

This study has demonstrated that bottomland hardwood forests differ significantly in the levels of functions, between minor and major bottoms, that together differ significantly from deepwater swamps. These results highlight how these minor bottomland systems differ substantially from popular conceptions of forested wetland functions, which are taken largely from research on deepwater swamps. This enhanced understanding of forested wetland functions will aid in managing these systems, identifying feasible and relevant goals for wetland restoration activities, and specifying criteria and indicators of sustainable management.

The intent of this research was to better understand how a mature bottomland forest in a minor bottom setting functions. The results reveal a very diverse, highly productive, nutritionally dynamic, and plant compositionally varied ecosystem that is changing in space and time. To maintain the ecosystem and ecosystem functions while managing a minor bottomland for multiple uses will be exciting and challenging. Beneficiaries of this research include forest managers, regulatory agencies, and interested nongovernment organizations. Ultimately, the public benefits from sustainable management of this important resource.

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 decisionmaking.

Collaborative Work Continues on Decisionmaking Support Software

Recent events have increased the pressure on forest managers to make ecologically sustainable, socially acceptable, and economically feasible decisions. Managers are expected to predict short- and long-term effects of implementing different alternatives. The scope and complexity required to support decisions which directly affect ecosystem management is extensive. Although a large body of scientific knowledge exists on relations between forest structure and pattern and ecosystem attributes, this information is spotty, widely scattered in technical journals, and frequently difficult to interpret and apply. Furthermore, the incorporation of stakeholders' knowledge and goals, the adoption of a "soft" science approach and the integration of social disciplines, theories, and measurement techniques is a significant challenge to many traditionally trained resource managers. One of today's greatest scientific challenges is the development and testing of new theories and tools that describe the multiple ramifications of management decisions and that provide a practical, understandable decision process. Developing, evaluating, and adapting new decision processes and their supporting software tools is a critically important endeavor.

NED decision analysis process receives award for continued development and application.

To meet these needs, scientists from the Northeastern and Southern Research Stations have been cooperating since 1992 to design, construct, and test NED, an ecosystem management decision support system. The objectives of NED are to develop and test 1) an operationally practical decision

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analysis process and 2) the necessary decision support tools for conducting ecosystem management. The adoption and use of efficient and affordable decision processes and their supporting software tools would represent significant progress in ecosystem management. Forest managers and interested stakeholders can have 1) a transparent, clear, and understandable process, that 2) provides logical and concise results, where 3) choices are explicit and open to examination, and 4) limits on time, expertise, and money are expressly accommodated. The NED decision analysis process and software tools can provide research scientists with a vehicle to synthesize and deliver biological and socioeconomic knowledge in a useable format. NED can provide managers with a powerful, yet understandable, decision support tool to help them cope with the biological and political complexity inherent in their job. The completion of the first version of NED in 1999 was impressive enough to result in winning a $325,000 award from the USDA National Research Initiative in their year 2000 competitive grants cycle. This award is meant to help fund the next generation of NED software and to perform numerous case studies for real clients in real-world forest management situations.

Forest Inventory and Analysis Data Used to Develop New Analysis Tools

The Forest Inventory and Analysis database (FIA) represents a significant outlay of taxpayers money, so new applications and uses of these data represent efficiency. The Southern Appalachian CCT has included working cooperatively with the Growth and Yield Group at the USDA Forest Service Forest Management Service Center in Fort Collins to use the FIA database to develop a regional prototype of a general tree growth simulator. This computer-based simulator will be used by the National Forest System as the primary source of growth data in the development of forest plans and for the implementation of project-level and NEPA-level planning analyses. A comprehensive accuracy test of the prototype is in progress, involving the performance of individual model components, such as the mortality, diameter growth, and height growth constructs. The species list and growth information from FIA plots is being used to develop a species-list-driven method of classifying lands into productivity classes. This will provide an easier-to-use method based on measured tree heights and stand age. Another new application of these FIA data involves populating geographic

FIA data use enhances Southern Appalachian cross-cutting theme

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information system (GIS) databases with plausible estimates of diameter distributions for delineated stands GIS data layers that do not contain FIA sample plots. The idea is to use extensive GIS databases that are either already available or are inexpensive to develop which contain variables that serve as linkages to the information in the detail-rich FIA database. A major component of this research is to find a way to use remotely sensed data as a surrogate for mean size of trees in a stand. This stand mean tree size surrogate will serve as a strong linkage variable to the measured diameter distribution data in the FIA database.

Roost Site Selection by the Indiana Bat in the Southern Appalachians

Conservationists and wildlife biologists have grown increasingly concerned over the status of forest bats in the United States and worldwide. Almost half of the 18 species of bats that inhabit Eastern United States forests are considered to be threatened, endangered, or sensitive. The status of many other species is simply not known. The Indiana bat, *Myotis sodalis*, is one of the species that is of the greatest immediate concern. Indiana bats were listed as an endangered species by the USDI Fish and Wildlife Service in 1967. The major cause of their decline was thought to be disturbance and destruction of their winter hibernation sites. Therefore, caves and mines used by Indiana bats in winter have been protected from human disturbance. However, despite this protection, Indiana bat populations have declined from 808,000 in 1960 to 353,000 in 1995-97. This substantial decline suggests that factors other than disturbance to the hibernacula are responsible for the decline. Therefore, research and conservation efforts have turned to summer maternity habitat as a possible limiting factor.

New information about maternity roost trees will lead to models to predict potentially suitable sites for Indiana bats.

Female Indiana bats form small maternity colonies of 10-20 individuals during late spring and summer. Colonies are usually located between the bark and the bole of snags or trees with a lot of exfoliating bark (e.g., white oaks and shagbark hickories). Until recently, no maternity colonies had been found south of Kentucky. However, in 1999, a maternity colony was located on the Nantahala National Forest in western North Carolina. This provided us with the opportunity to learn more about roost site requirements of Indiana bats and to determine potential habitat factors that may be limiting their populations. We initiated a cooperative study in the summer of 2000 to determine the factors that

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contribute to maternity roost site selection at the tree, stand, and landscape levels.

Researchers from Tennessee Technological University captured three adult female, one juvenile male, and one adult male Indiana bats in July 2000 in Great Smoky Mountains National Park in eastern Tennessee. Tiny (0.5g) radio-transmitters were glued to the backs of the bats and they were located in their roost sites over the following 5-8 days. We obtained habitat data from the six roost trees that were found by researchers in 2000 and the maternity roost tree on the Nantahala National Forest in 1999. Before this study, maternity roosts have only been found in hardwoods, primarily ash, oaks, and hickories. In contrast, the maternity roost on the Nantahala National Forest was in a hemlock snag and 3 of the 6 maternity roosts found in or near Great Smoky Mountains National Park were in pine snags. This suggests that the Indiana bat may be able to utilize a wider range of roost tree types than previously thought.

Data on the habitat immediately surrounding each roost tree, the stands in which each tree was located, and the landscape surrounding each of the stands will be used to develop habitat models of Indiana bat roost site selection in the Southern Appalachians. These models will help scientists isolate important habitat features that are associated with Indiana bat maternity roost selection and aid the National Forest System, National Park Service, and managers of other public and private lands to develop appropriate habitat management strategies for Indiana bats. The models can be applied across the landscape to predict other potentially suitable sites. Managers and scientists will thus be able to use these models to select the best sites for searching for new colonies.

Using Trees to Clean Polluted Groundwater

Groundwater pollution is a major problem in many areas of the United States and conventional clean-up methods, such as pumping and treating groundwater, are costly. Researchers at the Coweeta Hydrologic Laboratory in North Carolina are engaged in a collaborative project with the Department of Defense, the U.S. Geological Survey, and the Environmental Protection Agency to evaluate the use of trees to accumulate and metabolize pollutants in shallow groundwater in Texas, Florida, Colorado, and South Carolina. To be an effective tool, vegetation must transpire a substantial quantity of water from the primary location of the pollutant plume (such as the soil horizon and/or groundwater). Coweeta's role in the project is to quantify transpiration in young poplar plantations as well as native vegetation, and to develop and apply physiologically based models to predict future stand level transpiration rates. In the first phase of study, transpiration was

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measured using sapflow collars and sapflow probes. In addition, leaf level water relations were measured to determine sensitivity to climatic and seasonal variation. Results showed that in the first year after planting, poplar plantations in central Texas transpired approximately 25 cm, which is equal to about one-third to one-half the amount of transpiration for mature hardwood forests in other regions of North America. Model projections indicate that the stand will transpire and metabolize enough water in future years to be an effective phytoremediation tool. Because of the importance of transpiration in evaluating the efficacy of using phytoremediation, these estimates and the methods developed to quantify transpiration represent a major advance in phytoremediation technology. Coweeta has developed modeling and measurement tools to be used by the Environmental Protection Agency (EPA), Department of Defense (DOD), and other resource managers evaluating site clean-up alternatives. Where phytoremediation is applicable, a significant cost savings will be realized compared to conventional methods. Because of the importance of this work, a Coweeta scientist was invited to the EPA "State-of-the Science" Conference on Phytoremediation to share research results.

Poplar stands are expected to be an effective "phytoremediation" tool.

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

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. The Sustainability and Productivity of the Interior Highlands Ecosystem Cross-Cutting Theme 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.

Prediction Systems for the Growth of Shortleaf Pine in the Interior Highlands

Shortleaf pine is the premier species of the Interior Highlands, yet our knowledge of the growth and development of shortleaf pine lags far behind the other southern pine species. Predicting future stand conditions is an important element of land-resource management, and a long-term goal has been to develop systems for projecting the development of shortleaf pine stands. Two papers published this fiscal year consolidate the information contained in earlier works into functional prediction systems for shortleaf pine growth in even- and uneven-aged stands.

Before the current effort, predicting the development of shortleaf pine was very restrictive, and management alternatives were difficult to compare. For example, thinning regimes were fixed to the specific levels and intervals tested by the research. However, the development of the new prediction systems allows a high degree of flexibility because they are based on the behavior of individual trees rather than a group or population of trees. In the new systems, a tree's growth is predicted from a number of stand and site features that are provided by the user. In addition, the chances of tree mortality are also predicted. In this approach, the individual trees making up a stand are 'grown' through time.

Predicting future stand conditions will be both more accurate and more flexible.

The prediction systems presented in the FY00 publications make predicting future stand conditions both more accurate and more flexible.

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They allow managers to make wise choices among different management systems, different rotation lengths, and different silvicultural treatments, such as thinning interval and intensity. Managers of the shortleaf pine resource will benefit from the developed prediction systems. It will make their jobs easier because they will have greater flexibility in testing management alternatives.

Release of the Ozark-Ouachita Highlands Assessment

The Southern Research Station played a key role in the writing, editing, and publication of the Ozark-Ouachita Highlands Assessment. Over two years in preparation, the assessment pulls together information on terrestrial vegetation and wildlife, air quality, aquatic conditions, and social and economic conditions in the assessment area of Missouri, Arkansas and Oklahoma. SRS scientists in Arkansas provided lead authorship for two chapters in the terrestrial vegetation and wildlife report: Chapter 3, Status and Trends of Vegetation, and Chapter 4, Silvicultural Practices.

Assessment provides valuable reference document for planners and managers of public and private forest lands.

The assessment did not develop new information in and of itself. Instead, the assessment represents a compilation and summary of data from hundreds of sources, and places those data in a single five-volume set. It reports a wealth of information about conditions in the Ozark and Ouachita Mountains, and the relationship of national forest lands within the context of the forested land base across the assessment area.

One primary use of the assessment will be to assist national forest managers and planners with the process of revising the forest plans on the Ouachita, Ozark-St. Francis, and Mark Twain National Forests—which together have accounted for roughly 10 percent of the timber harvest from public lands over the past few years. However, the data contained in the assessment can be used by State, county, and municipal governments, by forest industry and other industries that rely on natural resources, by nongovernment organizations interested in forest resources and values, and nonindustrial private forest landowners. The assessment is a reference document that will be of significant value to scientists, planners, and managers of public and private forestlands, and the public.

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Symposium on Ecosystem Management Research in the Ouachita and Ozark Mountains

The 1999 Symposium on Ecosystem Management Research in the Ouachita and Ozark Highlands was held October 26-28, 1999 in Hot Springs AR. Mr. F. Dale Robertson, retired Forest Service Chief, presented the keynote address entitled "A history of ecosystem management research in the USDA Forest Service." Seventy other papers and posters were presented at the Symposium. The meeting concluded with a field tour of ecosystem management research stands.

Latest scientific information on a diversity of forest management practices presented.

Information was presented in three major lines of research. In the stand-level Phase II research line, papers and posters were offered in the context of post-treatment results five years after treatments were imposed for overstory vegetation, understory vegetation, wildlife, soil and water quality, logging and economics, visual quality, and arthropods and microbial diversity. In the landscape-scale Phase III research line, papers and posters were offered based on 5 years of baseline pre-treatment data collection with respect to vegetation, wildlife, aquatic ecology, hydrology, and social sciences. In the category of related Interior Highlands research, papers and posters were offered on Missouri ecosystem projects, the Ozark-Ouachita Highlands Assessment, and the National Forest Communities Project.

Papers presented during the Symposium offered participants a look at the latest scientific information available on the effects of a diversity of forest management practices on a host of resources and values. The greatest value will be achieved with the release of the Symposium proceedings.

Bird and Small Mammal Responses to Alternative Pine Regeneration Methods in the Ouachita Mountains of Arkansas

Research underway on the Ouachita and Ozark National Forests in Arkansas and Oklahoma is providing forest managers with a wealth of information on responses of various forest resources (timber, water, wildlife, etc.) to alternative pine regeneration systems. As one component of this long-term, multidisciplinary research and demonstration initiative, SRS and university scientists monitored responses of forest birds and small mammals to two even-aged (clearcut/plant and

Initial data suggest that harvested stands have increased numbers of small mammals and birds over unharvested stands.

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shelterwood) and two uneven-aged (single-tree and group selection) regeneration systems. Spring songbird and winter small mammal communities and a diversity of wildlife habitat features (e.g., acorn and fruit availability) were studied in four 35- to 40-acre stands of each of these treatments plus four untreated, late-rotation (60 + year old) reference stands. These 20 stands were located randomly over the Ouachita National Forest in eastern Oklahoma and west-central Arkansas and the southern-most district of the Ozark/St. Francis National Forest. All study areas are located predominantly on southerly aspects, as these are the sites from which most of the timber is harvested on these national forests. Two years of data were collected before stand harvesting during the summer of 1993. All preharvest data from this research were summarized in a 1994 Forest Service General Technical Report (GTR-SO-112). Findings for the first 5 post-harvest years, which were presented at an October 1999 symposium, will be published as an SRS GTR.

Because all stands were largely even-aged at study initiation, single-tree and group selection stands are in transition to an uneven-aged stand structure having three or more pine age classes; before they attain this structure, these stands must be thinned additional times and obtain satisfactory pine regeneration and survival. Consequently, it is too early to draw definitive conclusions regarding comparative advantages of even- and uneven-aged systems for birds and small mammals. However, initial data suggest that early-transition single-tree and group selection stands should have similar bird and small mammal abundance, species richness, and diversity as clearcut and shelterwood even-aged stands. Harvested stands had higher bird abundance, richness, and diversity than untreated stands within years, and these measures increased each year after harvest. Small mammal numbers were highest after the first post-harvest growing season, declined markedly in subsequent years, but remained 2.6 (single-tree) to 4.1 (clearcut) times greater than unharvested stands after the fifth post-harvest growing season. As with birds, within-year small mammal abundance, species richness, and diversity measures were not statistically different among the four regeneration methods, but these measures were generally higher than for unharvested stands. While periodic surveys are scheduled to continue for many years, initial findings are already being used to aid in forest management decisions on these two national forests.

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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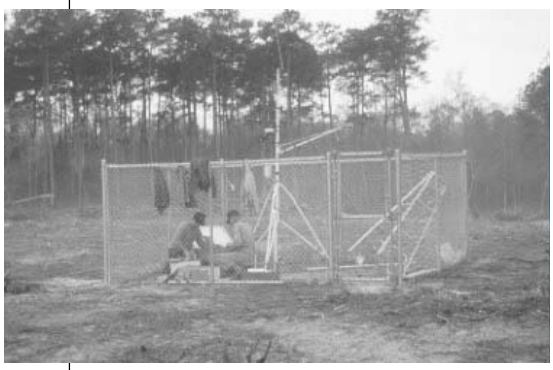
Large Scale Assessment and Modeling

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. Research and development under this CCT is contributing to conceptual frameworks for interdisciplinary research to address regional environmental questions in the South.

National Assessment of Climate Change Impacts on the United States

The national Global Change Program has a $1.7 billion annual budget. The program has studied climate change impacts on forest ecosystems since 1991. The 2000 National Assessment is the first opportunity to synthesize the body of information that has developed since the beginning of the program. The national assessment report will have a wide distribution to the U.S. House, Senate, and Executive Offices. The Southern Global Change Program, based in Raleigh, NC, took the lead in the development of the forest sector for the national and southeastern regional report.

This is the first complete assessment of climate change impacts ever assembled for United States forests. Some of the information has been published separately, but this was the first integrated assessment. We learned that forest productivity would largely increase across the South during the 21st century. Hardwood productivity will increase more than pine productivity. Pine forests will shift northward. Increased productivity will likely result in reduced timber prices. This could shift land area away from forests and toward alternative land uses such as agriculture and development.

Forest productivity is expected to increase across the South during the 21st century.

The information is being transferred via a wide range of outputs that includes special issues of the journals *BioScience*, *Science and the Total Environment*, and *Ecosystems*, a foundation and summary report, regional report and sector reports in order to reach many customer levels including policy makers, land managers, and the general public. This information will have practical application for use in mitigating the impacts of climate change on our forests.

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Human Influences on Southern Forests: The Southern Wildland-Urban Interface Assessment

Wildland-urban interface issues being studied.

As populations and urbanization expand in the South, human influences on southern forests are increasing. Managing natural resources in the wildland-urban interface presents new challenges and opportunities for natural resource professionals. For example, the 1998 fire season in Florida and the 2000 wildfires out West demonstrate that fire management, prevention, and control in the interface are increasingly important. Additionally, new management techniques are required for increasingly smaller forestland parcels in the interface.

Acquiring additional skills, knowledge, and tools for managing resources, and forming collaborative partnerships are essential for those working in the interface.

The Southern Research Station and the Southern Region of the USDA Forest Service, along with the Southern Group of State Foresters, are assessing wildland-urban interface issues to help address this growing need for information and tools. The main products of the assessment are an assessment publication, a summary report, a project Web site (Interface South: www.interfacesouth.org) and a regional wildland-urban interface conference to be held in November 2001. The assessment findings will be unveiled at the conference.

Assessment focus groups were conducted in six locations across the South: Birmingham, AL; Loudoun County, VA; Houston, TX; Biloxi, MS; Helen, GA; and Daytona Beach, FL. These focus groups helped to identify, refine, and validate interface issues to be explored in the assessment. Participants came from a variety of professional backgrounds, including foresters, firefighters, developers, planners, realtors, forest industry, and nonindustrial private forest landowners. The summary focus group report is available on the Interface South Web site.

The Status of Southern Forests: Productivity, Ecological Diversity, and Sustainability

Cooperative assessment evaluates the status of forest resources in the Southern United States.

The USDA Forest Service Southern Region and SRS initiated a two-year effort to compile and analyze data and information necessary to evaluate the status of the forest resources of the Southern United States — their productivity, ecological diversity and sustainability. Forest resources being assessed include timber and forest products, biological attributes, and aquatics. The geographic scope of the assessment includes the 13 States of the Southern Region: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and

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Virginia. The Southern Forest Sustainability Assessment is being conducted in close cooperation with Southern State forestry agencies, the USDI Fish and Wildlife Service, the Environmental Protection Agency, and Tennessee Valley Authority.

Some initial issue identification was completed as part of the Federal interagency staff's recent effort to define issues surrounding forest ecosystem sustainability for the Southeastern Natural Resource Agency Leaders Group. More detailed and comprehensive analyses will be required to ensure that all pertinent and answerable questions are surfaced for this assessment.

While the geographic scope of the project is the 13 Southern States, data and information will be retrieved and analyzed at the State and "section" ecological unit levels. Reporting at these scales will maximize the assessment's usefulness at the State and local level and provide an ecological context that transcends political boundaries.

State-level analysis and reporting fits well within traditional means of collecting, storing, and reporting forest inventory data. Questions answerable by the SRS Forest Inventory and Analysis data will be readily addressed at this scale. The ecological unit "section" level analysis will prove useful in answering questions on an ecological basis. This scale of analysis, however, provides challenges regarding data compilation and interpretation, as data of different ages and formats must be combined in order to be analyzed.

The scope of subjects to be evaluated will be limited to those for which data and information are available and which contribute answers to the critical questions regarding forest resource sustainability. During the region-wide assessment, collection of new data will not be feasible, given the limited time and resources available to address the 13-State area. It is likely, therefore, that some important questions will not be answered by this evaluation. These will be noted as requiring further study.

Because some resource questions are best addressed at a smaller scale, a second tier assessment also is planned. Its purpose will be to focus on smaller areas, i.e., ecological units, States, or portions of states, where sustainability appears to either be in question or demands additional attention. This scale of assessment should facilitate more detailed data analysis and evaluation of potential cause/effect relationships.

The assessment will result in a bound publication containing a variety of tabular, graphic and geographic information system (GIS) data accompanied by narrative analysis. The region-wide assessment will be reported separately from the smaller area assessment. The latter will also include tabular, graphic and GIS displays and narrative analysis, but will also likely reflect the use of satellite imagery.

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Diversity, Distribution, and Conservation Status of the Native Freshwater Fishes of the Southern United States

The Southern United States supports more native fishes than any area of comparable size on the North American continent north of Mexico but also has a high proportion of its fishes in need of conservation action. The Southern Research Station led an expert panel in a comprehensive review of the diversity, distribution, and status of all native freshwater and diadromous fishes across 51 major river basins of the southern United States. Up-to-date information is critically needed to fill communication gaps among scientists, natural resource managers, policy makers, and the public. The sheer number of native southern fishes, the rapidity of taxonomic discovery in the region, the backlog of fishes awaiting analysis, and the growing numbers of imperiled fishes act to preclude rapid, accurate communication of science-based information on native fishes. The information is essential to planning and resource development as the Southern United States experiences rapid changes in population, demography, and development accompanied by increased demands on water resources and forests and increased conflicts among user groups.

Comprehensive review of status of native and diadromous fishes in the South completed.

The area of coverage included all of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia, as well as the Delmarva Peninsula of Delaware and Maryland, southern West Virginia, southern Missouri, southeastern Kansas, eastern Oklahoma, and the Gulf Slope rivers of Texas, exclusive of the Rio Grande drainage. Scientists representing 10 universities, museums, and Federal agencies served on the panel that was coordinated by SRS.

The review synthesized for the first time the entire known fish fauna across all major river basins of the Southern United States, including all described and well-documented, but undescribed, species and subspecies. The review included 661 native freshwater and diadromous fishes. Of this total, 560 native fish species were documented, and 49 other fishes await formal analysis and taxonomic description. Many fishes (43) have recognized subspecies that may represent full species. Notably, 28 percent of these fishes are known from only one river basin, and 37 of 51 river basins had at least one unique fish.

The panel regarded 186 fishes, or 28 percent of the entire fish fauna, as extinct, endangered, threatened, or vulnerable. Three fishes are extinct and at least two others may be extinct, 41 are endangered, 45 are threatened, and 101 fishes are vulnerable. These results represent

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a 125 percent increase in fishes regarded as jeopardized in the region in the last 20 years during which time fishes ranked as endangered have more than doubled. Overall,

the trend is clear. Jeopardized fishes are successively being moved from the vulnerable category to that of imminent threat of extinction.

The information will serve as a planning tool to help set priorities for conducting species recovery efforts, status surveys, and biological research on management of watersheds to maintain aquatic biodiversity. The list will play a primary role in considering species as candidates for listing under the federal Endangered Species Act or for recognition as species of concern at the State level. The information has already been used as a benchmark analysis by the USDI Fish and Wildlife Service (USFWS). The information provided an up-to-date science-based assessment of fishes for their recently published "Strategy for the Recovery and Conservation of Southeastern Fishes" (Biggins et al. 2000. Proceedings of a Workshop, Southeastern Imperiled Fishes Working Group, October 26-28, 1999, Chattanooga, Tennessee). The strategy is a consensus-based action plan developed through a multi-State and Federal agency coalition of resource agencies that provides direction and guidance for the conservation and recovery of southern fishes. The national office of The Nature Conservancy used the review as a source document to refine and update heritage rankings of fishes across the Southern United States. The Southern Division of the American Fisheries Society and the Southeastern Fishes Council hosted a daylong symposium (Savannah, GA, February 5-6, 1999) for which the information was featured as the leadoff presentation and along with the USFWS strategy, set the framework for the symposium. Importantly, the synthesis brings to the fore the potential for extreme losses in aquatic biodiversity if land management development is not carefully conceived and implemented to protect water resources.

Successes - Our Strategic Framework in Action

Large Scale Assessment and Modeling

Economic Effects and Risk-Mitigating Factors of Catastrophic Wildfires in Florida

The catastrophic wildfires in northeast Florida during the summer of 1998 consumed nearly a half million acres of forests and agricultural crops and fields. The scale of the catastrophe and its proximity to urban areas in the State left land managers and government decisionmakers asking about the economic costs of the disaster, why it happened, and what would be the best management options for avoiding such events in the future. We conducted a full-scale economic analysis of the 1998 wildfires to assess the degree to which vegetation management can mitigate economic losses from wildfires in Florida. We conducted a variety of analyses to answer the described questions. First, we reassessed the economic costs of the 1998 wildfires in northeast Florida. Second, we evaluated the stand and neighborhood factors that affected wildfire risk in the 1998 catastrophic season in northeast Florida. Third, we evaluated changes in the size distributions of wildfires over time and across ecoregions in the State. Fourth, we evaluated how the annual amount of wildfire in counties of Florida was affected by the interactions among ecological factors, climate, previous wildfires, human population pressures, and prescribed fire.

Urbanization linked to increased wildfire risk.

We refined and expanded the scope of an earlier Federal effort to quantify the economic costs of the 1998 wildfires in Florida. This analysis revealed that losses to the economy were higher than previously estimated. We identified the types of forests in northeast Florida with the highest and lowest risk of burning during the extreme 1998 season. We found that the primary risk-mitigating factor in wildfire in Florida is past levels of wildfire. The analysis indicated that prescribed burning activity had no significant effect on wildfire area beyond the current year. Our analyses confirmed that the extent of wildfire in a county is strongly associated with La Niña events. We determined that urbanization, as measured by housing density relative to forest area in a county, was significantly and negatively related to wildfire area in most years.

The research findings of these analyses can be used to inform public debate on the costs of wildfire and help develop more effective wildfire risk mitigation strategies in Florida and nearby States. The improved understanding of the nature of the wildfire size-frequency distribution in Florida can be used to better estimate the relationship between small fires and the large, catastrophic fires that account for the majority of damage. The wildfire area models could be used to de-

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Large Scale Assessment and Modeling

velop county-level wildfire risk prediction models able to predict annual wildfire activity, aiding the Florida Division of Forestry in allocating wildfire suppression and presuppression resources across the State. They could also be used by resource managers to develop long-term strategies for reducing wildfire risks in extreme La Niña events.

Our findings will benefit three groups: the research community, resource managers, and the public. Researchers will be better able to model broad-scale wildfire risk and quantify the economic and production risks associated with alternative vegetation management strategies. The wildfire area models that we estimated can serve as one component of a larger economic model of the loss-minimizing levels of suppression and presuppression activities by resource managers. Resource managers will use the wildfire area prediction capabilities to better manage expenditures and allocate wildland fire resources. The ultimate beneficiary will be the public, which finances wildfire suppression and presuppression activities of land managers, experiences direct economic losses, and suffers health problems from smoke.

Lead contacts for the Landscape and Regional Integrated Assessment and Modeling cross-cutting theme: RWU SRS-4851 at Research Triangle Park, NC and RWU SRS-4852 at Raleigh, NC.

Successes - Our Strategic Framework in Action

Inventory and Monitoring

The goal of this CCT is to provide current resource information and analysis on forest ecosystem sustainability issues and to improve techniques to inventory, monitor, and evaluate resources.

The Southern Annual Forest Inventory System

The Forest Inventory and Analysis (FIA) program collects, analyzes, and reports information on the status and trends of America's forests. The FIA program is America's forest census. The southern FIA program is responsible for 13 Southern States, plus Puerto Rico and the Virgin Islands. Timely information is a high priority for southern forest ecosystems, which occupy 40 percent of the region's 535 million acres of total land area. These 213 million acres of forest provide important economic, social, and esthetic values to the region and nation in recreational opportunities, watershed protection, wildlife habitat, and economic benefits from timber production.

New and improved techniques developed for implementing annual inventories.

For the year 2000, FIA collected annual inventory data in seven States (Arkansas, Georgia, Kentucky, Louisiana, South Carolina, Tennessee, Virginia), completed data collection for the final periodic survey of Alabama and North Carolina, and participated in the planning of 2001 annual inventories for Florida, Texas, and Puerto Rico.

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Inventory and Monitoring

The Southern FIA Program has changed dramatically over the last several years. The FIA program has been converting to an annual inventory system, with a sampling scheme that is consistent across State and regional boundaries. While the initial implementation of an annual system in the South used traditional procedures and protocols, we have been making significant progress in devising new and improved techniques for implementing annual inventories. In addition to new sampling protocols the program has derived new statistical methods and estimators of forest resources.

Through publication of four journal papers and five conference and proceedings papers, we have documented significant changes in Southern FIA's sample design and protocols for forests and other land uses, and new statistical methods and estimators of forest resources. We have developed new volume estimation procedures for individual trees, with equations which are capable of estimating volume for any length or section of a tree.

Other important research areas are under development. These areas include the development of sampling, analysis, and reporting protocols for nontimber products output such as ginseng and pine straw. The use of digital camera systems to measure plot and tree level variables is being investigated and pilot-tested for operational use on FIA plots.

Research results and inventory information are used extensively to assess resource sustainability by forest industry, State forestry agencies, State economic development programs, consultants, and other Forest Service units. The research results and inventory methods and information are increasingly important for policy formulation and management of resources because of the importance of the resources to State, regional, and national economies and the environment.

Forest Health Monitoring Program

The Forest Health Monitoring (FHM) program focuses on the health, broadly defined, of the nation's forest resources. FHM uses information from many sources to analyze and assess several Criteria and Indicators of health that have been adopted by the Federal government for national assessments such as the Resource Planning Act (RPA) Assessment. FHM also has research and evaluation components that are aimed at developing new ways to collect and interpret data and facilitating assessments of specific regional issues such as air pollution and tree decline. States are active participants in the management and implementation of the FHM program, as are other Forest Service programs including Forest

Information published assessing the health of forest resources.

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Inventory and Monitoring

Inventory and Analysis (FIA), and Forest Health Protection (FHP). The SRS hosts the four-person National Program Office and three University cooperators at the Research Triangle Park Laboratory and one FHM scientist at the Asheville Headquarters. The FHM National Program Manager is part of the FHP staff in the Washington Office and works collaboratively with the SRS to maintain the National Program Office.

In 2000, the transfer of responsibility for plot measurements nationwide to FIA was accomplished, resulting in a new focus for FHM on research, evaluation, and assessment topics. Many of the changes in the FIA program (such as measurement protocols, quality assurance, and statistical design) were developed and prototyped by the FHM program over the past decade. Two reports on forest health were prepared including a forest chapter for the interagency Mid-Atlantic Integrated Assessment, and the National Technical Report on FHM data for the years 1991-1998. In addition, the national FHM office produced several manuscripts for publication, pamphlets and fact sheets about FHM, and other products. Significant research products included the publication of the first global assessment of forest fragmentation, a contribution to the National Electronic Atlas, and the further development and public distribution of the National Land-Cover Pattern Database. FHM managers often participate in regional user group meetings, engage in cooperative agreements with universities to provide additional expertise in forest health measurements and data management on behalf of FIA and FHP, and handle briefings and budgets for the National FHM program.

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 and meet other critical information needs. Many result from ongoing work that was begun several years, or even decades, before the current Strategic Framework was developed.

"Forest Plants of the Southeast and Their Wildlife Uses" Published

A forest plant identification field guide has been a critical need to further wise management, support precision research studies, and stimulate a wider appreciation of forest plants. There are over 4,000 plant species in the Southeast that inhabit forests, their openings, margins, and rights-of-way. There are a number of species that are common across the region. This book presents the common, as well as some unique, species by genera, including wetland plants, exotic invasives, and keystone species. The genera treatment permits users to know the characteristics of the most prevalent species in that genus where similar looking plants are also listed. This is the first research report summary on uses of these plants by mammals, birds, butterflies, and moths.

The need for a plant identification field guide to assist natural resource managers and researchers was identified and discussed for many years at the annual meeting of the Forest Vegetation Management Section of the Southern Weed Science Society. In 1990, a committee was formed to develop this concept. Over a 4-year period, ideas on content, coverage, and format were shared and discussed. Photography and writing was accomplished in 4 years with thousands of images paired down to 644 and the species number expanded to 330 from the original list of 50.

The book was written for the most part in lay terms, with necessary botanical terms illustrated along with descriptions in a glossary. As stated in the review in the July 2000 issue of *Forest Science*,

New field guide summarizes use of plants by mammals, birds, and insects.

"Several important features separate this book from other floras. Each description includes sections on the ecology and wildlife value of the species. Ecological information on a given species includes whether it is a nitrogen fixer, the types of stand conditions and communities in which it is found, and how it persists and spreads…..An important service of the book is to provide ecological and wildlife information in a highly palatable format that represents decades of literature and field experience."

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An interactive CD-ROM version of the book will be developed. These plant identification and ecological tools should yield a new level of knowledge and appreciation of the local flora and fauna, needed for wise management.

This "one-of-a-kind" book will benefit forest managers, researchers, technicians, owners, and administrators; wildlife managers, researchers, technicians, and hunters; conservation managers and botanists; forestry, wildlife, botany, and secondary students; wildflower and wildlife enthusiasts; and general public. An informed public should yield wiser use and management of our forests for multiple use and sustainability. The book also provides a firm scientific foundation for the formulation of scientifically based forest management policy.

Forest Service Tests Contribute to the Labeling of Two New Termiticides

The Southern Research Station has a long history of providing reliable termiticide efficacy data to our pest control stakeholders. This nationally recognized program provides unbiased and authoritative data to the Environmental Protection Agency (EPA) for product registration.

The cost of controlling subterranean termites and repairing their damage is estimated at $2 billion annually in the United States. These losses do not include those incurred by the U.S. military or the growing impact from the Formosan termite. Termite control also carries with it the highest risk for the pest control industry of all the categories associated with urban pest management, and increasing restrictions on and cancellations of insecticides make termite control less reliable and more costly. Two new products, Termidor SC and Termidor WG (Aventis Environmental Science), were registered by EPA this year, in part based on our long-term testing. These products are now commercially available to the American public for termite control.

New termite control products made available to the public.

Recovery of Tannins from Spent Liquors in Vegetable Leather Manufacture

Through a collaborative effort with E.H. Hall/Westfield Tanning Co., Westfield, PA, Gannett Fleming Inc., Clearfield, PA, and Louisiana College, Pineville, LA, we have been working to find a way to use the spent tanning liquor generated in the leather manufacture process. Because this spent liquor cannot be added to their wastewater treatment process and since only low value uses can be found for a part of it, the product (in amounts of approximately 40,000 pounds per week) has been dried and stored.

We have demonstrated a novel tannin recovery process both at a laboratory and pilot plant scale and have shown that the recovered tannin can be reused in the leather

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manufacturing process. Close to 50 percent of the spent liquor tannins can be recovered as purified tannins. The recovered tannin has been shown to have excellent penetration rate and the leather produced has good physical properties. Recovery and use of these tannins in Hall/Westfield's process alone can save on the purchase of about a million pounds of tannin per year, and can reduce the disposal problem. This recovery process will reduce the use of fresh water at a rate of about 1 million gallons per year. It also assures that no tannin from spent tanning liquors will enter wastewater streams. The construction of a recovery plant could allow Hall/Westfield to process spent vegetable tanning liquors from other tanneries in the region.

Novel tannin recovery process demonstrated that will reduce fresh water use and disposal problems.

Having found a high-value use for a waste stream amounting to nearly 2 million pounds per year and approximately 1 million gallons of fresh water per year, this process offers a way to assure improvements in water quality in northwest Pennsylvania. E.H. Hall/Westfield could process spent liquors from neighboring smaller tanneries and make even more significant improvements to water quality as most of those spent liquors are discharged to rivers.

Footprints on the Land: Demographic Trends and the Future of Natural Resources in The United States.

Population and demographic change are accelerating nationwide. Public and private natural lands are impacted. A national assessment was conducted to identify where the greatest impacts are likely to occur over the next decades. This book, published by Sagamore Publications in Illinois, is the first nationwide treatment to interpret the meaning of population and demographic trends for the fields of forest and natural resources management.

Book will interpret population trends for natural resource managers.

Hotspots of population, economic and recreation pressures on natural lands, public lands, protected wilderness, water/wetlands, and wildlife habitat have been identified. Identification of such hotspots provides information to Federal, State, local and private natural resource interests for developing comprehensive local strategies for sustaining the integrity and productivity of natural lands before the opportunities to do so are lost.

Grant to Study Fuel Reduction Alternatives

Widespread fuel reduction treatments are needed throughout the United States to restore ecological integrity and reduce the risk of destructive wildfires. Prescribed

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burning can be used but smoke management and public policy continue to be problems. Alternative fuel treatments are attractive but the appropriate balance among cuttings, mechanical fuel treatments, and prescribed fire is often unclear.

National fire and fire surrogate study will shed light on alternative fuel treatments.

We received a grant of $2.3 million from the interagency Joint Fire Sciences Program to cooperate in the National Fire and Fire Surrogate Study. This study will compare the effects of alternative fuel reduction treatments on numerous ecological and sociological variables in 11 ecosystems across the country. Study sites are being established in a Piedmont pine-hardwood ecosystem on the Clemson University Experimental Forest and in a Florida flatwood ecosystem at Myakka River State Park. Three SRS scientists are cooperating with nine faculty members of Clemson University, the University of Florida, and Florida A&M University to compare the effects of prescribed fire and mechanical removal on vegetation, fuels, fire behavior, ecosystem structure, soil compaction, nutrient cycling, forest floor dynamics, mammals, herpetofauna, avifauna, entomology, pathology, treatment costs, and utilization economics.

Each individual study will contribute to a combined analysis of how fuel reduction treatments affect ecosystem function on the local and national scale. During the 5 year study, the grant will provide support for 11 graduate students, 10 undergraduate students, and nine SRS employees. Two SRS scientists serve on the national steering committee for the Fire and Fire Surrogate Study and one serves on the study's executive governing board.

Prescribed Burning Survey in the National Forest System

Recent analyses of fire policy have called for increased prescribed burning to prevent wildfire damage and to enhance fire-dependent ecosystems and forest health. The Forest Service has set a goal of burning 3 million acres per year by the year 2010. Achieving such a goal requires a solid baseline assessment of current activity, wise allocation of prescribed-fire resources, and an understanding of the barriers to implementation of burning programs. The results of a survey of burning activity and costs on national forest lands from 1985 to 1995 were published in an attempt to provide the needed baseline information. Ninety-five of 114 national forests responded. Acreage burned and costs for conducting burns were reported for four types of prescribed fire: slash reduction; management-ignited fires; prescribed natural fires; and brush,

Survey of burning activity and costs provides valuable baseline information for future decisionmaking.

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grass and rangeland burns. Anticipated burning levels over the next 10 years and burning levels needed to achieve desired management goals were presented. Survey rankings also were presented for 9 resource enhancement targets, 14 potential barriers to increased burning, and 12 factors influencing burning costs. The information provided should be useful in identifying opportunities for reintroducing fire and choosing appropriate environmental, social, and economic tradeoffs.

GPR technology shows promise in studying root biomass.

The Use of Ground-penetrating Radar (GPR) to Study Tree Roots

Approximately 20 to 40 percent of forest biomass is in root systems. Many forest management activities — fertilization, tree improvement, site preparation — impact the percentage of biomass that gets partitioned into root systems. Roots are critical for the function of trees and they provide a large sink for sequestering carbon. Although roots are such a critical part of forest function, they are below-ground and very difficult to study. Roots and below-ground processes are now among the least understood components of forest ecosystems. In collaboration with a scientist from the Agricultural Research Service, we have explored using ground penetrating radar (GPR) to quantify root biomass on a range of site types in the Southeast. The goal was to find a faster and cheaper method to measure root biomass.

Current GPR technology was not found useful on very wet or very clayey sites. On other sites GPR analysis was able to explain over 50 percent of the variation in root biomass across different management treatments. Because root biomass harvesting is so time consuming and expensive, GPR shows great promise for augmenting root biomass sampling.