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**Southern
Research Station**

Science Update
SRS-001

Sustainability and Productivity of Southern Pine Ecosystems

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Introduction

Scientists at the Southern Research Station (SRS) have developed a means to address critical forest resource needs in the 21st century. Throughout the South, we are working with public and private landowners to face unprecedented natural resource management challenges (United States Department of Agriculture, Forest Service 1997). By providing access to research results and scientific discoveries, by developing useful technologies, and by responding to an ever-widening customer base, we are building on a 75-year tradition of leadership. That leadership will help champion the conservation and productivity of southern forest resources.

Then and Now—The Palustris Experimental Forest (near Pineville, LA). Sixty years ago unbridled demand for southern forest resources set the stage for long-term productivity studies.

Human society's burgeoning demands for natural resources have brought new challenges to those of us on the front lines of land management. In facing those challenges, we have committed our time and energy to several principles. Above all, we recognize that sustainability is the key to responsible natural resource management; and that any resource issue, problem, or opportunity must be considered in a human context. With our partners and other resource users, we are identifying issues and needs that will determine the direction and effectiveness of SRS research and development programs. The biological, physical, and social sciences we use will support sustainable resource management well into the new millennium.

The SRS strategic framework forms a basis for our multidisciplinary approach to research. The framework describes three broad research priorities: (1) measuring and monitoring forest resources: *What do we have?*; (2) understanding ecosystem structure, function, and processes: *How does it work?*; and (3) ensuring environmental quality and sustainable productivity: *How can we use it without losing it?*

Successful implementation of the framework will require expanded collaboration with our partners and better integration of our science programs with those of academia, industry, and others. Achieving the sustainability of nature's resources while incorporating human values will require research and development that address a wide range of questions that our partners, cooperators, and neighbors have posed.

To increase the value of our work and the usefulness of our products, we must assimilate and apply decades of vital research results into state-of-the-art science. In addressing issues and needs identified during the strategic planning process, we have outlined six cross-cutting themes (CCT's). Four focus on predominant manifestations of the South's forest resources: (1) Southern Appalachians, (2) Interior Highlands, (3) southern pine ecosystems, and (4) wetland/bottomland/riparian areas. The remaining two, (5) inventory and monitoring and (6) large-scale assessment/modeling, focus on the sustainable management of all forest ecosystems and types.

Adaptive management engages partners, cooperators, and neighbors with SRS scientists, members of the South's premier forest research community. Connectivity is the key to our shared success.

The CCT's reflect institutional emphasis rather than any structured, programmatic approach to research and development. They are dynamic, fluid, and flexible, enabling the research community to adapt to evolving customer needs and respond to emerging issues. They will help us integrate the work of our highly decentralized scientific organization, build partnerships, and develop products that meet or exceed our customers' expectations.

Over 20 SRS research work units (RWU's) are contributing scientific support and financial resources to the challenges that come to light in the individual CCT's. While each RWU continues to support traditional, core research programs, the communication and interaction among them are establishing CCT connectivity.

Objectives

The Sustainability and Productivity of Southern Pine Ecosystems CCT provides the basis for a broad and strategic framework. It allows us to identify critical issues, information gaps, and research needs for ecologically sound, economically viable, and socially acceptable management of the southern pine and pine-hardwood ecosystems. Equally important, CCT development provides a mechanism to bring together scientists, managers, and other stakeholders who can reach consensus on priorities for sustaining southern pine and pine-hardwood ecosystems. Responding to research needs will lead us to a more corporate and comprehensive understanding of key issues, science questions, and approaches to sustainability.

Definitions

The World Commission on Environment and Development (1987) defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Southern pine ecosystems include those pine and pine-hardwood forests that are located within the southern Coastal Plain and Piedmont areas. Several RWU's have focused their silvicultural and ecological research on Coastal Plain pine ecosystems for many years. While controversy surrounds nearly every aspect of forest policy, management, and use in the United States today, our scientists have reached a broad consensus on two important points: (1) sustainable development is a desired outcome and measure of success, and (2) research and development are critical to achieving sustainability. Again, if we are to consider wood fiber supply, recreation, water yield and quality, abundance and diversity of flora and fauna, and other valuable forest resources, managing these resources for their sustainability will require us to recognize human actions. In the context of ecosystem sustainability, forests should produce desired resource values, user products, and services in ways that maintain ecosystem health (Burkett and others 1996).

Sustainable management of wood fiber supplies, water quality and yield, recreation resources, and abundant flora and fauna helps restore and maintain ecosystem health.

Historical Conditions

Since 1921 Forest Service researchers have worked with forest landowners and managers to meet the South's timber needs, while repairing degraded stands and establishing new forests on lands that had been laid waste by cut-and-leave logging, open-pit mining, overgrazing, and hillside farming. The 13 States of the South span a wide spectrum of climates, landscapes, and forest types. Temperatures range from subtropical on the coast to cool and humid in the Appalachian Mountains. In the 1500's a mosaic of fire-influenced forests extended from the Atlantic Coast to the plains of central Texas and Oklahoma. Wildfires and fires set by Native Americans created open savannas and maintained mountain balds. There were longleaf and slash pines in the Coastal Plain; loblolly and shortleaf pines and oak in the Piedmont; oak, hickory, chestnut, and fire-dependent pines in the mountains; and oak, gum, and cypress in the bottomlands.

As European and other immigrants settled in the South, the forests provided timber for home building as well as fertile valleys that could be cleared for livestock grazing and habitat for game. As they moved inland, the settlers cleared forest for farmland, towns, and roads. By the early 1920's, much of the cultivation had resulted in severe erosion and the eventual abandonment of cropland and pasture, especially in the Piedmont. Uncontrolled wildfires raged over the land and in the absence of any operational forestry programs, only part of the idle acreage reverted to forest. Trees did regenerate in many areas, though, and the South's forests supplied wood for a growing pulp and paper industry from the 1930's through the 1960's.

Settlement of the inland South dramatically changed the forest landscape. In the early 1900's Forest Service researchers had begun grappling with the effects of cut-and-leave logging, overgrazing, hillside farming, and uncontrolled wildfire.

Current Conditions

Past agricultural and silvicultural practices have had serious effects on the forest mosaic throughout the South. Much of the land that once grew longleaf pine has been converted to loblolly or slash pine, species that are easier to regenerate and have a competitive advantage in the absence of fires. Overall past forest management practices have brought an increase in available wood volume and further increases are possible in stands that have remained in poor productive condition. Although available wood volumes have increased and populations of some managed game species have recovered, the number of threatened, endangered, and sensitive (TES) animals, plants, and plant communities is increasing. World trade has expanded and the importation of lumber and wood products has increased; but new, potential threats to forest resources have come from exotic insects, pathogens, and weed pests.

In the face of increasing demands for wood fiber, introduced weed species are posing research challenges that are unprecedented in scope and scale.

The South's forests provide wildlife habitat, a wide diversity of plant species, recreational opportunities, clean water, and fresh air. As home to abundant and diverse wildlife populations, over the last 40 years the Southern States have increased significantly their populations of some game species, e.g., deer and turkey. This has been largely the result of responsible management and a growing knowledge of wildlife habitat needs and species diversity. Southern forests also nurture a multitude of nongame fauna and a wealth of native flora. Recreational opportunities, as well as natural beauty, have made the South an attractive vacation land—or a place to settle.

Species of animals and plants that have been driven to the brink of extinction are dependent on research that focuses on ecosystem integrity.

Values and Demands for Resources

The South supplies 67 percent of the Nation's pulpwood, 50 percent of its plywood, 40 percent of its hardwood lumber, and 33 percent of its softwood lumber. Timber is the region's highest valued crop, representing an annual economic value of $90 billion. In an average year, removal of wood products in the South totals 8.9 billion cubic feet, only about 4 percent of which comes from national forests. In addition to being an essential source of wood products, the region's forested lands support a robust recreation business; they provide clean air; supply abundant water for domestic, agricultural, and industrial uses, as well as recreation; maintain diverse habitats for plants and animals; and serve as a potential sink for atmospheric carbon sequestration.

Habitation needs are universal. The South can expect increasing demand for products and amenities of its forests.

Our human population growth has been accompanied by increased demands for forest resources and a chorus of opinions about how America's forests should be managed. Expanding urban populations have clear expectations of environmental quality and the availability of resources. Coupled with the growing affluence in American society is a growing interest in conserving and enhancing soil, air, water, wildlife, fish, and recreation resources. On both the national and global levels, humankind's desire to maintain or enhance living standards often increases our demands for forest benefits. The South can expect a greater demand for pulpwood, lumber, and other products, as well as outdoor recreation opportunities. Most pressures on forest resources will be felt on private ownership, which constitutes nearly 90 percent of the South's forests.

Barriers to Sustainability

Trends in soil and fertility losses, epidemic levels of insect pests and pathogens, losses of TES species, encroachment of exotic weeds, forest fragmentation, and other problems affecting forest health—all complicate the challenge of ensuring southern pine ecosystem sustainability. The history of most forest management practices is short; there has been little documentation of their long-term effects on forest sustainability. For example, loss of soil productivity can result from the repeated removal of biomass from the forest floor. Annual losses may be small, but cumulative losses may have significant impacts. We need, then, knowledge of the long-term effects of forest management practices on basic forest resources, such as soil productivity, water quality and quantity, biodiversity, and wood production.

Epidemic outbreaks of southern pine beetle pose a fundamental challenge to public, private, and industrial ownerships.

A more obvious risk to sustainability occurs when forest ecosystems are lost to encroachment from urban development, highway and powerline expansions, and other human activities. As the amount of forest land decreases, societal demands exert even greater pressure on the forests that remain.

Other barriers to sustainability result from dramatic environmental changes that are brought about partly by rapid population growth and urbanization, and partly by the dynamic domestic and international demands for resources. Human demands, once primarily for wood products like paper and furniture, now include nontraditional products like ginseng and galax, and recreational pursuits like hiking, bird watching, and solitary contemplation. In short, there are cultural and systemic barriers to sustainability, as well as gaps in our understanding of forest resource issues.

Management Challenges

Disseminating research results that will foster conscientious responses to the growing demand for forest resources is perhaps the research scientist's greatest challenge. In the South, as elsewhere, there are competing demands for limited resources. Most notably, intensive management for timber and other forest resources is sometimes in direct conflict with TES habitat protection. Allocation of the resources that sustain us has become a critical issue, especially in the South, where 90 percent of the forests are within private ownership.

Forest insect pests and the periodic occurrence of wildfire do not acknowledge ownership boundaries. Global demands for sustained productivity require cooperative research and shared stewardship.

Most small forest landowners in the 13 Southern States have little capacity to conduct research to improve resource sustainability. Nonetheless, by applying the knowledge and technology developed by government, industry, and university research, they can benefit substantially. In addition, managers of privately owned industrial forest lands can apply the results of cooperative research to sustain wood production and other forest benefits, such as wildlife habitat and environmental quality.

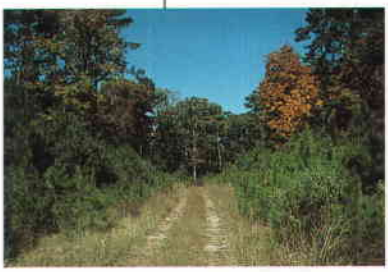
In response to booming populations and economies, the global demand for affordable construction materials, paper products, fuelwood, and wood chemicals is growing exponentially. Recent timber harvest reductions in the American West have brought unprecedented pressures on the South, especially its private forest lands.

Montreal Process Criteria

The Montreal Process (Canadian Forest Service 1995) evolved from the Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests, which was convened in Geneva, Switzerland, in June 1994. The Process describes a comprehensive set of criteria and indicators for forest conservation and sustainable management that is being used by the international forestry community. The criteria were designed to provide: (1) a common understanding of what is meant by sustainable forest management; and (2) a common framework for describing, assessing, and evaluating a country's progress toward sustainability at the national level. Although the criteria are not intended to assess sustainability at a regional or forest level, they do provide an internationally recognized template for categorizing or grouping research questions and needs. We have used the seven criteria to broadly consider research questions about southern pine ecosystems:

The road from local to global responsibility is fraught with legal, institutional, and economic issues. International frameworks provide the scaffolding upon which sustainable development is possible.

1. Conservation of biological diversity;
2. Maintenance of the productive capacity of forest ecosystems;
3. Maintenance of forest ecosystem health and vitality;
4. Conservation and maintenance of soil and water resources;
5. Maintenance of forests' contribution to global carbon cycles;
6. Maintenance and enhancement of long-term, multiple, socioeconomic benefits to meet the needs of human society; and
7. Legal, institutional, and economic framework for forest conservation and sustainable management.



Research Goals and Questions

The Sustainability and Productivity of Southern Pine Ecosystems CCT is very broad, both technically and spatially. Key elements of it apply to much of the SRS research program, as well as to the programs of forest industry, southern universities, and some private research institutions. We have sought, therefore, to discuss general research questions associated with the sustainability of pine ecosystems and have organized our discussion using the Montreal Process criteria. We hope more clearly and specifically to pose questions about southern pine forests. To that end we are asking our collaborators and customers to help articulate key needs that fall under this CCT.

Successful restoration and maintenance of biological diversity in southern ecosystems require economically and environmentally feasible technologies.

Conservation of Biological Diversity

The Southern United States is nearly unmatched in biological and genetic diversity. At multiple scales the region's diversity continues as a dynamic interchange of several environmental elements: physiography, which ranges from the nearly level Coastal Plain to the Southern Appalachian Mountains; widely variable geologic and pedologic substrates; and complex biogeographic and anthropogenic history. On this rich landscape a long history of intensive and extensive human use has occurred. Our growing human population, coupled with the many and varied land-use practices that the human species has brought to bear on the resources, e.g., more intensive agriculture and forestry, has had significant effects. It has contributed to over-exploitation of plant and animal resources; simplification of ecosystems; alteration of natural processes, e.g., reducing the frequency and extent of wildfires; habitat fragmentation; changes in genetic variation and dynamics; and habitat degradation and loss.

The combination of wide biodiversity at multiple scales and the extensive uses made of southern

landscapes complicate most efforts to conserve and restore diversity. First, there are few relatively undisturbed reference sites within southern pine ecosystems, making it hard to know which elements have been lost or even to interpret the patterns that remain. Without reference sites a scientist must interpolate patterns from fragments and incomplete historical data. The status and distribution of rare species or rare genotypes are particularly difficult to determine. For many rare species little is known about population dynamics and their habitat needs, so research progress may be limited. Further some historical uses have brought changes, e.g., depleted soils, that are not typical of the component species' recent evolutionary history. Also, fire exclusion policies that have been in effect since the 1920's have removed a controlling element from many pine ecosystems, resulting in changed floral, faunal, and structural diversity. Reintroducing the natural disturbance regime probably would not restore diversity. Mimicking nature is not so easy. Ecosystem structure and function will first have to be restored. Where complex land ownership patterns and the growing urban/wildland interface are occurring, the use of fire is problematic. Finally the underlying ecological diversity of southern pine ecosystems will make it hard to find general solutions for maintaining and restoring biological diversity.

In order to address this criterion for sustainability, scientists from many disciplines and research traditions must work together (by collaborating in study design and data collection or by integrating data from multiple disciplines) to address three basic research goals:

1. Define baseline biodiversity at multiple scales, e.g., landscape, stand, within-stand (species diversity), and within-species (genetic diversity) across southern pine ecosystems;
2. Determine how alternative forest management practices affect biological diversity at various scales; and
3. Determine how biodiversity can be maintained and restored in the southern pine region, and develop economically and environmentally feasible technology to do so.

Maintaining the Productive Capacity of Southern Pine Ecosystems

Southern pine forests have become the World's largest source of wood fiber; however, we need to consider forest productivity in a much broader context. Recreational opportunities, socioeconomic worth, wildlife habitat, and other noncommodity aspects figure prominently in a forest's value. In addition, some very important questions remain regarding the sustainability of intensive silviculture. Science continues to show us how fertilization, control of competing vegetation, and the use of improved genotypes can improve plantation performance; but what are the risks of pushing tree growth to its limit? Is the shoot blight observed in some intensively managed plantations an effect of out-of-balance growth? Will such plantations be vulnerable to damage by pests or to the effects of severe and infrequent environmental conditions like 100-year-droughts? What about the long-term sustainability of soil resources over the course of repeated rotations?

Science has shown how fertilization, control of competing vegetation, and use of improved genotypes can improve production, but what are the long-term results?

Pine plantations are now managed using growth-and-yield models based on past stand growth. However, new plantations are growing at unprecedented rates and under novel conditions. Work is underway to develop versatile process-oriented models for use in these stands of the future. Alternative management practices may affect the quality of wood, as well as other forest resources. What about plantation ecology? Can forest reproduction be managed to benefit a wide array of flora and fauna? How does plantation forestry affect wildlife species, recreation, and other less tangible but very important values? Will such practices indirectly benefit riparian areas and other more sensitive forest ecosystems? How can the productive capacity of the South's vast nonindustrial forestry sector be increased? Are our strategies to increase productivity economically feasible or socially desirable? These important questions can only be addressed using a multidisciplinary approach.

Maintaining the productivity of southern pine ecosystems will require research that focuses on some key questions:

1. What is the ecosystem's potential capacity for supplying an array of forest products?
2. What are the limitations to sustained production?
3. How will forest management influence the ecosystem's long-term productive capacity?

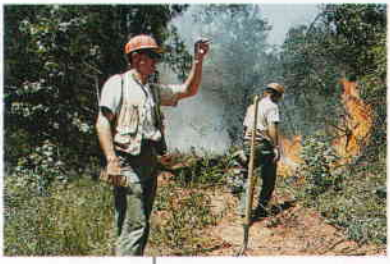
Maintenance of Forest Ecosystem Health and Vitality

As demands for wood and other forest products sharply increase, forestry professionals and nonprofessionals alike are striving to maintain and restore forest health. They are emphasizing improved forest health because much present-day forest land in the South was farmed long before modern soil conservation practices were known. In many areas the land was highly eroded or nutrient depleted from heavy use before today's forests were established. Many areas are succumbing to insect infestation, pathogens, and invasive weed species, any of which may threaten ecosystem health.

Heavy farming and other human uses of southern forest lands often resulted in highly eroded or nutrient-depleted soils.

Problems have come to southern pine forests. For example, nearly 500,000 acres of Florida's forest land burned in 1998. Although wildfire is a natural disturbance to which ecosystems have adapted, years of fire exclusion have brought unusually high fuel concentrations and, as a result, abnormal fires and fire effects. Other natural disturbance factors, such as hurricanes and southern pine beetles, are affecting the changed forest ecosystems; and those effects may be quite different from what occurs in normal, healthy forest communities. Land managers often have limited knowledge of the influence of disturbance regimes on some ecosystem components, as well as their importance to the ecosystem's overall health and productivity.

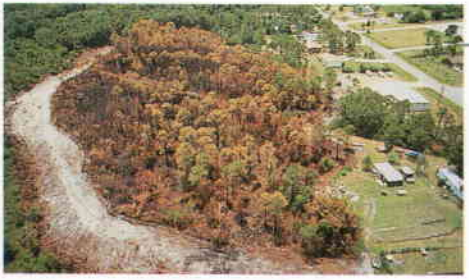
Other pressures from growing human populations include the fragmentation of forests by road construction, urban sprawl, and changing land-use patterns. How then do we increase forest productivity while improving forest health? What would landowners and society as a whole have to pay to implement such measures, and what benefits could they expect?



A key tool for restoring and maintaining forest health is prescribed fire.

Fundamental questions about maintaining and enhancing forest health in southern pine ecosystems include:

1. What is the condition of southern pine forests today? Research scientists need to collect baseline information about forest conditions if they are to ensure that future actions help improve forest health.
2. How do animals (earthworms to deer) and microorganisms affect the health of southern pine ecosystems? The functional role and impacts of only a few organisms in southern forests are understood.
3. How do fragmentation and changing land-use patterns affect southern pine ecosystem function and health?
4. What is the role of major forest disturbances in the overall health and renewal of pine forest ecosystems?



Fragmentation of resources presents challenges to forest managers across all jurisdictional boundaries.

Conservation and Maintenance of Soil and Water Resources

While land managers and property owners try to increase production from a relatively fixed, intensively managed land base, they are often constrained by wetland regulations. Forestry practices in the South are highly manipulative and can affect the soil properties on which sustained productivity depends; soil quality easily can be compromised. Forestry activities may have profound effects on both soil and water, which are closely linked throughout the South. The Clean Water Act requires that the impacts of forest practices on adjacent ecosystems, as well as the managed land itself, be kept to a minimum. Nonetheless, silvicultural operations can influence water quality through sedimentation, hydrologic regimes, changes to channel structure, and biogeochemical processes. If soil and water degradation are to be avoided, we need to better understand the nature of such impacts, as well as appropriate methods for restoring soil and water components of affected ecosystems. Sustaining soil productivity and restoring the productivity of damaged sites reflect a key conservation ethic, and it makes good sense from an economic perspective. As human populations and forest management dramatically increase, soil and water conservation become especially important. Quantifying baseline conditions is a critical first step in developing management practices that will mitigate and improve soil and water conditions and help ensure that forest and aquatic ecosystems provide their bounty for future generations. The research required for these purposes will involve a variety of resource disciplines and respond to the following major questions:

Soil and water-quality conservation is a universal, ecological necessity.

1. What are the baseline conditions of soil and water resources in the southern pine region?

2. What are the interactions among management practices, soil conditions, and water quality?
3. What methods can be used to mitigate and improve soil and water conditions in southern pine forests?
4. How does context, i.e., arrangement of different forest types and management regimes on the landscape, affect soil and water resources?

Maintenance of Forest Contribution to Global Carbon Cycles

Some scientists have suggested that forests and forestry play an important role in atmospheric carbon sequestration and thereby help mitigate greenhouse gas accumulation and global change. Pine ecosystems in the South, which constitute one of the most important forest assets in the World, potentially could have a significant impact on the World's carbon cycle. However, the southern pine region is an aggregate of many forest types that are managed at various intensities. Pine plantation silviculture itself is evolving rapidly and management tools like fertilization, site preparation, vegetation control, and improved genotypes have greatly influenced net ecosystem productivity (NEP) by reducing rotation ages and by altering soil carbon dynamics. Global warming, by affecting tree growth and function, and by influencing rates of soil respiration, may further influence NEP. Of course in forests managed and harvested for wood products, the absolute amount of carbon sequestered from the atmosphere depends on how the harvested wood is used. Wood fiber is processed into any number of products, the lifespans of which will vary from months to centuries. Carbon costs, which are associated with management, harvest, transportation, and processing, all contribute to the carbon-cycle equation. So in terms of carbon sequestration, how do southern pine forests compare to other lands where the uses are altogether different? Given the complexity and scale of such issues, we are not yet able to predict

Long-term studies of plantation ecology are yielding valuable information about greenhouse gas accumulation, carbon cycling, and global climate change.

the effects of southern pine forestry on the global carbon budget. Nor can we make policy and management decisions that will allow both competitive industrial forestry and the maintenance of southern pine plantations as an overall carbon sink. Answers to these questions will require multidisciplinary research and synthesis on a regional scale.

The following broad questions about carbon cycling must be addressed:

1. Is the southern pine ecosystem an overall source or a sink of atmospheric carbon?
2. How does forest type influence the ecosystem's status as a source or sink?
3. What is the influence of different forest management techniques on the long-term status of pine forests as a source or sink?
4. What are potential effects of global climate change on carbon sequestration?

Maintenance and Enhancement of Long-Term Socioeconomic Benefits to Meet the Needs of Societies

Southern pine forests provide a diverse set of benefits to landowners, as well as the general public. They are a source of raw materials and income for industrial landowners and wood fiber consumers. They not only provide private, nonindustrial landowners with wood, but also offer American society recreation opportunities, scenic beauty, places that respond to our spiritual needs, and habitat for flora and fauna. Public forest lands also provide these benefits. In addition, they provide watershed protection, ecosystem stability, and a stabilizing component in local and regional economies. It is clear, therefore, that the land-use choices of private and public landowners, the demands of forest product suppliers and consumers, and the many values that we humans place on the natural World will determine the character and extent of the southern pine resource. What is not clear, however, is how we can best interact with the ecosystems upon which we all depend.

In addition to wood fiber, the South's forests provide recreation opportunities, places that nourish the human spirit, and habitat for flora and fauna.

Southern Research Station scientists and their counterparts in the university community are using applied research to better understand the commodity and noncommodity values derived from private and public forests. Key questions include:

1. How do commodity and noncommodity values affect the amount and character of southern pine resources and vice versa?
2. How do social and human factors influence management of southern pine forests?
3. What are the potential approaches or strategies that can be used to help limited-resource landowners increase the total value of their forests?
4. What are the relationships between rural communities and the southern pine resource?
5. How best can we assess the noncommodity values of southern pine forests?

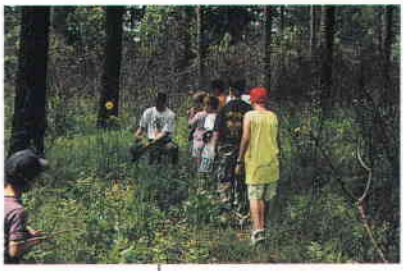
Noncommodity forest values know no boundaries.

Legal, Institutional, and Economic Framework for Forest Conservation and Sustainable Management

Management of southern pine forests is tempered by the legal, institutional, and economic framework on which land-use decisions are made. This framework affects the long-term sustainability, productivity, and ecological integrity of the southern pine ecosystem. For example, landowners face a myriad of laws and regulations that directly or indirectly affect their use of southern pine resources. Also tax, inheritance, and environmental laws can affect the flow of capital into and out of forest management—and these affect investment in long-term forestry. In the South this framework has implications for the long-term sustainability of ecosystem outputs, timber markets, and other commodity and noncommodity values. Changes in land-tenure patterns are leading to fragmentation and revised management objectives that may, in turn, restrict management options that are or will be available to the landowner.

The following questions consider the framework for forest conservation and sustainable management:

1. Policymakers can implement regulations and incentive programs to encourage certain types of forest management, but how effective will these techniques be? How will regulations affect the resource(s) they are designed to protect? How will the effects differ over time? And what will be their effects on other desired behaviors?
2. What are the effects of recycling, use of nonwood substitutes, national and international competition, and technological change? What values do southern forests produce and what will be their long-term sustainability?
3. What are the welfare and market implications of sustainable forestry? What will be the long-term ecological consequences of implementing changes in forestry policies and practices?
4. How are limited-resource southern pine forest owners affected by current or proposed tax, inheritance, or environmental laws notwithstanding the unpredictability of market changes?
5. How do these effects compare with those experienced by other groups? Are laws affecting southern pine forests meeting the policy objectives of lawmakers? How are institutional factors related to long-term sustainability of the southern pine resource?



Conservation education will help ensure the long-term stewardship of nature's resources.

Examples of Collaborative Research and Development

A number of multidisciplinary research activities are occurring at SRS sites. Many are designed to encourage additional cooperative efforts. Here are a few examples:

Longleaf Pine Restoration and Management

In 1994, 17 scientists from 14 SRS research projects joined with employees in the U.S. Department of Agriculture Forest Service, Southern Region to develop a broad plan for longleaf pine ecosystem restoration and management. Early team efforts focused on an assessment of current conditions, strategic planning, and partnership building. While SRS scientists had supported related research for decades, this team effort provided an opportunity to develop a more integrated approach to longleaf pine ecosystem research. The SRS's long-term, core longleaf research studies were bolstered by ecosystem management grant monies. Those funds were used to develop an internal, competitive grant program that would provide seed funding for new studies or to enhance ongoing studies. By 1997, over 70 manuscripts, abstracts, and posters resulted from this effort. More importantly a process of collaboration and communication was then available to scientists with common interests and goals.

Prior to widespread harvest of virgin longleaf pine in the early 1900's, this species occupied over 90 million acres in the American South.

In partnership with the newly formed Longleaf Alliance, scientists and managers from across the South now meet regularly to address collaborative research and management strategies related to sustainability of the longleaf overstory and understory communities. The SRS longleaf program addresses important scientific questions related to restoration ecology, fire ecology, smoke management, impacts of silvicultural alternatives on plant and animal communities, improved technology for longleaf overstory/understory regeneration, and the socioeconomic factors associated with sustainable management of both Federal and non-Federal lands.

Long-Term Soil Productivity/Monitoring Productivity and Environmental Quality

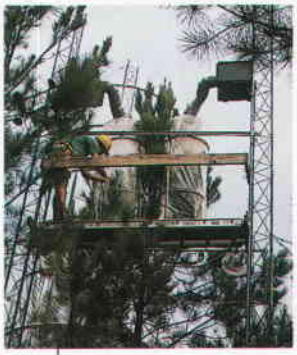
In 1990 the Forest Service began a long-term soil productivity (LTSP) study in major commercial timber types within national forests across the country. The SRS is studying the loblolly pine type and has set up installations in Texas, Louisiana, Mississippi, and North Carolina. Following the harvest of a mature stand of trees, research scientists and their partners studied nine combinations of soil compaction and organic matter removal. The ecosystems now developing on those sites are monitored closely to determine relationships among soil compaction, organic matter removal, and tree growth. A series of companion studies involving forest industry, the SRS, and several universities have begun. Dubbed MPEQ (Monitoring Productivity and Environmental Quality in Southern Pine Plantations), the effort includes studies in east Texas, north and southeast Louisiana, and south Georgia. In both the LTSP and MPEQ studies, timber stands are documented by extensive sampling of soils and all aboveground vegetation. Pine growth and a variety of soil and other biological processes will be monitored through the next harvest rotation.

Soil compaction, removal of organic matter, and tree growth are carefully measured in long-term SRS studies.

The regional nature of the LTSP study and the types of environmental monitoring that are conducted have enabled scientists from four SRS RWU's to begin a study of coarse woody debris decomposition on the sites. Decomposition rates for various sizes of woody debris will be correlated to environmental conditions on the sites and to the role of termites and other wood-inhabiting insects. Over time, changes in chemical composition (tannins and structural chemicals) also will be determined and related to other measured variables.

Southeast Tree Research and Education Site

The Southeast Tree Research and Education Site (SETRES) was established in 1992 as a major project of the Southern Global Change Program. It was designed to examine the interactive responses of loblolly pine growth and physiology to changes in atmospheric carbon dioxide (CO_2), nutrition, and water. The SETRES is a strong and active collaboration of the Forest Service, North Carolina State University's Forest Nutrition Cooperative, and several industrial partners. The CO_2 experiments progressed from installing branch bags to enclosing entire 14-year-old trees in open-top chambers. This work was completed in winter 1999.



A collaborative effort with North Carolina State University's Forest Nutrition Cooperative and several industrial partners, the SETRES was designed to examine the interactive responses of loblolly pine growth and physiology to changes in atmospheric carbon dioxide, nutrition, and water.

The SETRES is a large study containing four blocks of 50-m^2 plots. Stand responses are being assessed and, so far, have clearly demonstrated the plasticity of loblolly pine in response to fertilization. Growth rate has tripled in 5 years. In addition, collaborative partners have joined the study and are using the well-executed and maintained experimental design. Collaborative projects like the SETRES are good examples of work performed under a CCT. The following are other examples of ongoing research on this important site:

Impacts of elevated CO_2 on loblolly pine physiology (NC State); whole-tree and stand water relations (Duke University); treatment impacts on wood quality (NC State); CO_2 impacts on pest resistance (NC State); impacts of fertilization on soil water quality (Duke University); impacts of treatments on aspects of long-term soil productivity (NC State and Purdue University); root growth and dynamics (Duke University); seasonal variation in carbon gain as affected by environmental responses (Virginia Tech); testing and applying mathematical growth models (Southern Global Change Program, University of New Hampshire, Louisiana State University, and Oak Ridge National Laboratory); and inclusion in a long-term multisite soil archives (Duke University).

Most of these projects included the training of graduate students and the SETRES contributes in large measure to the continuing education of southern foresters. The SRS scientists will maintain the SETRES as a long-term experiment and include it as a centerpiece of regional studies.

Regional Competition Control Project

In the early 1980's, the U.S. Department of Agriculture Forest Service's Vegetation Management Project in Auburn, AL, began developing a cooperative, long-term study known as the Competition Omission Monitoring Project (COMP). The project is composed of a multidisciplinary group of cooperators from the former Southern and Southeastern Forest Experiment Stations, several southern universities, and many forest industry cooperators. The group operates under the premise that increases in crop tree growth and yield alone would be insufficient to justify some forest vegetation management treatments. On some ownerships, these benefits would have to be weighed against possible changes in soil productivity, wildlife habitat, biodiversity, and wood quality as well as the possible effects of treatment on insect populations and pathogens. The study's key features include its uniform design and sampling protocol on each of the 13 sites, which are found from Louisiana to Virginia in several physiographic provinces.

After more than 15 years of study, several multiple-author papers have been published and the study remains viable, even though there have been major changes in corporate ownership and investigation staff. The study's lasting strengths stem from an informal team organization that is committed to sustaining high-value, cooperative, long-term studies; where the most meaningful information is derived only after 10 to 20 or more years of continuing investigation. In addition to addressing the study's first objectives, the COMP also is considering several economic evaluations of commodity and noncommodity values. Its

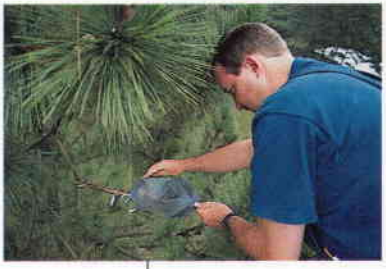
Continued monitoring of vegetation management enables scientists to weigh the benefits of increased crop tree growth with changes in soil productivity, wildlife habitat, and biological diversity.

members are conducting surveys of public preferences and how they are linked to study treatments. The COMP framework also provides opportunities to examine the ecology of mixed- and single-species stands and the processes that influence resource conservation, uptake, and cycling within stands that developed on competition-control treatment sites.

Partnerships and collaborative research provide a range of other new opportunities as well. For example, several SRS RWU's and their university partners are conducting studies to assess the use of fire and other tools for reducing or removing forest fuels. Their collaborative efforts are helping reduce the risk of wildfire and restore forest health and productivity throughout the South.

Outcomes/Products

We consider development of the pine ecosystem CCT to be a practical endeavor designed to produce tangible products. In addition to filling research gaps, much progress can be made by simply integrating current knowledge. Outcomes from this integrated approach will strive to ensure that:



Unique to the forest research community Worldwide, lands and resources available to scientists at the SRS are the subject of well-documented, long-term studies.

1. Science-based information is available to all interested users and contributes to forest management practices on mixed land ownerships;
2. Research programs are substantial, integrated, and well organized—they respond to the needs of all forest users, to whom research results are widely disseminated;
3. Management options are designed to maintain forest ecosystem processes, functional relationships, and structure at all spatial levels;
4. SRS personnel provide information about the southern pine and pine-hardwood ecosystems, which will enhance a broad range of social, environmental, economic, and cultural values;

5. Cooperation and coordination among and between landowners, agencies, and organizations are used to achieve broad societal goals with regard to the southern pine ecosystem; and

6. Improved forest management practices reduce the number of TES plant and animal species that are listed.

To achieve such results we will need a number of new tools:

1. Integrated models that predict the effects that alternative vegetation management and harvesting treatments would have on plant succession, floral and faunal diversity, soil, water, wildlife, timber growth and properties, ecosystem structure and function, and economic efficiency;

2. Guidelines for managing pine and pine-hardwood forests that will simultaneously meet varied landowner objectives and sustain productive, functional ecosystems;

3. Guidelines for restoring longleaf pine and other ecosystems, including the use of prescribed fire to economically restore native flora and associated fauna;

4. Operational models for mitigating smoke hazards and documentation of the long-term effects that season and fire frequency have on tree growth, coarse woody debris and snags, and the composition and structure of understory vegetation including TES species;

5. Documentation of temporal trends in resource conditions and implementation of monitoring to evaluate the influence of management practices on long-term productivity;

6. Documentation of the socioeconomic, legal, tax, institutional and demographic effects of alternative management practices, land-use changes, and the associated fragmentation of forest; and

7. Guidelines based on cutting-edge science and technology that optimizes timber production on selected ownerships.

The Need for Collaborative Research

Over the last century, changes in societal values and the compounding effects of pressures on forest resources have redefined the research needs of forest industry, small landowners, and public resource managers. A new global marketplace has accelerated competition, causing stakeholders to reexamine long-term, generic research that, through often duplicative efforts, has wasted scarce resources (Burkett and others 1996). There are now opportunities for government, industry, and universities to develop collaborative, cooperatively funded research programs—programs that will help move forest science forward into a new century. We are confident such an approach will produce research results that are both useful to domestic and international forest policymakers and beneficial to those they serve.

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The Forest Service, U.S. Department of Agriculture (USDA), is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives as directed by Congress to provide increasingly greater service to a growing Nation.