USDA FOREST SERVICE FS-4000-1 (8/76) **RESEARCH WORK UNIT DESCRIPTION** Ref: FSM 4070	1. Number FS-SRS-4105	2. Station SRS
	3. Unit Location Auburn, Alabama	

4. Research Work Unit Title
Integrated vegetation management for sustaining southern forests and longleaf pine ecosystems

5. Project Leader (Name and address)
Charles K. McMahon, USDA Forest Service, 520 Devall Dr. Auburn, Alabama 36849

6. Area of Research Applicability	7. Estimated Duration
Primarily Southeastern United States with some national and international applications	5 years

8. Mission
To develop integrated vegetation management strategies and practices that enhance and sustain Southern forest diversity and productivity and to develop management systems and models for restoring and sustaining longleaf pine ecosystems.

9. Justification and Problem Selection

The Southern US Forest Region is characterized by high forest productivity, rich ecological diversity, and the prominence of a large private forest ownership. Today research must address ways to sustain and enhance forest productivity for an expanding array of goods and services while conserving soils, biodiversity, water quality and quantity, and special habitats for plants and wildlife. Practical and sustainable management systems are urgently needed by the 5 million private forest landowners in this region to achieve these goals. Conflicts surrounding the use and management of natural resources on both private and public lands will increase as we face population growth, urbanization and demographic shifts to the South. The combination of past land abuse, altered natural disturbance patterns, exotic pest invasions, and human pressures and development, leave us with dynamically changing forest ecosystems. It is projected that the acreage in pine plantations on private lands in the southeast will double by 2040, as will the expansion of non-native plants on all landscapes. Urban and suburban development is subtracting about one percent annually from the forestland base. Commodity and non-commodity outputs and amenities from our shrinking forest resource must be increased and enhanced. Ecologically sound and socio-economically viable forest vegetation management prescriptions and strategies will be critically needed by both public and private forestlands. On public lands, restoring degraded ecosystems, such as longleaf pine, is now a major management goal. After decades of decline, regeneration of this fire-adapted species is increasing on private lands. For more than 20 years, SRS 4105 in Auburn, AL has provided research leadership in forest vegetation management science, and longleaf pine ecology and management. We propose to continue research and development efforts in these critical areas, in support of the SRS goals and strategies. The comprehensive list of proposed accomplishments under each broad problem area can only be met by a continuation of the team approach with internal and external partners. A partial list of cooperators is shown in section 11.

Signature		Title	Date
Recommended:	G. Samuel Foster Signature on File	Assistant Director for Research	Signed on 8/16/00
L. Whitmore, Signature on File		Assistant to Staff Director	Signed on 8/28/00
W. T. Sommers, Signature on File		Staff Director, VMPR	Signed on 8/29/00
Approved:	Peter J. Roussopoulos Signature on File	Station Director	Signed on 9/11/00
Concurred:	Robert Lewis, Jr. Signature on File	Deputy Chief for Research	Signed on 9/21/2000

Forest Vegetation Management Research and Development

Introduction

An evolving mixture of land use characterizes the southern landscape. An expanding highway and right-of-way network divides an integrated complex of crop and pasturelands, pine plantations, and upland and bottomland mixed forests. The landscape is highly dissected with streams and rivers, and bordered by swamps and estuaries. Invasive plants are now continually encroaching on all land use. Specialized vegetation management strategies and methods are under development for all these land uses. Forest vegetation management will play a major role in this mostly forested landscape. Integrated forest vegetation management practices and strategies are required at the landscape level; and specialized systems are needed for a variety of forest types, site conditions and landowner objectives. Long-term investigations are especially critical for developing management strategies and integrated treatments for sustainable forest ecosystems in the South.

Modern forest vegetation management practices and strategies have been developing in the Southeastern region for the past 40 years. Most modern practices have been developed through partnerships between Forest Service research and forest industry. Unprecedented growth gains in pine plantations and predictable establishment of hardwoods have been realized by these new practices, especially those employing herbicides. Still much is to be learned about the consequences of these practices on water quality, biodiversity, and soil sustainability. Equally important is the need for a better understanding of those factors that influence the social acceptability of various vegetation management alternatives. Access to the full menu of vegetation management alternatives--biological, chemical, manual, mechanical and prescribed burning--will be required to achieve healthy, diverse, productive and sustainable forest ecosystems.

Problem selection

The use of herbicides offers safe, economical, and effective ways of achieving many goals related to forest health and sustainability. However, they are often perceived by the public to cause harm to the environment. As a result, many public land managers consider herbicides as socially unacceptable and are hesitant to use these tools. The private non-industrial forest owners, who dominate the Southern region, are more accepting of forest herbicides than their public-land counterparts. However, some are still apprehensive about their use. At the same time, the use of herbicides is on the increase on industrial forestland to increase forest productivity. Forest herbicides are also viewed as critical to solving current and future forest health problems related to the accumulation of forest fuels and the invasion of non-native plants. Yet this effective and safe vegetation management tool continues to be viewed as too risky by some policy makers and managers.

More than 30 studies in the South on the environmental fate and impacts of forest herbicides have shown that herbicides do move off treated sites, but the concentrations that appear in streams and soil solution, are below EPA drinking water standards and dissipate rapidly. Furthermore, no adverse environmental impacts either on treated sites or in the associated aquatic ecosystems have been documented. The infrequent use, low toxicity and low prescription rates are built-in safeguards for their use. It has also been demonstrated that the use of selective herbicides can improve wildlife habitat and help restore degraded ecosystems. Adverse wildlife impacts do not generally extend beyond those normally seen in other forest operations. Toxicological studies have shown exposure of wildlife to forest use herbicides is insufficient to cause health problems. There is much evidence that modern forest herbicides are safe from the standpoint of human health and safety and environmental impacts, when applied correctly.

One of the most serious potential impacts from forest management operations is sedimentation in aquatic ecosystems. Studies have shown that use of mechanical vegetation management methods can result in 20 to 400% more sediment than observed on chemically prepared sites. Thus, one can argue that when herbicides are used properly they can help protect water quality by reducing sedimentation in streams and riparian zones when compared to mechanical methods.

The average per acre cost in the southern US for mechanical site preparation is $122 compared to $70 for ground application and $97 for aerial applications of herbicides. Thus aerial chemical site preparation is the method of choice used by the industrial sector for production forestry. When site preparation is inadequate (as it frequently is with the least intensive mechanical treatments), a second stand treatment is often required to release the crop trees. Mechanical methods are not well suited for crop-tree release treatments. While manual methods can accomplish the release of crop trees in some situations, they are relatively ineffective, more expensive, and much more dangerous to workers than chemical methods. Therefore chemical release is still the method of choice in the South.

An area of critical concern across the US is that of wildfires. Wildfires cause enormous damage to some forest ecosystems, public and private property, and usually result in additional deposition of large amounts of sediment into aquatic ecosystems. Anecdotal reports indicate herbicide use may alter or reduce fuel loads and afford some protection from fire, but comparative studies are lacking. Such treatments for altering the structure and quality of fuel could reduce fire intensity and subsequent sediment yields, further protecting aquatic ecosystems and other resources.

There are many forest management objectives for which herbicide is an appropriate tool. A major problem in managing natural resources in today's socio-political environment is that there have been too few integrated comparisons of vegetation management alternatives, and too few syntheses of information to provide a scientific basis for decision making. **Thus, a lack of understanding of the environmental risks and benefits associated with the forest herbicide practices, as compared to other vegetation management alternatives, jeopardize their continued availability to forest managers. (Problem 1)**

Forest Vegetation Management research is now developing "ecological tools" for meeting many natural resource goals and objectives. In addition to enhancing commodity outputs, vegetation management techniques and technology are needed to create and maintain desirable plant and animal habitats; restore damaged forest landscapes; control invasive plants; maintain recreational areas, trails, and scenic vistas; and maintain rights-of-way for multiple uses. The principles of Vegetation Management can also be used to create mixed and uneven-aged stands, a desired future condition for many of our national forests and some privately owned woodlands.

To guarantee sustainable forest management while increasing commodity and non-commodity productivity, ecologically sound and socio-economically viable vegetation management prescriptions will be critical for both public and private forestlands. Coupled with prescription development is the imperative for understanding how integrated vegetation management treatments affect forest ecosystem sustainability, resiliency, and function. Much of this information will come from the continuation and expansion of long-term studies already in place, with a renewed focus and more multi-disciplined research partnerships.

There are a number of vegetation management prescriptions today that integrate herbicide, prescribed burning, or mechanical methods, yet there are many information gaps on the proper selection of the optimum combination to meet multi-resource goals. And the biocontrol alternative has yet to be fully incorporated. New combinations will be required as forest management strategies evolve. Completely new treatments and strategies will be needed for non-native plant control and containment. Little is known about the effects of vegetation management treatments on long-term site productivity and biological diversity. Until both the short- and long-term consequences of vegetation management treatments have been determined on the principal pine and pine-hardwood forest site types in the Southeast, it will be difficult to know what treatments and combinations provide the most ecologically sound and cost-effective results. **Thus, a lack of vegetation management strategies and prescriptions for sustainable forest management, and the lack of knowledge of their multi-resource benefits and impacts, limits their acceptance and application in southern forestry. (Problem 2)**

Longleaf Pine Ecosystem Research and Development

Longleaf pine ecosystems once occupied over 90 million acres in the South. Today less than three million acres remain, with many of the remaining acres in an unhealthy state, due partially to the exclusion of fire. The longleaf ecosystem figured prominently in the cultural and economic development of the South. Today, these forests and landscapes represent significant components of the region's ecological diversity, provide essential habitat for many rare animals and plants and offer new economic opportunities for many private landowners. Some longleaf pine communities sustain very high numbers of vascular plants per unit area, and rank among the most species-rich plant communities outside the tropics. The continuing loss of longleaf forests has prompted increasing concern among conservation and natural resource organizations. Restoration efforts are now underway on National Forests and other public lands in the Southeast. Active research and technology transfer partnerships have been formed between the public forestry sector, (National Forests, Department of Defense, U.S. Department of Interior, States, etc.) and the private forestry sector.

A major impediment to restoration and management efforts is the lack of reliable models and supporting data bases which can accurately predict the regeneration, growth, yield and mortality of longleaf under a range of site conditions and management regimes which include even-aged, two-aged, uneven-aged, and also natural and artificial regeneration systems. Also lacking is an understanding of how fire regulates ecological processes and structures in longleaf ecosystems and how this knowledge can be translated into prescriptions and user guidelines. **Thus, reliable restoration and management systems and models for sustaining longleaf pine ecosystems are needed. (Problem 3)**

10. APPROACHES TO PROBLEM SOLUTION

Approach to Problem 1: A lack of understanding of the risks and benefits associated with the forest herbicide practices, as compared to other vegetation management alternatives, jeopardize their continued availability to forest managers.

This broad problem area is divided into two elements.

Element 1. Comparative environmental risks and benefits for vegetation management alternatives. Complete studies begun in the last 5 years and evaluate the knowledge accumulated over the last 20 years with emphasis on a state of knowledge synthesis to incorporate the newest evidence relative to risks and benefits from forestry, wildlife, and aquatic impacts research.

Research in Problem 1 is focused on the impacts of forest management practices on ecosystem functioning in forest watersheds. Species diversity for aquatic and terrestrial plants, population dynamics and community function in aquatic ecosystems, and water quality are important parameters for assessing the impacts of forest management practices. Identifying attributes of methods and practices for mediating against potential adverse environmental impacts is an important component of Problem Area 1 research.

Forest management must continue to become more intensive on portions of our forest lands due to increasing population pressure, increasing human needs for multiple use of forest lands, and the concomitant reduction in area available for intensive forest management coupled with ever increasing needs for wood fiber. In order for those lands under intensive forest management to provide sustained yields and to protect the ecosystems they encompass, research must provide adequate comparisons of the impacts of various methods for accomplishing the most important aspects of forest management on a landscape basis: harvest, site preparation, stand establishment, crop-tree release, and fuel management for protection of forest ecosystems from catastrophic fire events. These impacts include aquatic ecosystem contamination from pesticides and sediment, terrestrial and aquatic ecosystem species diversity and functioning, etc. Much of the next five years will be spent in reporting results from studies currently under way and those recently completed. Where possible, published reports will synthesize the information we already have available from a variety of sources. New studies will be conducted using landscape scale approaches and whole watersheds as the primary treatment unit. Such approaches require multi-disciplinary team participation. Cooperators include university, forest industry, and other FS units working toward common goals.

Accomplishments planned for the next 5 years include:

1. Complete field studies begun in the last 5 years and publish:

   a. Fate of sulfometuron methyl and imazapyr in forest ecosystems with a synthesis of the literature leading to a comprehensive evaluation of their potential adverse environmental impacts.

   b. Impacts of imazapyr applied at rates up to 100 times the normal prescription on benthic macroinvertebrates in cypress domes.

   c. Comparison of aquatic ecosystem impacts of clear cutting with and without streamside management zones utilizing mechanical or chemical site preparation.

   d. Comparison of the effectiveness of three different streamside management zone widths for mediating against movement of sediment and herbicide to streams.

   e. Movement of triclopyr from single stem injected sites to streams.

   f. Relative rates of movement of triclopyr, imazapyr, and hexazinone to streams following simultaneous application to watersheds in the Ouachita Mountains of Arkansas.

   g. Impacts of different harvesting regimes on stream channel geomorphology in the Ouachita Mountains of Arkansas.

2. Initiate new studies:

   a. Optimal streamside management zone width needed to mitigate aquatic impacts of forest herbicides and sedimentation.

   b. Environmental impacts of tank mixtures and new herbicides as they become available.

Element 2. Forest Vegetation Management and water quality standards and guidelines. Continue to participate in the review and development of water quality standards and guidelines for forest vegetation management.

Water quality standards are codified in several places including the Clean Water Act, the Safe Drinking Water Act, and are affected by regulatory actions including EPA's regulations on total maximum daily loads (TMDL), and changes in definitions of non-point source pollution and polluters. The hundreds of thousands of landowners in the South have varying reasons for forest ownership, differing management objectives, and unique time frames and financial resources. Professional foresters are challenged to prescribe silviculturally sound management activities while accounting for individual needs, protecting non-commodity forest resource values and minimizing off-site adverse impacts to public resources, such as water quality, aquatic habitat and biota. In order to provide guidance to forest managers and owners and to meet the objectives of the Clean Water Act - "to restore and maintain the chemical, physical and biological integrity of the Nation's waters", each state in the South has adopted Best Management Practices (BMP) for the prevention of non-point source pollution from forestlands. Each has instituted programs to encourage the use of BMP when forests are treated with management practices that involve soil disturbance, chemicals or fire. While there is general BMP consistency among the states, significant variation also occurs. Other water quality standards and regulations in the US and around the world are similarly variable and at times contradictory. When technical reasons for such variation are not evident, managers and owners of forestland in affected states are understandably confused and the credibility of these guidelines is diminished. This research and development effort is intended to improve understanding of the technical basis of water quality guidelines and promote regional, national, and international consistency by identifying and describing standards that are based on sound scientific principles.

Accomplishments planned for the next 5 years include:

1. Evaluate existing and proposed water quality standards and their rationale for pesticide-related issues. Compare and publish water protection standards around the world for principal wood-fiber producing nations. This effort will involve cooperators in the major fiber producing nations of the world and will focus on individual water quality regulations and rationale within individual states, provinces, and regions.
2. Participate vigorously in the water quality debate, related to pesticide issues, at the local, state and national level through publications and invited presentations.
3. Continue to participate in national and regional training workshops related to pesticide use and benefits and risks communication strategies.

Approach to Problem 2: Lack of vegetation management strategies and prescriptions for sustainable forest management, and the lack of knowledge of their multi-resource benefits and impacts, limit their acceptance and application in southern forestry

This broad problem area is divided into two elements

Element 1. Forest vegetation management prescriptions and practices. Continue to develop and evaluate forest vegetation management treatments, prescriptions, and strategies for the purpose of enhancing forest productivity for commodity and non-commodity values. Evaluate the longer term consequences of vegetation management prescriptions by continuing the measurements and monitoring of six long-term cooperative studies that are unique in the region at 22 sites that are examining both pine and pine-hardwood cultures. Add other multi-resource assessments on these sites when opportunities for funds and research partners arise. Publish timely findings on multi-resource and functional outcomes.

Research and development of new treatments and combinations are still needed to expand silvicultural tools for mixed-uneven-aged management and intensive culture of pines and hardwoods, and all levels in between, including restoration activities. Integrated prescriptions are needed that properly employ prescribed burning, herbicides (selective and broadcast), mechanical, manual, and biological approaches to achieve predictable desired future conditions. Long-term studies on the establishment and development of pine and pine-hardwood stands, both plantations and mixed-aged stands, are a major responsibility of this problem area.

The region-wide cooperative study on competition—The Competition Omission Monitoring Project (COMP)--continues to forge the basic research needed in the developing field of forest vegetation management. This multi-site study across several eco-provinces is providing both basic and practical understanding of loblolly pine plantation development over the long term (presently all sites age 16 years). A common study design at 13 locations is testing plantation development with and without woody and herbaceous plant competition, including maximum growth in the absence of competition. Evolving partnerships on these sites are yielding information on a list of concerns and questions regarding extensive versus intensive forest culture. Monitoring of soil productivity and floristic succession will continue as part of this project and other ongoing investigations, and will be reported over the next 5 years. Also, these studies are generating invaluable long-term growth and yield data, both at the single-tree and stand level, for loblolly pine and hardwood associates.

Because of the rapid developments in forest vegetation management and forestry herbicide use, there is a continuing technology transfer (TT) responsibility to managers of the National Forests, non-industrial and industrial lands across the Southeast and nation. Synthesis publications have been the hallmark of past technology transfer efforts usually through partnerships with regional forestry organizations and societies, along with continuing education, workshop, and invited presentations. Innovations in information transfer will be incorporated in this area during the next 5 years, with website development and partnering on websites. Activities will further expand to encompass more TT effort with exotic plant control and containment within the region.

Accomplishments planned for the next 5 years include:

1. Continue measurements of the long-term regional study--The Competition Omission Monitoring Project (COMP)--at 13 locations examining pine and pine-hardwood stands, with and without the herbaceous component; and to gain multi-resource information while examining critical processes, investigating and reporting on the following:

   a. Remeasure pines and hardwoods for all sites at stand age 20 (about 8,500 pines and 15,000 hardwoods), and report on results at age 11 and 15.

   b. Remeasure understory vegetation at all sites at age 20 (1,000 plots) and report on succession and floristic diversity during the first 15 years.

   c. Complete analyses of soil samples collected at year 15 for all 13 sites and report on soil changes between age 0 and age 15 as influenced by the intensity of vegetation management, including changes in carbon and nitrogen sequestration, indicators of acidification (calcium and magnesium levels), and growth limiting nutrients (phosphorus and potassium levels).

   d. Sample pine trees on all sites to determine influences of treatments on wood properties. The scope and intensity of this examination will depend upon the acquisition of outside grant funds.

2. Continue vegetation management prescription development and technology transfer of new and developing treatments, including the following:

   a. Report on the effectiveness of selective basal bark treatments tested on common woody species at several timings, two rates, and two locations

   b. Devise and test treatments suitable for multi-attribute management on National Forest Systems and non-industrial private forestry lands.

   c. Contribute as needed to the development of effective and safe use of backpack and tractor application systems for forest herbicides.

   d. Continue to provide technology transfer assistance to the National Forest System, States, and forest industry on developments in integrated vegetation management systems and on the safe and effective application of forestry herbicides.

3. Document baselines of the influence of vegetation management treatments on stand-level attributes, community succession, floristic richness and biodiversity, and soil development. Without baselines, the outcomes from other research cannot be adequately assessed, especially levels of floristic richness and diversity as well as soil nutrient and physical qualities.

   a. Publish results from COMP on the long-term changes in floristic species and soil factors.

   b. Report on soil changes and recovery in nutritional and physical soil properties during the first 9 years following a full array of site preparation and soil remediation treatments (from chainsaw felling only to root raking and harrowing with herbicides and fertilization).

   c. Document how mixed pine-hardwood stands in the loam-hills ecotype change using a chronosequence from age 1 to 110 in structure, composition, understory flora, and soils (carbon and nitrogen sequestration).

d. Analyze data and report on a multi-attribute assessment of site preparation effects on loblolly pine stands. Replicated study stands were on National Forests at 15 years old and industrial forests at 11 years old. Stand attributes that have been investigated include differences in structure, floristic diversity, soil sustainability, primary productivity and health indicators, user preferences, projected yield, and economic outcomes.

Element 2. Non-native invasive plant species control and management. Develop and evaluate vegetation management treatments, prescriptions, and strategies for control of invasive plants in the region. Continue to develop a program addressing invasive/exotic plant management with elements in research, extension, and collaborative planning with States, the National Forest System, and industry for monitoring, control, and containment. Seek grants with collaborative partners to expand the scope of the program and publish results of studies underway

Non-native and even some native invasive plants are forming a new and increasing component of our Southern forests. Billions of dollars in lost forest productivity are at stake as well as our native plant communities and wildlife habitat. Plant invaders can completely alter fire regimes, nutrient cycling, hydrology, and energy budgets in native ecosystems. Prevention, early control and containment, and monitoring are the needed elements to combat and manage non-native plant invasions. The active role that has been played in the past by SRS 4105 in developing a collaborative kudzu-integrated management program will be expanded further to focus on the most threatening invasive species. Collaborative programs are the key to dealing with this problem. Research, extension, and collaborative support roles will be a part of planned activities. Potential research programs will depend on securing cooperative funding opportunities and partners.

Accomplishments planned for the next 5 years include:

1. Continue prescription development and research on invasive/exotic plant management. Analyze data and report on comparative studies underway on control treatments for cogongrass, Chinese privet, Chinese wisteria, and trumpetvine. Establish new research studies as part of multi-partner research team, with the scope contingent upon acquisition of grants.

2. Continue to collaborate with partners in state universities, state governments, and Forest Service on survey and monitoring strategies, control, containment programs for non-native invasive plants.

3. Assist Forest Service (Forest Inventory and Analysis and Forest Health Monitoring groups) in training State surveyors and provide identification tools for the first regional inventory of exotic plants.

4. Enhance technology transfer assistance to forest landowners, managers and regulators on the management of exotic plants as well as the management of native plant communities.

Approach to Problem 3: Reliable restoration and management systems and models for sustaining longleaf pine ecosystems are needed.

This broad problem area is divided into three elements:

Element 1. Fire Ecology of Longleaf Pine Ecosystems: Evaluate the influence of fire as a natural and anthropogenic disturbance that regulates ecological processes and structures in southern forests and assess its value as a means for restoring and sustaining longleaf pine ecosystems.

Interruption of natural fire regimes in the Southeast has resulted in alteration of native plant abundance to a degree that threatens long-term longleaf pine ecosystem sustainability. The decline of longleaf pine, native grasses and forbs and increase in competing trees and shrubs, forming high-density midstory fuel ladders, are the direct results of decreased fire frequencies. These altered ecosystems have become increasingly vulnerable to destruction by catastrophic fire, which may also directly threaten human life and property, and invasion by noxious weeds and undesirable woody plants.

Restoring periodic fire as a disturbance agent is fundamental to the ecological restoration and maintenance of longleaf pine ecosystems. However, prior to proceeding with widespread implementation of prescribed fire on a management scale, reliable information concerning the appropriate fire frequencies and seasons needs to be determined for the wide range of site conditions currently and potentially occupied by longleaf pine ecosystems. While some plant communities are currently of the proper composition and structure for immediate use of fire, numerous others must be altered by other means such as mechanical, chemical or biological treatment (see element #2) before fire can be safely and effectively applied to achieve desirable results. Thus a period of intensive restoration may be required prior to using prescribed fire to achieve and maintain desired landscape mosaics of healthy forests in concert with long-term sustainable management plans.

Accomplishments planned for the next 5 years include:

1. Quantify the response of plant community composition, structure, diversity, productivity and nutrition; forest fuels; coarse woody debris; soil properties; and wildlife habitat conditions to prescribed fire on longleaf pine sites.

2. Evaluate the efficacy of prescribed fire treatment as a means for regulating ecological processes to achieve more desirable longleaf pine ecosystem conditions.

3. Assess ecosystem conditions resulting from the seasonality and frequency of prescribed fire treatments across a wide range of longleaf pine ecosystem types to determine which fire regimes provide beneficial or deleterious site-specific results that can be translated into useful recommendations for management.

Element 2. Restoring and Sustaining Longleaf Pine Ecosystems: Determine the efficacy of mechanical, chemical and biological treatments as management techniques for forest ecosystems that require alteration of composition, structure and/or processes to overcome biophysical thresholds that impede restoration and/or maintenance as longleaf pine ecosystems.

Periodic fire is widely recognized as an essential ecological process that historically sustained natural longleaf pine forests. The reintroduction of fire through prescribed burning is frequently proposed as the principal means for restoring and maintaining these disturbance-dependent ecosystems. However, if ecosystem degradation has progressed beyond key biophysical thresholds, then effective restoration will likely not be achieved simply by the reintroduction of fire. Where the herbaceous understory has been severely degraded, fine fuels may be insufficient to obtain desirable results from prescribed fire. Where excessive fuels from woody plants have accumulated, such as midstory fuel ladders, a severe risk of further damage to the ecosystem (and associated human life and property) exists, if prescribed fire is applied. Fire will also be ineffective in restoring the longleaf pine ecosystem wherever its fundamental elements of composition are absent.

Therefore, restoring healthy longleaf pine ecosystems on sites that have been degraded beyond key biophysical thresholds will likely require mechanical, chemical and/or biological treatments. These techniques may often be needed as initial treatments to restore essential components and structures in the ecosystem, as a prerequisite for the safe eventual reintroduction of prescribed fire. Considering the wide range of existing conditions among longleaf pine ecosystems, from mildly to highly degraded, it is quite likely that combinations of treatments will be needed for developing effective restoration and maintenance prescriptions. Mechanical, chemical and biological treatments, either in place of fire or as a prerequisite to fire, need to be evaluated.

Accomplishments planned for the next 5 years include:

1. Assess the effectiveness of mechanical midstory reduction using various harvest machine systems for diminishing the stand-replacement fire hazard and improving the composition, structure and diversity of the plant community on a variety of sites representative of the longleaf pine ecosystem throughout the southern United States.

2. Evaluate the efficacy of roller chopping and mowing treatments, both individually and in combination with prescribed fire, for improving plant community characteristics and decreasing the fuel load and catastrophic fire risk associated with saw-palmetto understories and midstories in the longleaf pine and southern slash pine ecosystems of the Coastal Plain.

3. Examine the usefulness of herbicides for improving the composition, structure, diversity and productivity of longleaf pine ecosystems as a prerequisite to prescribed burning or as a replacement for fire under circumstances that prelude its use.

4. Determine treatment combinations and develop type-conversion prescriptions necessary for effectively re-establishing longleaf pine ecosystems on sites currently dominated by a variety of off-site forests, including loblolly, slash and sand pines and various hardwoods, considering the initial status of the ecosystem and management constraints.

Element 3. Silvicultural Systems and Prediction Models for Sustaining Longleaf Pine Ecosystems: Evaluate even-aged and uneven-aged silvicultural methods for naturally regenerating longleaf pine ecosystems, including assessment of changes in plant diversity, forest succession, seed production and site productivity. Develop models that combine the strengths of density-dependent individual-tree models and stand growth and yield models.

Developing silvicultural systems that successfully regenerate longleaf pine seedlings is crucial to the long-term viability of longleaf pine management and to survival of the ecosystem itself. While the technology of reliable containerized longleaf pine seedlings has been well developed and is highly useful for many restoration and reforestation efforts, artificial regeneration may not always be an economically viable option for lands receiving lower-intensity management. Therefore, it is essential that reliable natural regeneration techniques be developed as a management option for longleaf pine. A fundamental challenge for sustainable longleaf pine silviculture is to maintain conditions within the longleaf pine ecosystem that facilitate natural regeneration. Uneven-aged and even-aged silvicultural methods, that provide a structure appropriate for seed dispersal, germination and development, should afford effective regeneration in the longleaf pine ecosystem. Further refined shelterwood approaches (such as deferment harvesting) and group selection procedures (which capitalize on the natural gap-phase regeneration dynamics of longleaf pine) have substantial potential as regeneration methods that, in combination with prescribed fire and other silvicultural techniques, could significantly enhance the long-term sustainability of the longleaf pine ecosystem.

Since traditional stand-level growth and yield models are known to have inflexible structures and limited resolution, new models are required to address the needs of ecosystem management on public lands and longleaf pine culture on private lands. To address the wide range of conditions encountered throughout the range of the longleaf pine ecosystem, the model must incorporate stand dynamics and environmental variables. In meeting land manager needs for higher resolution and greater spatial detail, the model must incorporate growth processes at both the individual tree and stand levels. A density-dependent individual tree model will be developed from newly devised sampling methods and measurement techniques, which allow quantification of within-tree growth and competition among tree crowns

Accomplishments planned for the next 5 years include:

1. Determine the geometric configuration of canopy gaps created through uneven-aged silvicultural treatments which best ensures natural regeneration success in longleaf pine forests and quantify the composition, cover and diversity changes in understory plant communities during gap-phase regeneration in these ecosystems.

2. Continue long-term studies of longleaf pine, under even-aged and uneven-aged management, focusing on essential aspects of stand regeneration including pollen, cone and seed production and tree seedling germination and development.

3. Continue the long-term, naturally regenerated Regional Longleaf Pine Growth Study (RLGS).
   a. Conduct 40-year remeasurements and install 5th set of plots in the 20-year old age class.
   b. Refine relationships between stand characteristics, thinning activities, and pole production.
   c. Develop tree growth and mortality models that are independent of tree/stand age.
   d. Reexamine climate/growth rate relationships from 20-year old time-replication plots.
   e. Relate understory species abundance and diversity to stand characteristics and past fire history.
   f. Expand the geographic range of study into the Carolinas and Georgia.
   g. Complete analyses of pine needle fall with respect to stand characteristics and climate.

4. Complete the development of a three-dimensional density-dependent individual tree model for longleaf pine forests on Eglin Air Force Base

11. COOPERATORS (partial list):
Auburn University, Alabama A&M, Tuskegee, Mississippi State, Louisiana Tech, Virginia Tech, Florida State, Florida A&M, Stephen F. Austin and Tarleton State Universities. The Universities of Florida and Georgia
Auburn University Silvicultural Herbicide Cooperative
T.R. Miller Mill Company, AL; Champion International, AL, International Paper, Weyerhaeuser, Potlatch, Tenneco Packaging, The Timber Company,
American Cyanamid, Dupont, and Monsanto Corporations
NCASI (National Council of the paper industry for Air and Stream Improvement)
Tall Timbers Research Station; Jones Ecological Research Center
Southern State Forestry Organizations in AL, GA, FL, TX
Southern Research Station Research Work Units: 4703 Auburn, AL; 4104 & 4105 Athens, GA; 4201 Clemson, SC; 4154 RTP, NC; 4111, Pineville, LA; 4802 New Orleans, LA; and 4801 Asheville, NC
The Longleaf Alliance, The Nature Conservancy
Southern Region National Forests in AL, GA, FL, MS, LA, SC, NC, TX, AR
Department of Defense Bases: Eglin Air Force Base, FL; Fort Benning, GA
International forestry organizations in Australia, Canada, England, France, New Zealand and the Peoples Republic of China

12. ENVIRONMENTAL CONSIDERATION: An environmental analysis will be conducted for each new field study to determine if it is covered by: a) the categorical exclusions as described under FSH 1909.15, Section 31.1, September 21, 1992; b) an existing Environmental Assessment (EA) or Environmental Impact Statement (EIS); or c) requires a new EA or EIS.

13. STAFFING and FUNDING

Problem	Scientist-Years (SY's) of the RWUD				
	year1	2	3	4	year5
1	1.25	1.25	1.25	1.25	1.25
2	1.25	2.25	2.25	2.25	2.25
3	2.50	2.50	2.50	2.50	2.50
Total SY's	5.00	6.0	6.0	6.0	6.0
$ (In millions)	1.25	1.5	1.5	1.5	1.5

At present the research scientist staff includes one Supervisory research chemist as the project leader, three research forest ecologists and one volunteer emeritus research forester. In addition, one support chemist and one support physical scientist support the work of Problem 1. One technician supports Problem 2 and one technician supports problem 3. Temporary lab and field technicians support all three problem areas. Problem 3 technician is located on the Escambia Experimental Forest near Brewton, AL, approximately 3 hours from the Andrews lab in Auburn. This 3000-acre experimental forest is located in south Alabama and is managed by the unit. It is under a 99-year lease (established in 1947) from the T.R. Miller Mill Company of Brewton, AL. and supports many long-term longleaf pine research studies and demonstration areas. Future plans include the addition of one research forester to fill behind the emeritus scientist position to support Problem 3 (element 3), and one research forest ecologist to support the expanding work of Problem 2 related control and management of exotic and non-native invasive plants (element 2). One technician will also be needed to support problem 3 (elements 1 and 2).