McMahon, C.K., Barnett, J.P. 2001. Sustainability and productivity of southern pine ecosystems: a thematic framework for integrating research and building partnerships. In: Kush, John C., compl. Forest for your future – restoration and management of longleaf pine ecosystems: silvicultural, ecological, social, political and economic changes, Proceedings of the third Longleaf Alliance Regional Conference; 2000 October 16-18; Alexandria, LA. Longleaf Alliance Report No. 5: 161-168.

SUSTAINABILITY AND PRODUCTIVITY OF SOUTHERN PINE ECOSYSTEMS: A THEMATIC FRAMEWORK FOR INTEGRATING RESEARCH AND BUILDING PARTNERSHIPS

Charles K. McMahon (USDA Forest Service, Southern Research Station, 520 Devall Dr, Auburn, AL)
James P. Barnett (USDA Forest Service, Southern Research Station, 2500 Shreveport Highway, Pineville, LA)

ABSTRACT: In 1997, the USDA Forest Service Southern Research Station (SRS) published a Strategic Plan that formed a framework for addressing the Sustainability of Southern Forest Ecosystems. Six crosscutting themes were identified to facilitate research integration and partnership building among the widely dispersed SRS research work units. The Sustainability and Productivity of Southern Pine Ecosystems theme outlined in this paper, 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.

Introduction: In 1997, the USDA Forest Service Southern Research Station (SRS) published a Strategic Plan that formed a framework for addressing the Sustainability of Southern Forest Ecosystems (USDA Forest Service 1997). With our partners and other resource users we identified issues and needs that will determine the direction and effectiveness of SRS research and development programs. The SRS strategic plan forms a basis for a collaborative multi-disciplinary approach to these programs. The plan describes three broad research goals:

1. Measuring and monitoring forest resources. (What do we have?)
2. Understanding ecosystem structure, function, and processes. (How does it work?)
3. Ensuring environmental quality and sustainable productivity. (How can we use it without losing it?)

In order to achieve these goals, six operational crosscutting themes (CCT's) were established to integrate the work of our highly decentralized organization, build partnerships, and develop products that meet customers' needs. Four crosscutting themes focus on predominant manifestations of the South's forest resources, while two themes focus on the sustainable management of all forest ecosystems in the Southern Region. The themes include:

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

These themes represent a framework for organizing research and development activities in a way that lowers traditional disciplinary and institutional boundaries. They are not highly structured formal programs. They are dynamic and flexible; enabling the SRS research community to adapt to evolving customer needs and respond to emerging issues. Over 20 SRS research work units are contributing scientific support and financial resources to the challenges embedded in the themes. In addition, each research unit continues to support traditional SRS research and development studies and programs not covered by the themes.

OBJECTIVES

The Sustainability and Productivity of Southern Pine Ecosystems theme provides the basis 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, the theme development process provides a mechanism to bring together scientists, managers, and stakeholders, who can reach consensus on priorities. This theme is very broad, both technically and spatially. Key elements apply too much of the SRS research program, as well as to the programs of forest industry, southern universities, and some private research institutions. This paper is an abridged version of the pine theme booklet (USDA

Forest Service 2000) prepared by the members of the theme steering committee.[1] The booklet is now available on-line from the SRS web site http://www.srs.fs.fed.us

DEFINITION

In 1987, the World Commission on Environment and Development 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. **Sustainable productivity** in the context of forest ecosystems relates to the full spectrum of resources that people value in forests including wood fiber, recreation use, water yield and quality, abundance and diversity of flora and fauna, and other valuable 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).

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. 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. 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 threatened, endangered, or sensitive (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 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. A more obvious risk to sustainability occurs when forest ecosystems are lost to encroachment from urban development, highway and power line 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 domestic and international demands for resources. Human demands, once primarily for wood products, now include non-traditional products, and recreational pursuits.

Management Challenges: 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. Most small forest landowners in the 13 southern States have little capacity to conduct research to improve resource sustainability.

---

[1] SRS Sustainability and Productivity of Southern Pine Ecosystems theme steering committee: James Barnett, Rod Busby, Marianne Burke, Floyd Bridgewater, Don English, James Hanula, Nancy Herbert, Kurt Johnsen, Brad Kard, Kier Klepzig, Charles McMahon, Jeff Prestemon, Tim Rials, Bob Rummer, Mike Shelton, Ron Thill, Tom Waldrop, Joan Walker, and Nancy Walters. Theme co-leaders are Barnett and McMahon.

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 could apply the results of cooperative research to sustain wood production and other forest benefits. 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.

The Montreal Process (MP) is a process that describes a comprehensive set of seven criteria for forest conservation and sustainable management that is being used by the international forestry community. The MP 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 (Canadian Forest Service 1995). The MP 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 sort the broad issues and research questions about southern pine ecosystems.

MP Criterion #1: Conservation of Biological Diversity

The Southern United States is nearly unmatched in biological and genetic diversity. On this rich landscape a long history of intensive and extensive human use has occurred. Our growing human population, coupled with the varied land-use practices 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. There are few relatively undisturbed 'reference' sites within southern pine ecosystems, making it hard to know which elements have been lost or to interpret the patterns that remain. The status and distribution of rare species or rare genotypes are particularly difficult to determine. 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 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. 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. 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 must address three basic research goals:

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

MP Criterion # 2: 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, socio-economic worth, wildlife habitat, and other non-commodity aspects figure prominently in a forest's value. In addition, some very important questions remain regarding the sustainability of intensive silviculture. Science has shown 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? 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? Alternative management practices may affect the quality of wood, as well as other forest resources. How does plantation forestry affect wildlife species, recreation and other, less-tangible but very important values? Will such

practices indirectly benefit other more-sensitive domestic and international forest ecosystems? How can the productive capacity of the South's vast non-industrial forestry sector be increased? Are our strategies to increase productivity economically feasible or socially desirable? 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?

MP Criterion # 3: Maintenance of Forest Ecosystem Health and Vitality

As demands for wood and other forest products sharply increase, forestry professionals and non-professionals 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. 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 cosystem 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? Fundamental questions about maintaining and enhancing forest health in southern pine ecosystems include:

1. What is the condition of southern pine forests today? Baseline information about forest conditions is needed 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?

MP Criterion # 4: 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 lean 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 reflects 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 will help to ensure that forest and aquatic ecosystems provide their bounty for future generations. The fundamental research questions that must be addressed are:

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?

MP Criterion # 5: 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 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. In forests managed 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 life spans 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. Given the complexity and scale of such issues, we are not yet able to predict 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. 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?

MP Criterion #6: Maintenance and Enhancement of Long-Term Socio-Economic 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 forestlands also provide these benefits; but, 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. Southern Research Station scientists and their counterparts in the university community are using applied research to better understand the commodity and non-commodity values derived from private and public forests. Key questions include:

1. How do commodity and non-commodity 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 non-commodity values of southern pine forests?

MP Criterion # 7: 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 non-commodity 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. Policy makers can implement regulations and incentive programs to encourage certain types of forest management; but how effective will these techniques be? How will they 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 non-wood 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 vagaries 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?

Examples of Collaborative Research and Development: A number of multi-disciplinary, collaborative research activities are already occurring at the Southern Research Station. Many are designed to encourage additional, cooperative efforts. Here are just four examples that support the Southern Pine Ecosystems theme:

1. Longleaf Pine Restoration and Management

In 1994, 17 scientists from 14 SRS research projects joined with employees in the USDA 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. This team effort provided an opportunity to develop a more integrated approach to longleaf pine ecosystem research. The Station's long-term, core longleaf research studies were bolstered by Ecosystem Management grant monies; and 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 made available to scientists with common interests and goals. In partnership with the 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 socio-economic factors associated with sustainable management of both Federal and non-Federal lands.

2. 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 rotation. The regional nature of the LTSP study, and

the types of environmental monitoring that are conducted, have enabled scientists from four SRS research work units 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.

3. Southeast Tree Research and Education Site (SETRES)

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 (CO2), nutrition, and water. SETRES is a strong and active collaboration of the Forest Service, North Carolina State University's Forest Nutrition Cooperative, and several industrial partners. CO2 experiments have moved from installing branch bags to enclosing entire 14-year-old trees in open-top chambers. This work was completed in winter 1999. 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 SETRES are good examples of work performed under a crosscutting theme framework. The following are other examples of ongoing research on this important site: Impacts of elevated CO2 on loblolly pine physiology (NC State); whole-tree and stand water relations (Duke University); treatment impacts on wood quality (NC State); CO2 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); seasonal variation in carbon gain as affected by environmental responses (Virginia Tech); testing and applying mathematical growth models (Southern Global Change, University of New Hampshire, Louisiana State University, Oak Ridge National Laboratory, CSIRO-Australia); and inclusion in a long-term multi-site soil archives (Duke University). Most of these projects included the training of graduate students; and SETRES contributes in large measure to the continuing education of southern foresters. SRS scientists will maintain SETRES as a long-term experiment and include it as a centerpiece of regional studies.

4. Regional Competition Control Project

In the early 1980's, the USDA Forest Service Vegetation Management Project in Auburn, Alabama, began developing a cooperative, long-term study known as the Competition Omission Monitoring Project (COMP). The project is composed of a multi-disciplinary 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 study 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, COMP also is considering several economic evaluations of commodity and non-commodity values. Its 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.

The spirit of collaboration represented in each of these four examples is now being extended to explore new research and development opportunities. For example, several SRS research units and their university partners have recently begun collaborative studies to assess the use of fire and other tools for reducing or removing unhealthy forest fuel accumulations. Their efforts are helping to reduce the risk of wildfires and are also helping to restore health and productivity to southern pine ecosystems.

Outcomes/Products: We consider development of the Southern Pine crosscutting theme 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:

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. Station 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 is used to achieve broad societal goals with regard to the southern pine ecosystem.
6. Improved forest management practices, reduce the number of threatened, endangered, and sensitive (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 socio-economic, legal, tax, institutional and demographic effects of alternative management practices, land-use changes, and the associated fragmentation of forest.
7. Guidelines based on cutting-edge science and technology that optimizes timber production on selected ownerships.

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.

LITERATURE CITED

Burkett, V., S. Beasley, P. Roussopoulos and J. Barnett. 1996. Toward southern forest sustainability: a science agenda. Seventh American Forest Congress, Southern Region Forest Research Committee Report. Seventh American Forest Congress, Washington, DC. 27 p.

Canadian Forest Service. 1995. Criteria and indicators for the conservation and sustainable management of temperate and boreal forests; the Montreal process. Canadian Forest Service, Natural Resources Canada, Quebec, Canada.27 p.

USDA Forest Service. 1997. Strategic framework for the Southern Research Station. USDA Forest Service, Southern Research Station, Asheville, NC.24 p.

USDA Forest Service. 2000. Sustainability and Productivity of Southern Forest Ecosystems. USDA Forest Service, Southern Research Station, Science Update, SRS-001, Asheville, NC.27p.

World Commission on Environment and Development. 1987. Our common future. Oxford, United Kingdom: Oxford University Press.