USDA-Forest Service RESEARCH WORK UNIT DESCRIPTION Ref: FSM 4070	1. Number FS-SRS-4159	2. Station Southern Research Station
	3. Unit Locations Monticello, AR; Crossett, AR; Hot Springs, AR Nacogdoches, TX; Pineville, LA	

4. Reseach Work Unit Title

SRS-4159: Ecology and Management of Southern Pine Ecosystems

5. Project Leader (Name and Address)

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6. Area of Research Applicability	7. Estimated Duration
Regional; National	5 years

8. Mission

To develop and disseminate the scientific information needed to restore and sustain the production of a wide range of goods and services from pine- and pine-hardwood ecosystems of the southern United States.

9. Justification and Problem Selection Summary

Pine- and pine-hardwood-dominated ecosystems of the southern United States are major components of the forested landscapes in this region. The region is dominated by southern yellow pines, originating as naturally regenerated or planted pine and pine-hardwood stands. These forests are important not only for commercial timber, but also provide wildlife habitat and other ecosystem goods and services such as water production, carbon sequestration, nutrient cycling, and other important contributions. Decades (and in some places, centuries) of intensive human use, conversion, and perturbation have dramatically altered southern pine and pine-hardwood forests, diminishing many of their desired ecological and socioeconomic attributes. In the face of changing environments, species declines, and growing societal demands, landowners and forest managers are increasingly interested in restoring pine and pine-hardwood forests, but find themselves lacking the silvicultural, biological, and ecological information needed to do so. SRS-4159 focuses on a three-pronged research effort to develop and transfer the fundamental knowledge needed to restore and manage pine and pine-hardwood ecosystems in the southern United States. These include studying the silvicultural systems, wildlife ecology and management (emphasizing declining or threatened/endangered species), and ecosystem restoration options, and how these shared research priorities can be used to improve ecosystem goods and services for the benefit of human communities they support.

Signature	**Name**	**Date**
Recommended: MONICA SCHWALBACH Digitally signed by MONICA SCHWALBACH Date: 2020.05.22 15:03:51 -04'00'	Assistant Station Director	5/22/2020
Recommended:	Staff Director	
Approved:	Station Director, Southern Research Station	
Concurred:	Deputy Chief for Research and Development	

SRS-4159—Ecology and Management of Southern Pine Ecosystems

Monticello, AR
Crossett, AR
Hot Springs, AR
Nacogdoches, TX
Pineville, LA

Project Leader: Don C. Bragg

SRS-4159, the Southern Research Station's (SRS's) Ecology and Management of Southern Pines research work unit (RWU) includes three experimental forests (the Crossett, Stephen F. Austin, and Alum Creek EFs) and staff assigned to five duty stations in Arkansas, Texas, and Louisiana. This geographic distribution, staffing, and previous research emphasis on resource issues related to naturally regenerated forests dominated by loblolly (*Pinus taeda*) and shortleaf (*Pinus echinata*) pines means this RWU is well placed to study a range of restoration-related topics. With recent strategic emphasis placed by the U.S. Department of Agriculture (USDA) on using research to strengthen private land stewardship and help ensure the productivity and sustainability of National Forest System (NFS) lands, the Southern Research Station (SRS) has much to contribute toward the scientific study of pine- and pine-hardwood-dominated ecosystems. For example, with the region-wide prominence of active and generally intensive timber management, numerous issues have arisen over the ability of southern pine- and pine-hardwood-dominated forests to continue providing the full range of ecosystem services possible, from timber to carbon sequestration to wildlife habitat and clean water. This is particularly critically in the South, which is overwhelmingly privately owned (much by the timber industry) and where limited public lands, especially national forests, have been asked to shoulder much of the conservation efforts for threatened and endangered species and recreational needs. Given that the management of public and private land differs with regard to inputs, outputs, the duration of time for outputs to be achieved, and regulations, more study is needed to meet Forest Service and USDA strategic goals to improve the condition of the Nation's forests and grasslands and enhance recreational opportunities. To help satisfy these goals, SRS-4159 has become one of six RWUs in the SRS's Center for Forest Restoration and Management (CFRM). With three additional science centers (Forest Health, Forest Assessment and Synthesis, and Forest Inventory and Analysis), the CFRM is part of an innovative new approach by the SRS to better address regional and national research priorities while sharing resources, equipment, experimental forests, stewardship, and human capital. As a part of this new Center-based approach, SRS-4159 will collaborate with other RWUs in CFRM, in other SRS Centers, and with numerous outside partners to play a key role in developing and delivering an integrated program of restoration-focused research focused on southern pine and pine-hardwood ecosystems.

9. JUSTIFICATION AND PROBLEM SELECTION

As of 2012, planted and natural-origin pine- and pine-hardwood-dominated ecosystems of the southern United States covered approximately 93 million acres, or about 38 percent of the forested acreage in this region. Generally speaking, these forests include the four primary southern yellow pines (loblolly, shortleaf, slash (*Pinus elliottii*), and longleaf (*Pinus palustris*)), numerous "minor" pine species (e.g., pond (*Pinus serotina*), pitch (*Pinus rigida*), Virginia (*Pinus virginiana*), sand (*Pinus clausa*), spruce (*Pinus glabra*), and Table Mountain (*Pinus pungens*)), and a varying hardwood component. These pine and pine-hardwood forests represent the largest contributor to the southern timber industry, and have made the 13 southern states the largest industrial roundwood producer in the world. Because of the wide range of conditions under which these pine- and pine-hardwood stands grow, there are many associated understory species, including graminoids, herbs, shrubs, and vines, many of which are endemic to the region and some that are considered threatened or endangered. Trees and understory plants are only part of the ecological story of southern pine and pine-hardwood ecosystems—there are many species of

fish and wildlife in these forests. As with the plant communities, the varied habitats, availability of water, diversity of soils, natural disturbance regimes, and range of past and present land uses have contributed to the faunal richness of the southern United States.

Pine and pine-hardwood forests of the South were extensively exploited for timber and cleared for agricultural purposes almost from the beginning of Euroamerican settlement. This exploitation reached its zenith in the late 1800s and early 1900s. Commercial lumbering and naval stores extraction were particularly impactful on these pine-dominated systems, and sustained many human communities by employing loggers, millworkers, railroads, and supporting industries. The forests of the South, once cleared of timber, were often converted to row-crop agriculture or pasture. Other areas were repeatedly and often severely burned, or simply abandoned when the valuable timber was removed. By the early to mid-20th century, the now devastated pine and pine-hardwood forests of the southern United States needed to be rehabilitated and restored. Fortunately, the professions of forestry and wildlife management were also coming into their own during this period, and the practices of silviculture, fire protection, habitat restoration, hunting restrictions, and game species reintroductions were developed and refined. Large areas of cutover forest and abandoned agricultural lands were soon restocked with trees and the declining timber industry in the South rebounded with the restoration of merchantable timber and the advent of new wood utilization opportunities.

Indeed, as the timber industry thrived, the focus of silviculture shifted from restoration of naturally regenerated forests to the installation of intensively managed pine plantations. Technological advances aided in the propagation, establishment, and growth performance of numerous tree species, with fast-growing southern pines such as loblolly and slash receiving the most attention. The demand for southern pine timber spurred rapid advances in tree breeding, disease resistance, competition control (typically, chemical-based, rather than via prescribed fire or mechanical treatments), and density management. Each advance seemed to further replace existing natural-origin forests with planted, genetically improved pine seedlings. Pine plantation coverage in the southern United States continues to expand to the present day. This expansion has come at a considerable cost to less-valued native pine species, such as shortleaf and longleaf, and the silvicultural practices used to establish southern pine plantations can also be detrimental to the habitat of some wildlife species. Even natural-origin stands of loblolly and slash pine are at risk of being cleared for plantations that are geared towards wood volume production. This widespread change in land use has put more than just trees at risk. Pine and pine-hardwood ecosystems of the southern United States are a major repository of plant and animal biodiversity for North America, and many taxa have always been very limited in their distribution and abundance. The importance of biodiversity is well known and maintaining healthy forest ecosystems requires maintaining all native biological components. For instance, many wildlife species play significant roles in maintaining healthy forests. It is estimated that forest bats alone contribute billions of dollars annually in pest management by consuming insect pests of forests and agriculture, and neotropical migratory birds are the primary consumers of defoliating leaf caterpillars in forests. However, 25 percent of bat species are now federally threatened or endangered across the South, and many once-common bird species have declined precipitously or even gone extinct.

Habitat loss, climate change, invasive species, urbanization, pollution, and emergent diseases are increasing threats to the integrity of pine- and pine-hardwood-dominated ecosystems across the southern United States. As the number of threatened or endangered species has increased—such as the 10 percent of amphibian species now considered endangered or vulnerable—much of the species recovery effort has fallen upon public land managers. Federal laws, including the National Environmental Policy Act and the Endangered Species Act, require these managers to take into account protected species in all their management actions, and endangered plants and animals often drive or have a substantial impact on National Forest management practices and other federal undertakings. Those practices perceived by the public as being harmful to wildlife have caused significant curtailment of management actions (mostly on public lands, but now increasingly on private property) through administrative appeals, litigation, and

sustainability certification agreements. For instance, the endangered red-cockaded woodpecker (*Dryobates borealis*) was the driving force behind many of the pine woodland restoration efforts that have emerged across the southern United States. Emerging threats, such as the introduction of a non-native, invasive fungus that causes white-nose syndrome in bats, have become new management priorities as additional species of forest bats are being evaluated for potential listings.

To help support and address these conservation needs, a number of state agencies, non-governmental organizations, private landowners, and major initiatives have emerged in recent years to help address some of these conservation issues in ecosystems dominated by southern pine and mixed pine-hardwood forests. Perhaps most prominent of these is the Longleaf Alliance, which organized in 1995 to raise awareness of the dramatic decline of longleaf pine ecosystems, and to help spur restoration efforts. More recently, the Shortleaf Pine Initiative is coordinating various federal, state, and local government agencies, universities, and non-governmental organizations determined to arrest the decline of shortleaf pine across its range. Similar conservation efforts developed for a number of the wildlife species that have likewise declined with the regional impacts of land use practices on southern pine- and pine-hardwood-dominated systems. Major efforts to recover species such as the red-cockaded woodpecker, Louisiana pinesnake (*Pituophis ruthveni*), and bobwhite quail (*Colinus virginianus*) are some of the more prominent wildlife conservation efforts affecting the South.

While public and private conservation efforts have made some headway in addressing these challenges, many still remain. For example, biological diversity in southern forests is driven in part by a diversity of forest habitats. Although considered detrimental to commercial timber production, fire, pest outbreaks, and storm damage contribute to these diverse forest habitats. Effects of various natural and human-caused (including timber harvest) disturbances on the numerous wildlife and plant species that rely on disturbance remains uncertain, as do the impacts of invasive species, changing climates, landscape fragmentation, pollution, fire suppression, and forest-type conversions, amongst many others. In addition to these persistent conservation challenges, new research priorities continue to emerge. For example, as the science has advanced and conservation efforts have developed, it has become clear that the struggles of individual species, whether plant or animal, are best addressed through ecosystem restoration. Yet we lack a foundational understanding of how various management practices affect ecosystem responses, and how (or if) we can adapt traditional silvicultural tools to meet managers' needs. It seems highly likely that more tools are needed for the toolbox—this presents new opportunities and challenges for researchers.

By definition, restoring southern pine and pine-hardwood ecosystems requires that all components—not just the dominant tree species—receive attention from land managers. Integrating these challenges with a continued need for silvicultural production requires a more holistic research strategy. SRS-4159 is administratively housed in the SRS's Center for Forest Restoration and Management (CFRM). The CFRM is a newly created Science Center within the SRS that looks to develop and deliver the scientific information needed to restore and manage southern forest ecosystems. Developed to encourage collaboration, share resources and human capital, and meet the agency's science mission, these SRS Science Centers are oriented to provide results-based research outcomes that are closely aligned with local, regional, and national priorities. Locally (at the SRS level), CFRM's SRS-4159 and SRS-4158 (Restoring and Managing Longleaf Pine Ecosystems) research work units represent an integrated effort to study various components of pine- and pine-hardwood ecosystems, including those dominated by loblolly, shortleaf, and longleaf pines. As a part of the CFRM, SRS-4159 seeks to further SRS Strategic Framework goals and objectives (https://www.srs.fs.usda.gov/strategic-framework/goals-and-objectives/) by 1) providing sound science to sustain healthy pine and pine-hardwood dominated ecosystems; 2) delivering ecosystem-related benefits (such as timber and wildlife) to landowners, forest managers, local communities, and the general public; 3) applying knowledge to address regional and national issues, particularly in support of forest management and policy decisions on pine and pine-hardwood ecosystems; and 4) facilitating excellence in the Station through improvements to wildlife,

pine-, and pine-hardwood ecosystem research, management, and conservation. In addition to long-running regional partnerships, a list of 12 Shared Research Priorities (Appendix A) recently signed by the SRS's Station Director and the Southern Region's Regional Forester provides another platform for SRS-4159 to support the science needs of a close partner. SRS-4159's research program is also closely aligned with elements in the Forest Service's strategic plan to sustain the Nation's forests while delivering benefits to the American public and the global community, as well as the good neighbor, shared stewardship, and improving forest and grassland national priorities. Furthermore, the planned program of work of SRS-4159 has also been designed to support the USDA strategies of providing and sharing stewardship of our public natural resources, facilitating rural prosperity and economic development, strengthening private land stewardship using technology and research, and ensuring productive and sustainable use of the National Forests and Grasslands.

SRS-4159 MISSION:

DEVELOP AND DISSEMINATE THE SCIENTIFIC INFORMATION NEEDED TO RESTORE AND SUSTAIN THE PRODUCTION OF GOODS AND SERVICES FROM PINE- AND PINE-HARDWOOD ECOSYSTEMS OF THE SOUTHERN UNITED STATES.

To accomplish our program of research to support the above mission, the tasks in SRS-4159's RWU Description (RWUD) have been organized into the following Problem Statements:

Problem 1: We will discover and transfer the fundamental knowledge needed to restore, manage, and enhance the pine- and pine-hardwood-dominated ecosystems of the southern United States.

Many of the upland forests of the southern United States are dominated by the major southern yellow pines (loblolly, shortleaf, slash, longleaf) and some of the lesser-known southern pines (e.g., sand pine), in stands of both natural- and planted-origin. This has supported a significant timber industry for well over a century, and this industry has invested heavily in developing the science behind the management of these species, primarily for wood production purposes. Even with all of the resources invested in understanding the biology and silviculture of southern pines, much is still unknown about these pines and their associated ecosystems. Remarkably enough, this is also true about perhaps the most studied tree species in this region (if not the world)—loblolly pine.

Decades of research and development have noted that loblolly pine (and the other major southern pines) are remarkably responsive to silvicultural manipulations. Generally, they respond well to conventional practices such as stand density management, competition control, fertilization, site preparation, and tree improvement. Coupled with their fast growth and desirable wood properties, this has led to widespread adoption of a system of intensive management practices. These practices include large-scale clearing of existing forest and planting of genetically improved southern pine seedlings, supported by a number of other silvicultural practices to accelerate volume growth and shorten rotation lengths while improving planted tree survival. Prior to the widespread adoption of intensive southern pine silviculture, management practices focused on natural regeneration using the silvical charactersitics of the major southern pines. Background work to support these management practices started in the early 20th century with basic research into tree biology, wood quality, and growth patterns, followed by applied studies on stand manipulation, improvements to regeneration success, and competition control. Long-term, large-scale silviculture-based research on Forest Service experimental forests across the region later helped determine the effectiveness of many treatments, and affirmed the efficacy and economy of natural regeneration-based silviculture in southern pine forests.

Even with this extensive history of scientific research, fundamental questions remain about the ecology and management of some southern pines. This is especially true for species such as shortleaf and longleaf pine, as well as the less common pines of the region, which have not received as much study as the prominent commercial timber species (loblolly and slash pine). This lack of research is changing as

conservation concerns regarding longleaf and shortleaf pines have spurred new research efforts and management initiatives. Longleaf pine, for instance, has had a dedicated Forest Service research work unit (SRS-4158) focusing on questions of reproductive biology, regeneration, stand management, disturbance response, and associated plant (understory) communities for a number of decades. Widespread recognition that pine- and pine-hardwood forests across the southern United States need additional investments in resources to further their restoration and improve upon the ecosystem goods and services they offer supports a broadened program of scientific study. Not surprisingly, then, both shortleaf and longleaf pine have been specifically identified as one of the Shared Research Priorities (Priority #6, Forest Restoration; see Appendix A) recently recognized by the SRS Station Director and the Southern Region's Regional Forester.

To this end, we will discover and develop new knowledge about the ecology of pine- and pine-hardwood-dominated ecosystems across the southern United States, to refine the silvicultural principles and practices for these ecosystems, so that land managers can make better management decisions and take more effective action to achieve desired results on public and private forest lands. This will include the synthesis and evaluation of regional, continental, and global factors on these ecosystems to provide scientists, managers, and landowners the knowledge and tools to restore healthy, diverse, and productive ecosystems resilient to human influences and environmental changes.

We will use our expertise on the ecology and management of southern pine- and pine-hardwood-dominated ecosystems, including understory plant species, associated wildlife species, disturbance regimes, and site conditions, to assess, quantify, and predict the possible silvicultural and restoration options. Specific problems are as follows:

Problem 1a: We will discover and transfer knowledge on reference conditions related to the patterns, processes, ranges of variation, and disturbances needed to restore and enhance pine- and pine-hardwood-dominated ecosystems of the southern United States. This represents an important—if incomplete—component needed to describe and understand forested ecosystems that are being managed today. Reference state information, while often used as the sole standard for restoration success, is only one element of a much more complex set of guidance needed by managers to guide their efforts. While restoration efforts benefit from quantitative and qualitative guidance derived from reference conditions and historical ranges of variation, they should also incorporate the inherently dynamic nature of ecosystems, be adaptable to change or unanticipated circumstances, and amenable to alternative measures of success. This is especially true given that current environmental conditions are often unfavorable for the return to historical ranges, and future (novel) conditions will likely be much different under changing climates, different land management practices, landscape fragmentation, invasive species, etc. After all, knowing what past disturbances or initial conditions or spatial distribution a particular forest type experienced at a given geographic location can suggest what may be possible under a range of scenarios. Reference conditions can be derived from historical sources of information (such as maps, pictures, explorer journals, surveyor notes, early scientific studies and inventories); contemporary sampling of existing trees, stands, or sites (including field botanical surveys, dendrochronology, palynology, archeological surveys); large-scale inventories (e.g., Forest Inventory and Analysis data); remotely sensed imagery; and model simulations, amongst others. In addition to the development of reference conditions for ecosystems, we will also use many of these same types of historical sources to describe the past work at the Crossett, Stephen F. Austin, and Alum Creek EFs, as well as local/regional histories of human settlement, lumbering (and other natural resource exploitation), agricultural uses, wildlife management, and forestry practices.

Problem 1b: We will discover and transfer knowledge about the ecological patterns and processes that govern stand dynamics and development in the pine- and pine-hardwood-dominated ecosystems of the southern United States. These patterns and processes include different and

sometimes interrelated dynamics, including regeneration, establishment, self-thinning, canopy recruitment, and mature tree senescence (including natural disturbance and harvesting). Supporting information can come from manipulative experiments of individual seedlings, plot-level outplantings, and stand level implementations of treatments. Not all sources of discovery will come from experimentation. This information can also be gathered during botanical inventories of pine- and pine-hardwood-dominated ecosystems, natural history observations, dendrochronological research work (including assessments of stand origins and age structure, fire return interval, season of burn, fire-related recruitment and canopy ascension), species response to disturbances, biomass dynamics, ecological concept development, amongst other topics. In addition to basic knowledge gained, studies of ecological pattern and process can be used to improve and refine silvicultural practices and other treatments needed to manage and restore immature, mature, mixed age, and old-growth pine- and pine-hardwood forests of the South.

Problem 1c: We will discover and transfer knowledge about the effects of large-scale events (both natural and anthropogenic) on the pine- and pine-hardwood-dominated ecosystems of the southern United States. Understanding the effects of climate change, large-scale natural disturbances (such as fires, insect outbreaks, wind events, ice storms), exotic species invasion, forest management activities (silviculture), ownership fragmentation and parcelization, pollution, agricultural manipulations, and other anthropogenic influences on forested landscapes is critical to help managers anticipate when forest ecosystems are affected by these events. This knowledge should allow managers to make appropriate changes in management plans and silvicultural prescriptions. These events can occur across a range of spatial scales, including individual trees, stands, landscapes, and regions, and some event-controlling factors that are global in scale (e.g., climate, commercial trade). They can also occur over a range of time scales, from seconds to many years. Another critical research element related to these events is understanding how natural systems respond to and recover from events in both time and space.

Problem 1d: We will continue to study, refine, and develop silvicultural approaches for the pine- and pine-hardwood-dominated ecosystems of the southern United States. This is a fundamental and foundational role of this research work unit. Silviculture-driven studies of various tree species, stand conditions, forest environments, and landscape-level controls were initiated by the predecessors of the current unit decades ago at experimental forests near Crossett, Hot Springs, and Nacogdoches. The development of silvicultural systems (even-aged and uneven-aged, using natural and artificial regeneration) to produce timber products, wildlife habitat, forage, and other desired outputs in an efficient, controlled fashion has resulted in management options for these ecosystems that have served landowners well for decades. Because this work lends itself to the prediction of how management activities affect current and future stand conditions, they can also be used to predict the influences of silviculture—the most common disturbance agent in most forests of eastern North America—on ecosystem patterns, processes, and dynamics. After all, even traditional silvicultural practices can play a critical role in the development and implementation of large-scale restoration efforts. We will also look to adapt conventional silvicultural practices in southern pines—for example, pine plantation management—for new outcomes, such as the prospects of denser plantations retained longer to increase carbon sequestration and yield high-quality products at the end of a much longer rotation.

SRS-4159 has the facilities and equipment to engage in research in Problems 1a-d. This work will be achieved using SRS-4159 scientists, scientists in other SRS units, and collaboration with external partners (e.g., NFS staff, university faculty, other state and federal agencies).

Problem 2: We will discover and transfer knowledge about the effects of forest management, insect pests, disease, fragmentation, invasive species, emerging threats, and climate change on wildlife and

wildlife habitat in southern pine-dominated ecosystems, so that managers have better tools to restore and manage wildlife populations that are healthy, diverse, and sustainable.

The threat of endemic forest pests and diseases on the highly valuable and ecologically critical southern pine and pine-hardwood forests has long been a research priority of the SRS. Exotic species and newly introduced diseases of all types now further threaten the forests of the southern United States through the loss of both timber resources as well as other ecosystem-level impacts. For example, emergent diseases are also threatening wildlife populations worldwide. White-nose syndrome in bats, chytrid fungus in amphibians, snake fungal disease in snakes, avian influenza in birds, and chronic wasting disease in deer are just a few of the new diseases that have recently been identified that have the potential to adversely affect wildlife populations. These diseases often cause catastrophic losses in populations, and in some cases lead to federal and state listing of species. Information on these emergent diseases and exotic pests is usually lacking, and often creates major obstacles to forest and wildlife management. Not surprisingly, researching insect and disease impacts on the pine and pine-hardwood forests is a major part of the Shared Research Priorities (Priority 12, specifically, and elements of Priorities 2, 3, 5, 6, and 7; Appendix A).

Wildlife species are integral components of healthy forest ecosystems and are typically a primary concern of the general public when it comes to forest management. Threatened, endangered, or declining wildlife species also impact management programs on federal lands. Consequently, healthy and resilient wildlife communities are a priority to land managers, and avoiding habitat degradation and population declines are fundamental goals, which can be achieved through thoughtful management driven by research. Wildlife communities are comprised of numerous species including birds, mammals, reptiles, amphibians, and insects, and information on life history, habitats, and effects of forest management are lacking or not yet evident for most species. Although the number of species comprising a wildlife community is daunting, species of special concern tend to take priority for study and management over others. Community-level studies sometimes are used to evaluate trends regarding the effects of management on groups of species, but these studies are usually coarse, and provide only generalized information on species response to to management actions. Effects of different management actions on individual species provide the most detailed information on species-management interactions, and ways to restore important habitats or recover imperiled species.

This requires that RWU staff work closely with land managers on priority research. Historically, forests of the Interior Highlands and Mid-South were open, with low basal areas, sparse midstory and abundant herbaceous vegetation in the understory. Fire suppression activities of the 20th century created closed-canopy forests, with dense midstories and little vegetation on the forest floor. As a result of fire suppression, wildlife species associated with fire-maintained forest communities declined. Species such as the red-cockaded woodpecker, Louisiana pinesnake, and Bachman's sparrow *(Peucaea aestivalis*) have declined substantially. Land managers are working to restore large areas of woodlands across the South in an effort to emulate historical forest conditions and associated wildlife species. These management activities include timber harvest to reduce overstory basal area, midstory reduction or removal, and introduction of controlled burning on three- to five-year intervals. Information on responses of numerous plant and animal species to these efforts is often lacking. Managers seek information on the impacts of their efforts and tools to more efficiently restore and maintain these woodlands.

Biotic threats are not the only ones affecting the pine and pine-hardwood forests of the South. Plant and animal species distributions are currently in flux due to climate change. Northward shifts in range are occurring more rapidly than previously predicted. Global meta-analyses of plant and animal species have documented recent range shifts toward the poles averaging 3.8 miles per decade. Changes in climate have profound effects on many species. Bats in temperate areas are especially susceptible to the effects of climate change because many aspects of their life cycles, including migration, diet, and hibernation, are

temperature dependent. Since bats and birds are highly mobile, many may be able to adapt to changes in habitat or availability of food resources. However, less mobile species such as amphibians and plants may be less able to adapt to changing climate, including changes related to the micro-habitats they rely upon. Information on the responses of numerous wildlife species to a rapidly changing climate is lacking, especially across the South, and land managers need information on changes in wildlife communities for conservation planning. Specific problems are as follows:

Problem 2a: We will develop and discover knowledge about how forest management and forest fragmentation affect the quality and quantity of terrestrial and riparian/aquatic habitats and associated wildlife species, so land managers can make better decisions about managing riparian zones and wetlands for resource benefits that feature wildlife species of interest. Most forest management activities that alter components of an ecosystem will have an effect on ecosystem function and wildlife populations. Understanding the consequences of management activities is essential for managers as they attempt to sustain healthy wildlife habitats and populations, particularly when species of conservation concern are likely to be affected.

Problem 2b: We will quantify and model how population dynamics, ecosystem restoration, forest management, habitat fragmentation, invasive species, climate change, altered fire regimes, and their interactions affect biotic communities, with emphasis on species of conservation concern, so that managers can make better decisions about conservation and management of these communities across the landscape. Numerous plant and animal species rely on fire-adapted ecosystems across the South and land managers are seeking to restore large areas of these pyrogenic woodlands. Information on responses of wildlife and understory plant species to these restoration efforts is needed so that managers understand positive effects of their efforts and can tailor their activities to reduce negative impacts. Research on this problem is inherently complex, integrative, and multiscalar, ranging from population-level studies to determine the fine-scale effects of weather and population size on breeding success to the efficacy of captive breeding and/or reintroduction programs for threatened or endangered species recovery to studies of foraging and other critical habitat requirements. A primary goal of this research is to develop a better understanding of the impacts of various forest management practices and climate change on species across stands, landscapes, and regions to support management and conservation decisions. Ongoing research on threatened and endangered species such as the red-cockaded woodpecker, northern long-eared bat (*Myotis septentrionalis*), and Louisiana pinesnake will be continued. These efforts will support scientific advances while adapting lessons learned from those species to improve upon local, regional, and national efforts to conserve and recover declining species (such as shortleaf pine) before regulatory controls affect forest management practices.

Problem 2c: We will examine the direct and indirect effects of forest management on the ecology of forest bats and the resources essential for bat survival, including their insect prey base, to help land managers better provide habitats. Forest bats are important to forest ecosystems and federally protected species have significant impacts on land management decisions on federal lands and state agencies that receive federal funds. Forest management affects bats directly during management activities such as timber harvest or burning, or indirectly by changing the suitability of habitat. Effects of various silvicultural and restoration activities on bat habitat remains unclear and certain practices may enhance or degrade bat habitat. Management actions that harm endangered species are a particular concern for federal land managers. Effects of various management practices, including thinning, timber harvest, burning, riparian zone activities, road and trail construction, and herbicides on most bat species are in need of study.

Problem 2d: We will examine effects of white-nose syndrome on bat populations, including survival, winter activity, hibernation patterns, hibernacula selection, population declines, and potential

treatments to provide land managers with a better understanding of this disease and the tools necessary to maintain resilient forest ecosystems. In 2006, a nonnative, invasive fungus (*Pseudogymnoascus destructans*) was introduced into New York State from Eurasia. This fungus grows in cold cave climates where bats hibernate and causes a condition referred to as white-nose syndrome (WNS). The fungus grows into body tissues while bats are hibernating and results in approximately 95 percent mortality. WNS has caused dramatic population declines in a number of bat species across the eastern United States and is spreading rapidly westward. Populations of some species, including the northern long-eared bat, little brown bat (*Myotis lucifugus*), and tri-colored bat (*Perimyotis subflavus*) have been decimated. In response to this disease, the northern long-eared bat was recently listed as federally threatened, and the tri-colored bat is currently under review. Prior to this disease outbreak, both species were common in many areas of the South. A concerted effort among multiple state and federal agencies is under way to study the effects of this disease and potential treatments, which has become a national Forest Service priority. Information on ecology of species susceptible to WNS is lacking and differences in survival associated with latitude, hibernacula type, and species are in need of study. A potential avenue for mitigation of the disease includes providing optimal habitats for bats through forest management practices designed to improve conditions needed during key seasons when bats are most vulnerable.

Problem 2e: We will examine the direct and indirect effects of climate change and invasive species on the ecology of amphibians so that managers can make better management decisions and improve upon mitigation efforts. Recent evidence suggests that amphibian populations are declining globally and extinction rates greatly exceed historical levels. While many threats play a role in amphibian decline, climate change and invasive species are important factors that warrant special attention. Evidence suggests that climate change will cause shifts in plant species phenologies that will increase interaction potential between species with unknown consequences. Invasive plant species have been shown to directly and indirectly affect amphibian survival. We will evaluate impacts of climate change and invasive species on amphibian species that rely on pine forest ecosystems in the South.

SRS-4159 has the facilities and equipment to engage in research in Problems 2a-e. This work will be achieved using SRS-4159 scientists, scientists in other SRS units, and collaboration with external partners (e.g., NFS staff, university faculty, other state and federal agencies).

Problem 3: We will discover and transfer science outcomes related to the restoration of ecosystem function and resilience in pine- and pine-hardwood-dominated forests to improve the long-term socioeconomic well-being of affected communities. We will transfer our knowledge and expertise in southern pine ecosystems to managers and other scientists across the southern United States to develop cohesive restoration policies and practices that can help the federal government meet its strategic goals of customer service, improved producer viability, increased rural prosperity, better private and public land stewardship, improving public safety through lessened wildfire risk, and sustainable resource conservation. These objectives have long been at the core of what Forest Service Research and Development does; this problem does not represent a new initiative, but rather reflects how this work unit will help SRS ensure that our work parallels the agency's strategic goals. Recently, the need for research into pine and pine-hardwood forest restoration has received increased attention, and is a major component of the recently signed Shared Research Priorities, especially Priorities 5 and 6 (Appendix A).

Much of the past research of this unit has focused on specific, narrowly defined topics, such as seed biology, uneven-aged silviculture in loblolly and shortleaf pine stands, or bat roosting and foraging requirements in managed stands. Some of this work has been conducted on experimental forests within the unit, and this work will continue. These efforts have significantly advanced the science and management of pine- and pine-hardwood-dominated stands across the South by answering both the original resource question and discovering new topics for investigation. However, this is not the only level

of analysis possible. The ecosystems which we study comprise complex, interconnected, and constantly changing communities of organisms that respond to each other and their environment, frequently in ways we cannot (yet) explain. The complexity of these systems determines ecological response and therefore are often influential in the long-term success—or failure—of management efforts, whether focused on traditional production interests or geared towards ecosystem restoration.

The requirements of working in complex systems with emergent properties implies that our research also needs to be flexible—it should not just focus on narrow research questions, but should consider the implications across a range of scales. The SRS has developed an Experimental Forest Network (EFN) consisting of 19 experimental forests, and has begun to undertake a series of connected, large-scale, network-driven research projects on topics ranging from shortleaf pine conservation and pollinator studies to intensively monitored Forest Inventory and Analysis (FIA) plots, and SRS-4159 will work to become a key participant in this EFN. Work on unit EFs will continue, will be integrated with other experimental forests in the Station's network, and will be more closely developed in conjunction with National Forest needs and external partner interests. The following set of problems exemplify how this flexibility can be used to address critical new questions:

Problem 3a. Investigate how pine- and pine-hardwood-dominated landscapes are affected by interacting biotic and abiotic factors, particularly in support of large-scale restoration efforts. We will develop knowledge of spatially variable biotic and abiotic factors and their interactions that influence the structure, distribution, and condition of pine- and pine-hardwood communities across landscapes. Factors with spatial aspects include site quality variables (e.g., soil strength, water holding capacity, fertility); wildlife communities and habitat associations; natural disturbances such as fire and wind; population distributions; and reproductive processes such as pollination, hybridization, and seed dispersal. Human manipulation through silviculture and restoration efforts strongly influences the composition, function, and dynamics of complex ecosystems, especially in natural-origin pine- and pine-hardwood-dominated forests. These manipulations impact underlying biotic and abiotic systems, which makes understanding their response to change and interactions among each other critical to measuring restoration success.

Problem 3b. Research into opportunities to increase our understanding of the biota associated with pine- and pine-hardwood communities through the development, application, and improvement of ecological models and measurement techniques. Simulation models offer tools to test hypotheses, validate (or negate) assumptions, predict future outcomes under different scenarios, and identify research needs and resource shortcomings. The refinement of these tools and technologies (including GIS and computer models) can help design and/or customize restoration and management protocols suited to the diverse environmental conditions where southern pines are the dominant canopy species. Further refinements and technological developments can also be implemented to reduce or eliminate measurement errors. Improvements in resource conservation resulting from more viable and sustainable restoration actions should help public and private land managers better achieve forest management goals.

Problem 3c. Expand expertise on the socioeconomic costs and benefits of the restoration of southern pine and pine-hardwood ecosystems. We will establish research partnerships to assess the costs and benefits of restoring pine- and pine-hardwood-dominated ecosystems. Specifically, we will analyze the socioeconomic impacts of restoration efforts. For example, an analysis on the use of fire as a restoration tool should consider both the benefits (e.g., better tree regeneration; improvements to public safety) and risks (e.g., air quality degradation; inability to apply prescribed fire as needed) associated with this investment and what the implications of changing land use and ownership patterns are for its utilization. These analyses would include markets for products from current and changing land uses, as anthropogenic and natural disturbances occur. Analyses should account for

services and goods not traditionally considered (including carbon credits), the role of cost-share payments for certain land management practices, the value of the water quantity and quality, the presence of federally listed species (threatened or endangered) or declining species, and the impact of air quality regulations. This will provide landowners and managers with information about revenue streams and resource costs associated with various management activities and strategies.

Problem 3d. Develop new research directions and broader, more networked studies on experimental forests. Most SRS locations have access to a nearby experimental forest, upon which many have based their research over the years. On these experimental forests, we will seek new opportunities to partner with other Forest Service RWUs and working groups, university collaborators, other government agencies, non-governmental organizations, and corporate partners. These partnerships should help to leverage existing research support, develop new research questions, install and utilize new and existing technologies, broaden the scope of studies from local to regional/national/international scales, and join appropriate science-based networks. In addition to serving as large-scale field laboratories and repositories of biological diversity, experimental forests will continue to serve as demonstration areas to better inform fellow academics, resource managers, and the general public about the long-term history of various treatments as well as the opportunities presented by new management approaches.

SRS-4159 has the facilities and equipment to engage in research in Problems 3a-d. This work will be achieved using SRS-4159 scientists, scientists in other SRS units, and collaboration with external partners (e.g., NFS staff, university faculty, other state and federal agencies).

10. APPROACH TO PROBLEM SOLUTIONS:

Problem 1: Discover and transfer the fundamental knowledge needed to restore, manage, and enhance the pine- and pine-hardwood-dominated ecosystems of the southern United States.

Research directions and expected accomplishments by emphasis area for this RWUD:

Problem 1a. We will discover and transfer knowledge on reference conditions related to the patterns, processes, ranges of variation, and disturbances needed to restore and enhance pine- and pine-hardwood-dominated ecosystems of the southern United States.

1. *Historical conditions of shortleaf pine-dominated forests*. Shortleaf pine was likely the most dominant southern pine across much of the southern United States (outside of the longleaf pine belts) until the 20th century, but its decline, particularly in the latter decades of that century, has been notable and dramatic. A better accounting of how prevalent shortleaf pine actually was prior to the first decades of the 20th century using historical references is a necessary step in understanding the mechanisms of its decline. This will be accomplished using a series of retrospective studies involving both historical (anecdotal) accounts as well as early-to-recent FIA reports.

2. *Dendrochronology of the Lake Winona Research Natural Area.* This old-growth shortleaf pine-dominated remnant in the Ouachita National Forest has living trees that exceed 200 years old, and some stumps and snags that can be cross-dated to well over 400 years. When coupled with inventories and additional dendrochronological sampling, knowledge of stand age should permit an assessment of overstory recruitment in this natural area to better understand how fire (and potentially other disturbance events) influenced its development. This is an ongoing project with university collaborators using tree-ring and stand structure analysis over time.

3. *History of silviculture research at the Crossett, Stephen F. Austin, and Alum Creek EFs*. Silvicultural research on experimental forests has been key to many discoveries about the mechanisms of how deliberate interventions on forest structure and composition influence ecosystem goods and services, such as timber production or wildlife habitat. The work done decades ago on the

Crossett, Stephen F. Austin, and Alum Creek EFs, while fundamental to silviculture in this region, was often poorly documented. The development, implementation, and perpetuation of these early silvicultural studies may offer new lessons for modern practitioners, and justifies further investigation. This work involves reanalysis of historical data sets, reviews of old study plans and photographs, and synthesis of other lines of documentary evidence.

Outcomes in Problem 1a expected during the time covered in this RWUD:

- Narrative of the decline of shortleaf pine from the late 1800s to the present day; this is an outcome of an SRS EFN funded project (Phase 2) on the declining shortleaf pine (Priority 6B).
- Fire history of the Lake Winona Research Natural Area (Ouachita National Forest) using dendrochronology, site inventories, and historical documentation to help support Ouachita National Forest prescribed fire efforts in their shortleaf pine-bluestem landscape restoration efforts (Priorities 3 and 6B).
- Review article on the use of "farm forestry" demonstration areas in southern experimental forests to support the practice of silviculture.
- A study of shortleaf pine reproductive capacity and success across much of its botanical distribution; this is a planned SRS EFN project to support region-wide shortleaf pine restoration efforts (Priority 6B).

Problem 1b. We will discover and transfer knowledge about the ecological patterns and processes that govern stand dynamics and development in the pine- and pine-hardwood-dominated ecosystems of the southern United States.

1. *Relationship between wood specific gravity and southern pine ecosystem services.* Southern pines can produce large volumes of wood in very short time periods; however, this wood tends to be of low specific gravity relative to wood produced under less optimal growing conditions. Increasing specific gravity of southern pine wood (regardless of species) offers opportunities to sequester more carbon, produce stands that are more durable to some disturbances (e.g., ice storms, hurricanes), and may allow for ecosystem conditions to develop that are more favorable to other system components (e.g., understory vegetation, wildlife communities, stand maintenance with fire). This effort will involve a review of published evidence on the role of wood specific gravity and related ecosystem services, as well as new field research considering specific gravity and silvicultural practices.
2. *Silviculture and genetic complexity in southern pines*. Recent efforts by geneticists have documented potential increased rates of hybridization among southern pines, in particular between loblolly pine and longleaf and shortleaf pines. We know little about the role that silvicultural practices have played in this phenomena, and we know even less about how changing climate and widespread changes in management (e.g., pine plantation expansion across the South) may interact. Studies of older, natural-origin southern pine stands, coupled with further analysis of old progeny tests, should help us understand how southern pine genetics responded across the region to changes, and what this may imply for large-scale restoration efforts. For example, widespread planting selections based on a handful of desirable traits may have impacts on system resilience and responsiveness. Identifying other attributes of natural-origin stands of southern pine may offer other options that could meet different ecosystem management objectives, such as higher specific gravity to increase carbon storage. This effort will involve new studies that collect cambial, foliar, and megagametophyte DNA from a range of natural-origin pine- and pine-hardwood stands (including progeny tests) across the region to evaluate genetic diversity at a number of scales.

3. *Mixedwood management in southern pine and pine-hardwood ecosystems.* While much of the southern United States has been converted to monospecific plantations (e.g., loblolly and slash pines), a majority of the upland forest is natural-origin, mixed pine- and pine-hardwood forest cover. Indeed, historical evidence and modern examples clearly document how many natural-origin pine stands arose and flourished as mixed-composition, often with three or more pine species present in close proximity with numerous hardwoods. Little is known, however, about the processes that affected the relative dominance of any species in a given stand, how these mixed-composition stands sustained themselves across the landscape, how they responded to disturbance, and what role these stands played in sustaining diversity across multiple scales. The extent of minor and varying species in past mixed pine- and pine-hardwood forests, how they responded to various silvicultural techniques, and potential opportunities for future restoration efforts needs further study. Given the desire by many landowners to consider more than just merchantable pine volume as a system output, research is needed to ensure that silvicultural treatments can produce stands of mixed species composition, including those with multiple southern pines and a diverse assemblage of hardwood species. This effort will involve revisiting previous work on this topic and the installation of new studies on the manipulation of stand composition to customize the desired trajectories and outcomes.

Outcomes in Problem 1b expected during the time covered in this RWUD:

- Review paper on the use of wood specific gravity to reconsider silvicultural options in pine- and pine-hardwood stands in the southern United States.
- An analysis of carbon sequestration in conventionally managed natural- and planted-origin pine- and pine-hardwood stands.
- Research article on shortleaf pine genetic diversity across the state of Arkansas to support an effort partially funded by the Arkansas Natural Heritage Commission regarding the restoration of this declining species.
- Research article on the hybridization of loblolly and shortleaf pine, including a range of tests to detect hybridization.
- Graduate student thesis and papers on mixed wood management.
- Review paper determining the past abundance and role of southern pine in mixed-composition forests.
- Manager's guidelines for improving upon mixed-composition forests to increase pine success and how this may affect other established restoration targets.

Problem 1c. We will discover and transfer knowledge about the effects of large-scale events (both natural and anthropogenic) on the pine- and pine-hardwood-dominated ecosystems of the southern United States.

1. *Catastrophic disturbances and their impacts on southern pine ecosystems.* Ice storms, insect outbreaks, severe droughts, hurricanes, and catastrophic wildfires are some of the major disturbance events that affect southern pine- and pine-hardwood-dominated ecosystems. Changing climates, increasing human populations, landscape fragmentation, and the introduction and spread of invasive species strongly influence how these ecosystems respond, and therefore affect traditional silvicultural practices and large-scale restoration efforts. This effort will involve both review/synthesis papers on these topics, as well as opportunistic field-based research following disturbance events. This research also involves manipulations on experimental forests or other forested properties to test specific theories.
2. *The effects of fire in pine- and pine-hardwood-dominated ecosystems.* The absence of frequent fire has led to the accumulation of forest fuels, potentially resulting in destructive wildfires and

the loss of certain ecosystem functions, including widespread declines of fire-dependent biota. Well-timed prescribed burning may prove to be a solution in some landscapes, as it provides a mechanism for both the control of undesirable fuel accumulation, supports species-rich plant and animal communities, and can encourage the regeneration of desired tree species while helping to limit those less desired. Fire does pose certain costs, including reducing timber production, potential degradation of bole quality, risks of property damage, air quality concerns, and potential damage to soils. The reintroduction of fire to systems long bereft of its influence also may result in unacceptable outcomes, including high mortality of desired trees or wildlife species, the injury to trees that may prompt insect outbreaks, the spread of pathogens into these ecosystems, and the possible invasion of exotic species. Research has been ongoing for several decades to discern how fire effects pine- and pine-hardwood-dominated ecosystems across all biotic levels. These long-term efforts will continue, with a focus on obtaining information about prescribed fire techniques that address problems encountered by private landowners and public land managers interested in restoring these ecosystems. In addition, work associating fire regimes and open forest management will continue to develop, with more synthesis papers expected.

3. *Climate change and its influence on silviculture in pine and pine-hardwood ecosystems*. Climate change can directly impact silvicultural options through the effects it imposes upon stand structure, composition, and dynamics—for example, increased drought, heat, or pest loads may require different silvicultural prescriptions to prevent widespread regeneration failures. Climate change can also influence silvicultural practices by changing the markets for which timber management responds—for example, fuel markets or maximizing carbon storage based on carbon contracts are options for managers to consider. When implemented over large scales, these practices may dramatically reshape the role of southern forests and their effectiveness in producing a wide range of ecosystem goods and services, including timber. This effort will involve synthesis of existing silvicultural knowledge with historical conditions and projected future change, as well as the implementation of field trials (e.g., common garden studies looking at shortleaf pine) to develop recommendations for managers trying to anticipate novel climate scenarios.

<u>Outcomes in Problem 1c expected during the time covered in this RWUD:</u>

- Review articles on the influence of catastrophic natural disturbances, especially ice storms, insect outbreaks, and wind, on pine- and pine-hardwood-dominated ecosystems.
- Synthesis paper on climate change and southern pine silviculture.
- The effect of prescribed fire and timber management on understory plant communities in forest and woodland communities.
- Resilience of overstory trees following a wildfire that occurred during a drought.
- Contribute data to a nationwide Fire and Tree Mortality database.

<u>Problem 1d.</u> We will continue to study, refine, and develop silvicultural approaches for the pine- and pine-hardwood-dominated ecosystems of the southern United States.

1. *Uneven-aged silviculture in southern pines: a 21st century assessment.* Uneven-aged silviculture in southern pines was one of the first management systems developed. However, it fell out of favor decades ago to even-aged systems, both natural- and planted-origin, because of lesser volumes of wood production. When properly implemented, uneven-aged silviculture in southern pines has proven itself to be a reliable system that supports continuous forest cover and related ecosystem services. When coupled with harvesting systems and product markets compatible with the high-quality sawlogs generated by uneven-aged silviculture, can new

perspectives on this approach close the gap with even-aged approaches? This effort will focus on a synthesis paper based on a reanalysis of past data with contemporary challenges of silviculture in southern pine-dominated forests (both natural and planted).

2. *Restoration silviculture in southern pine- and pine-hardwood stands.* Silviculture has traditionally emphasized the practices needed to propagate, cultivate, and optimize forest conditions needed to maximize financial returns. While some of these treatments are directly amenable to restoring desired conditions (e.g., planting pines in a former agricultural field is one option to restore a piece of land into forest), other treatments are possible that can better yield other ecosystem goods and services. For example, canopy conditions can be manipulated to encourage trees of intermediate shade tolerance with low commercial value but high ecological value. Restoration silviculture in pine- and pine-hardwood stands will be developed to focus on the structural, functional, and compositional needs of these systems, especially those designed to emulate old-growth. This effort will continue ongoing work at the Crossett EF and new field studies will be installed on the Stephen F. Austin EF focusing on restoration silviculture, including harvest treatments and interim progress reports.

3. *The ecology and management of open pine- and pine-hardwood ecosystems*. Open pine- and pine-hardwood ecosystems have rapidly declined from pre-Euroamerican settlement, with alterations to historical fire regimes, implementation of silviculturally controlled forest dynamics, expansion of multiple invasive species, and the impacts of agricultural practices. These changes led to closed-canopy forests of fire-intolerant species becoming dominant across most of eastern North America. The decline of open forests has led to declines in many affiliated species of plants and wildlife, making the restoration of open forests a high priority for resource managers. Studies on environmental drivers, treatment options, and restoration outcomes are needed to determine what actions can restore this once-dominant cover type across much of the southern United States. Conventional silvicultural tools can help, but many of these focus on full stocking and encouraging continuous tree regeneration, and hence are antithetical to supporting understory communities or wildlife that depend on open spaces. A new suite of tools intended to restore and sustain these open forests are needed, and this effort will focus on the continued refinement and synthesis of knowledge on restoration ecology and its silvicultural applications, as well as more support for ongoing field studies on open forests on the Crossett EF.

4. *Long-rotation even-aged management.* Intensively managed southern pine plantations are typically managed with relatively low initial planting densities and thinned frequently to encourage maximum individual tree growth to yield sawtimber quicker. New priorities to store more carbon in forests (to ameliorate climate change) and to produce wood of higher strength suggest an alternative approach to even-aged silviculture (in either natural-origin or planted pine). Under this scenario, some may seek to grow a denser stand over a longer rotation (50-75 years); this may be an option for landowners interested in long-term carbon contracts with the potential of harvesting high-value poles or pilings. Balancing these denser stands with wildlife habitat requirements, forest health concerns, and the economic viability of this system (given higher planting densities and lower product-based returns) needs further investigation.

5. *Landscape-scale restoration of shortleaf pine to replace industrial loblolly pine plantations*. Over the years, the Ouachita National Forest exchanged large parcels of land with a number of timber companies to support mutually beneficial land management efforts. Much of this exchanged land was cleared of native forest and planted in loblolly pine; most of these converted lands are beyond loblolly pine's native range and is therefore considered to be off-site. Given the predicted increase in drought frequency and expected higher temperatures, both of which may

favor catastrophic insect outbreaks and drought-related mortality in these planted loblolly pine, the Ouachita National Forest is interested in converting these mature stands into more appropriate shortleaf pine and pine-hardwood stands. This effort will likely entail (in the short term) supporting assessments of existing landscape conditions; in the long term, this work will likely involve a number of large-scale field experiments on which silvicultural techniques are most effective in the conversion of planted loblolly pine to shortleaf pine.

Outcomes in Problem 1d expected during the time covered in this RWUD:

- Review paper on ecosystem services and uneven-aged silviculture in southern pines.
- Management guidelines for large-scale conversion of plant loblolly pine to shortleaf pine-dominated forests.
- A manager's guide for restoration silviculture in pine- and pine-hardwood forests.
- Synthesis papers on open forest ecology and management in pine-dominated stands.
- Paper on the prospects of long-term, even-aged pine management for carbon storage and high value end products.

Problem 2: We will discover and transfer knowledge about the effects of forest management, insect pests, disease, fragmentation, invasive species, emerging threats, and climate change on wildlife and wildlife habitat in southern pine-dominated ecosystems, so that managers have better tools to restore and manage wildlife populations that are healthy, diverse, and sustainable.

Research directions and expected accomplishments by emphasis area for this RWUD:

Problem 2a. Develop and discover knowledge about how forest management and forest fragmentation affect the quality and quantity of terrestrial and riparian/aquatic habitats and associated wildlife species, so land managers can make better decisions about managing riparian zones and wetlands for resource benefits that feature wildlife species of interest.

1. *Forest management and fragmentation effects on wildlife communities and habitat.* Forest management is the primary driver for forest-wildlife communities. Management practices such as harvest and burning determine the wildlife communities associated with any particular forest stand. For many species, individual treatments can have positive, negative, or neutral effects on abundance, reproduction, and survival. For more substantial treatments such as timber harvest and silvicutural systems, entire wildlife communities can differ among these different treatment methods. Slight differences among management prescriptions, such as varying residual snag densities can also have profound effects on the wildlife species expected to occupy a forest stand. For example, the bird community found in a young clearcut may have few or no species in common with an unharvested stand. For many wildlife taxa such as reptiles and amphibians, the effects of many management treatments are unknown.
2. *Forest management and fragmentation effects on riparian and aquatic habitats*. Declining amphibian populations have a major impact on the biodiversity of many ecosystems. Riparian and wetland habitats are critical to the lifecycle of most forest-dwelling amphibian species in the southeastern United States; however, most species have a terrestrial phase that is dependent on the surrounding forested habitat. The effects of forest management on aquatic habitats is poorly studied but understanding these effects is critical to inform management practices that are sensitive to maintaining the biodiversity of forested ecosytems.

Outcomes in Problem 2a expected during the time covered in this RWUD:

- Determine food web structure and wildlife community changes with variable management intensities.
- Determine the effects of forest management on aquatic ecosystems.

<u>Problem 2b.</u> Quantify and model how population dynamics, ecosystem restoration, forest management, habitat fragmentation, invasive species, climate change, altered fire regimes, and their interactions affect biotic communities, with emphasis on species of conservation concern, so that managers can make better decisions about conservation and management of these communities across the landscape.

1. *Ecosystem restoration and effects of altered fire regimes on wildlife populations.* Wildlife species associated with fire-maintained forest communities have declined over the past few decades due to fire-suppression activities. Species such as the red-cockaded woodpecker, Louisiana pinesnake, and Bachman's sparrow have declined substantially. Land managers are working to restore large areas of woodlands across the South in an effort to emulate historical forest conditions and associated wildlife communities. These restoration efforts and the periodic burning required to maintain these fire-dependent forests profoundly affect wildlife and plant species, but information on responses of numerous plant and animal species to these efforts is often lacking. Managers seek information on the impacts of their efforts and tools to more efficiently restore and maintain these woodlands.
2. *Effects of climate change on forest wildlife communities.* Changes in climate are happening more rapidly than previously predicted, often resulting in novel environments and new types of species interactions. Changes that affect the distribution of species (e.g., shifts of various species northward or to higher elevations) are well documented and increasing, as are the expanding ranges of exotic species. As species migrate to new areas, they encounter new habitats as well as different species to interact with, including parasites, predators, and prey, and they may themselves contribute to declines of other species. These new interactions affect survival, reproduction, and other vital life-history rates. Determining previous changes in range, current changes that are occurring, as well as modeling potential future changes will aid managers in determining what species occur or will potentially occur within their jurisdictions. Knowledge of the existence of newly arrived sensitive species and the novel ecosystem circumstances arising is critical information for land managers, especially given the regulatory statutes they are mandated to follow on declining, threatened, and endangered species.
3. *Species of conservation concern.* Among land managers, sensitive, threatened, or endangered species contribute a disproportionate amount of work due to the regulatory requirements associated with the national Environmental Policy Act and the Endangered Species Act. Goals of these research efforts on threatened or endangered species are to improve upon local, regional, and national efforts to conserve and recover declining species before regulatory controls affect forest management practices. For species already listed, the goal is recovery of species to stable populations, which reduces or eliminates these regulatory requirements. Research on these species are often complex, integrative, and multiscalar. Studies include population-level studies to determine the fine-scale effects of weather and population size on breeding success, efficacy of captive breeding and/or reintroduction programs for threatened or endangered species recovery, and studies of foraging and other critical habitat requirements. Ongoing research on threatened or endangered species such as the red-cockaded woodpecker, northern long-eared bats, and Louisiana pinesnake will be continued.

<u>Outcomes in Problem 2b expected during the time covered in this RWUD:</u>

- Model effects of climate change and associated changes in vegetation communities on the distribution of Seminole bats (*Lasiurus seminolus*) across the United States.
- Model the effects of fine-scale weather data and climate change on the foraging habitats and nesting success of the red-cockaded woodpecker.

- Determine the effects of woodland restoration and frequent burning on various components of wildlife habitat, such as snags, mast, and understory plant diversity.
- Determine avian response to longleaf pine restoration.
- Determine avian response to altered fire regimes in loblolly and shortleaf pine ecosystems.
- Determine small mammal and avian responses to prairie restoration efforts in the National Forests of Texas.
- Examine the effects of invasive grasses on small mammal and over-wintering bird populations.
- Determine American kestrel (*Falco sparverius*) nesting success and prey availability in fire-maintained pine ecosystems.
- Determine wild Louisiana pinesnake population levels, including the development of novel techniques to monitor/detect Louisiana pinesnakes.
- Identify continued threats to Louisiana pinesnakes and develop reintroduction techniques and strategies for this species.
- Identify current distribution and abundance of eastern spotted skunk (*Spilogale putorius*, a candidate species under review by the U.S. Fish and Wildlife Service) across their range.

<u>Problem 2c.</u> Examine the direct and indirect effects of forest management on the ecology of forest bats and the resources essential for bat survival, including their insect prey base, to help land managers better provide habitats.

1. *Forest management effects on bat foraging habitat.* Almost all North American bats rely on forests for survival. Forest management practices such as tree harvest, prescribed burning, site preparation, and other activities can have positive or negative effects on bats. These activities alter the structure of forests, affect the distribution and abundance of living and dead trees used for roosting, and influence the number of forest openings and edges used for foraging. Bats feed on a variety of night-flying insects, catching them in the air or picking them off vegetation. Many bat species prefer to hunt in small- to medium-sized forest openings or gaps such as those created by timber harvests, tree death, or tree-fall. Nevertheless, information on the effects of management practices such as thinning, midstory removal, and burning on foraging ecology of bats is lacking.

2. Forest management effects on roosting habitat. Roosts are often considered the most important habitat component, and roost switching during summer appears to be essential for most species. More than half of bat species roost in dead and dying trees, especially beneath loose bark and in tree cavities. A number of other species roost in the foliage of living trees. The characteristics of a dead tree (height, diameter, level of decay) and its position in the forest stand and the larger landscape are the most important factors in determining its suitability as a roost site. The density of roost trees needed to maintain forest-bat populations is unclear and may vary by forest type, region, and bat species. The structure of a snag, as well as its location within a stand and the surrounding forest matrix, is often more important than its species. Effects of management treatments on the abundance and quality of bat roost trees is lacking for most bat species and in most forest types. Stand manipulations surrounding important roost trees can be beneficial or detrimental to roosting bats as well, depending on the treatments. The effects of stand manipulations on roost tree use by bats is poorly understood.

3. Forest management effects on bat communities. In forests of the Southeast, bat communities can be composed of up to 18 species. Differences in life-history traits, roosting and foraging habitats, and effects of various habitat manipulations are generally unknown for most species.

Information is needed on how forest manipulations affect the abundance of different species or contribute to increases or decreases in species diversity of bats.

Outcomes in Problem 2c expected during the time covered in this RWUD:

- Examine the effects of woodland restoration and burning on bat and pollinator communities.
- Synthesis papers reviewing forest management and bat populations targeting both the scientific community and forest/land managers.
- Determine the availability of forest insect prey during winter and response of bats to winter insect abundance.
- Examine selection of winter tree roosts by northern long-eared bats in southern populations to determine attributes of roost trees, stand conditions, and surrounding landscape composition.
- Map and model use of talus slopes and cliff faces as roosting areas by small-footed bats (*Myotis leibii*).

Problem 2d. Examine effects of white-nose syndrome on bat populations, including survival, winter activity, hibernation patterns, hibernacula selection, population declines, and potential treatments to provide land managers with a better understanding of this disease and the tools necessary to maintain resilient forest ecosystems.

1. *Effects of white-nose syndrome on survival, reproduction, and population demographics of forest bats.* White-nose syndrome has profound effects on survival and reproduction of some bat species. Managers and researchers need information on these critical population parameters to determine and model population trajectories for species that are affected by WNS. These population parameters likely differ geographically due to climate, forest type, forest management practices, and numerous other landscape-scale factors that vary across regions. The adverse effects of WNS on population parameters may also differ based on climatic differences associated with latitude. For example, in southern areas where winters are shorter and warmer, effects of WNS on survival are unknown, but could be less severe than in more northerly latitudes.
2. *White-nose syndrome and selection of bat roosting sites.* White-nose syndrome may affect how bats select winter and summer roosts. For example, bats susceptible to WNS in the Northeast selected cooler winter hibernation sites compared to sites where they hibernated pre-WNS. These sites apparently reduce the growth rates of the WNS fungus on bats while they hibernate. Information on selection of winter roost sites for species that hibernate in caves and abandoned mines is critical to understanding potential effects of WNS on bat populations so that conservation actions can target the most important sites. For some species such as the northern long-eared bat, winter roost selection in areas of the Deep South may not involve hibernating in caves and abandoned mines. These species may remain active on the landscape during winter and roost in trees, which would suggest WNS may not affect those populations.
3. *White-nose syndrome effects on bat populations and communities.* White-nose syndrome has decimated populations of some species, including northern long-eared bats, little brown bats, and tri-colored bats. These declines have led to the federal listing of the northern long-eared bat as federally threatened, and the tri-colored bat is currently under review. Other species, including small-footed bats and Indiana bats have also declined due to WNS. These declines in certain species have contributed to changes in bat communities due to reductions in competition and interspecific interactions. Although dramatic population declines in some species have occurred in the northeastern United States, population trends in other areas such as the Southeast are unknown. Information is needed on current status of each species, population trajectories, and changes in

community composition in the Southeast.

Outcomes in Problem 2d expected during the time covered in this RWUD:

- Determine survival rates of hibernating tri-colored bats and effects of WNS on survival in abandoned mines of the South.
- Determine potential attributes associated with abandoned mines that provide greater survival of tri-colored bats during hibernation.
- Monitor potential population declines in northern long-eared bats.
- Model temporal changes in insect abundance to determine potential food abundance during different times of the year for bats forced to leave hibernation due to WNS.
- Mapping the northern long-eared bat genome and determine if isolated populations that do not hibernate (not susceptible to WNS) in some southern regions are genetically isolated.
- Determine changes in bat community composition after arrival of white-nose syndrome.
- Determine use of road culverts by tri-colored bats during winter in the Gulf Coastal Plain.

Problem 2e. We will examine the direct and indirect effects of climate change and invasive species on the ecology of amphibians so that managers can make better management decisions and improve upon mitigation efforts.

1. *Effects of climate change on amphibians.* Climate change is considered one of the greatest threats to biodiversity. Shifts in climate can effect the phenologies of numerous species representing a broad range of taxonomic groups; however, the effect on amphibians is much more pronounced than in other groups. Although amphibians are sensitive and respond quickly to shifts in climate, each species responds in its own way. Understanding these differential responses to climate is vital to predicting potential species interations that will result from climate change and will give managers insight into potential range shifts and population dynamics.
2. *Effects of invasive plant and animal species on amphibians.* Invasive species are another component of global change that profoundly effects biodiversity. Invasive plant species are known to alter the physical and chemical environment and change the trophic structure of the invaded habitats. Chinese tallow (*Triadica sebifera*) is listed as one of the worst invaders in the United States. This invasive deciduous tree species is now the fifth most common tree species in eastern Texas and Louisiana. Recent studies on Chinese tallow have demonstrated that the leaf litter has profound effects on the water chemistry and microbiome of experimental wetlands. These changes in water chemisrty have been shown to cause mortality in amphibian larvae and eggs. Understanding the threats posed by specific invasive species on native wildlife can inform managers on how to proiritize invasive species control and mitigate loss of biodiversity.

Outcomes in Problem 2e expected during the time covered in this RWUD:

- Determine the effects of Chinese tallow on amphibian populations.
- Model phenological changes in amphibian communities under changing weather conditions.
- Determine species interaction potential under varying climate change scenarios.
- Determine physical and chemical changes to the invaded environment caused by invasive plant species.

Problem 3. Discover and transfer science outcomes related to the restoration of ecosystem function and resilience in pine- and pine-hardwood-dominated forests to improve the long-term socioeconomic well-being of affected communities.

Research directions and expected accomplishments by emphasis area for this RWUD:

<u>Problem 3a.</u> Investigate how pine- and pine-hardwood-dominated landscapes are affected by interacting biotic and abiotic factors, particularly in support of large-scale restoration efforts.

1. *Natural disturbance impacts on southern pine ecosystems.* Natural disturbances have a strong influence on the development and sustainability of forested landscapes, yet the understanding of how they influence forest development and management actions is still less than ideal, even after decades of study. Translating existing research into best management practices will be critical to support large-scale restoration initiatives of the National Forest System, as well as other public and private landowners, as a changing climate continues to alter the physical and biotic environments affected by natural disturbances.
2. *Silviculture on experimental forests revisited.* The experimental forests in the SRS have long had large-scale, long-term studies of traditional silvicultural systems. While many of these are important to maintain unmodified into the future (to continue to research the longitudinal influences of treatments), others can be modified to better correspond with current trends in management (e.g., application of new herbicides unavailable when the study was originally installed) or have their past data reinterpreted using contemporary scientific needs (e.g., looking at the long-term differences in methods of cutting studies in terms of carbon accumulation). Additional, new silvicultural research focusing on restoration goals emphasizing a full range of ecosystem goods and services, rather than just timber production, also present new opportunities.
3. *Shortleaf pine restoration.* A recent and very rapid decline of shortleaf pine across its native distribution has led to efforts by the Forest Service, numerous state agencies, and a number of non-governmental organizations to restore this species across most of its historical range. Indeed, shortleaf pine restoration is specifically listed as a Shared Research Priority (Appendix A) between the SRS and the Southern Region of the Forest Service. Some of this decline has its origins in the loss of fire on the landscape, some is likely due to hybridization with loblolly pine, and a large portion is probably attributable to changing silvicultural practices across shortleaf pine's range. Scientists need to better understand all of the forces in play, including their interactions with each other, and managers need more information and better tools to restore this iconic species across multiple scales before shortleaf pine becomes a species of regulatory concern.

<u>Outcomes in Problem 3a expected during the time covered in this RWUD:</u>

- Continue ongoing studies on natural disturbances such as ice, wind, fire, and invasive species, with contributions to publications on these topics.
- Adapt long-term studies on SRS experimental forests to develop new understandings of how silvicultural practices may interact with natural processes and perturbations.
- Develop new restoration-based management guidelines for natural-origin pine-dominated stands focusing on ecosystem services or old-growth-like attributes.
- Develop silvicultural recommendations for restoration efforts at the stand-, landscape-, and regional scales in support of Shared Research Priorities.
- Develop and refine recommendations for large-scale restoration efforts related to shortleaf pine.

<u>Problem 3b</u>. Research into opportunities to increase our understanding of the biota associated with pine- and pine-hardwood communities through the development, application, and improvement of ecological models and measurement techniques.

1. *Modeling tree biomass.* Through the years, work on experimental forests has generated a large quantity of growth and yield data for naturally regenerated and planted southern pines under a number of different management options (e.g., planting spacing, prescribed fire, pruning, thinning). To date, these data have been used in a multi-agency modeling project that included other state and federal agencies and numerous university collaborators. While still useful for the more traditional measures of growth and yield (e.g., wood or pine straw production, economic evaluations), these data also have the potential to be useful in other measures of the ecosystem services (e.g., sequestered carbon) produced by pine- and pine-hardwood-dominated forests. This effort will involve the development of new models and refinement of existing ones, as well as supporting documentation.
2. *Improving tree height measurement and models.* Tree height has been measured for centuries; some tools currently used by those measuring this parameter were often developed decades ago and are based on assumptions that can be challenging to meet. Today, hand-held lasers, digital photography, LIDAR technology, and even remotely controlled drones can be coupled with more sophisticated measurement approaches that are less sensitive to the violation of assumptions to reduce or perhaps even eliminate a key source of error in the quantitative measurement of forest structure. This effort will involve the continued development of tools and techniques to improve upon tree height measurement and its prediction, including how this work may affect silvicultural research into pine- and pine-hardwood stands.

Outcomes in Problem 3b expected during the time covered in this RWUD:

- Measurement of long-term field installations to provide growth and yield information for modeling stemwood yields and associated commodities from pine- and pine-hardwood stands.
- New or improved ecological models of biomass, ecosystem production, wildlife habitat, forage production, and the goods and services produced by southern pine ecosystems.
- Methods paper(s) related to improving ways of measuring and modeling tree height.

Problem 3c. Expand expertise on the socioeconomic costs and benefits of the restoration of southern pine and pine-hardwood ecosystems.

1. *Cost-benefit analysis.* We will pursue developing research partnership(s) to develop tools for economic analysis of the benefits, costs, and potential risks associated with public and private investment and changes in land use when restoring large areas of pine- and pine-hardwood-dominated ecosystems. These may include (but are not limited to): 1) understanding the ecological tradeoffs between restored southern pine stands and the other forest types that they replace; 2) the impacts of prescribed fire as a management tool versus its impacts as an influencer of air quality; 3) the potential value of herbicide use to accelerate restoration versus repeated prescribed fire; 4) the socioeconomic impacts of shortleaf pine restoration following conversion of slash or loblolly pine-dominated stands on water quality and quantity; 5) the value of non-traditional ecosystem goods and services to human communities, private and public landowners, and the timber industry; and 6) the relative impacts of climate change on restored vs. unrestored pine- and pine-hardwood-dominated landscapes.
2. *Ability of pine- and pine-hardwood-dominated forest restoration to address global climate change through carbon sequestration while boosting other ecosystem goods and services.* When properly grown, southern pine's heavy, dense, strong wood offers multiple opportunities to improve upon the traditional timber-related component of ecosystem goods (e.g., dimensional lumber, poles, pilings, veneer) and developing markets for new wood products opportunities (e.g., cross-laminated panels and other mass timbers). The properties of southern pine wood

can also contribute to increased carbon sequestration, particularly if the wood is incorporated in durable uses. For example, we will examine the potential of southern pine-dominated stands as an opportunity to produce long-term climate benefits through carbon storage throughout the life-cycle of this species (standing tree to consumed wood product). This effort will continue to synthesize existing information on how silvicultural decisions affect wood quality and other ecosystem services outcomes.

3. *Identify opportunities to combine restoration and management treatments of pine- and pine-hardwood ecosystems with production of materials useful for bioenergy, nanotechnology, and other emerging material science advances.* Restoration and management practices can yield substantial quantities of woody material that may be less suitable for traditional timber products. Rather than leaving all such material onsite, a significant portion may be repurposed to support the economic development of emerging industries and thereby support rural communities. Other silvicultural practices (e.g., naturally regenerated southern pine-dominated forests managed on longer rotations) may provide additional ecological and societal benefits (e.g., more and cleaner water) that meet broader landowner objectives. These alternative practices still rely on cash revenues from a dynamic forest industry, so we will assess opportunities to link southern pine restoration and management activities with initiatives that support development of new industries. For example, recent developments related to engineered wood products, such as mass panels, may hold promise for southern pine silviculture that emphasizes wood quality (e.g., high specific gravity) over expedient volume growth, thereby allowing for a greater range of ecosystem goods and services (e.g., carbon sequestration) to also be produced while developing new commercial markets for wood.

Outcomes in Problem 3c expected during the time covered in this RWUD:

- Production of decision tools or keys for assessing the restoration potential and costs of restoration on target sites.
- Measures of socioeconomic impacts of pine- and pine-hardwood-dominated ecosystem restoration on human communities.
- A new strategy for long-rotation southern pine plantations designed to store carbon (as part of a long-term carbon contract) followed by harvesting for use as high-value and durable (persistent) wood products.
- Research support for alternative silviculture practices that emphasize wood quality and how this may support new forest products industries (e.g., mass panel production) using southern pine.

Problem 3d. Develop new research directions and broader, more networked studies on experimental forests.

1. *Large-scale experiments and demonstrations of shortleaf pine restoration approaches.* The Crossett, Alum Creek, and Stephen F. Austin EFs all have had a significant shortleaf pine component, but this species is rapidly declining across much of its range. Many national forests and state resource management agencies, as well as non-governmental organizations and private landowners, are looking for new restoration options for shortleaf pine, and the ability of SRS-4159 experimental forests to aid in this effort is considerable. This effort will entail the installation of a series of new studies looking at the performance of different shortleaf pine families from across the SRS EFN, and may include the establishment of mixed family shortleaf pine plantations as a restoration option.
2. *Flux tower measurements in mature, natural-origin, pine-dominated forests.* The construction of a 120-foot-tall eddy flux tower on the Crossett Experimental Forest in 2011 added a significant

capacity to this location. Currently, researchers from as far away as Indiana and Texas have set up experiments and observations using this facility; others use the data collected and posted online in their work. Given the relatively unique circumstances of this flux tower compared to others (e.g., being in a mature, natural-origin pine stand subject to periodic prescribed fire vs. a younger pine plantation), there are opportunities to expand upon the work being done. This effort will involve working with a number of university collaborators (currently from Indiana University and University of Minnesota) and other SRS RWUs to ensure the tower continues to collect relevant data.

3. *Experimental forest network across the Southern Research Station.* An effort is currently underway to better link all SRS experimental forests together in both their infrastructure, availability, and research project coordination. Some scientific questions cannot be suitably addressed by studies installed in a single location; other questions cannot be answered by observations limited in their biogeographic realm. Although not all studies can be implemented on each experimental forest (due to fundamental ecological differences and resource inadequacies), it should be possible to expand upon some topics in which the experimental design is controlled (kept constant) with the exception of geographic location. This work is new and novel and without much precedent, so the expected efforts on this direction will depend on how well integrated initial efforts (such as the establishment of FIA intensified plots on all SRS EFs) become.
4. *New plans for the Stephen F. Austin and Alum Creek EFs.* Originally developed to study pine silviculture in eastern Texas, then the influences of forestry on wildlife management, the Stephen F. Austin EF has contributed much to our understanding of a number of natural resource topics. However, forest management treatments (with the exception of the intermittent application of prescribed fire) have not been implemented since the early 1990s, and the forest has further matured and become overstocked. The need for widespread harvest treatments in the uplands of the experimental forest and a desire within the SRS to approach experimental forests differently have aligned. We plan to work with partners in the Angelina National Forest, Stephen F. Austin State University, the East Texas Plant Materials Center (USDA Natural Resources Conservation Service), and Texas Parks and Wildlife Department to develop a new overall management plan for the Stephen F. Austin Experimental Forest to feature restoration silviculture in most of the upland forests, with an emphasis placed on open, shortleaf pine-dominated forests. Alum Creek EF was established to study the influence of landscapes and silvicultural practices on hydrology; its dominance by shortleaf pine offers new opportunities to study this declining species in the heart of its most successful range. This effort will involve developing a network of partners and collaborators, ranging from other public agencies and non-governmental organizations, with a short-term goal of developing management plans for long-term research and demonstration objectives.

<u>Outcomes in Problem 3d expected during the time covered in this RWUD:</u>

- A common garden study of shortleaf pine reproductive capacity and success across much of its botanical distribution, starting with the EFN as a seed source.
- Baseline assessment of carbon flux in a mature loblolly and shortleaf pine stand using tower-based measurements.
- New strategic direction for the management and research on the Stephen F. Austin and Alum Creek EFs, with special emphasis placed on shortleaf pine and understory community restoration.
- Botanical inventories of the Crossett, Alum Creek, and Stephen F. Austin EFs and local natural areas.

11. ENVIRONMENTAL CONSIDERATIONS:

Most of the studies covered in this RWUD to be conducted by SRS-4159 involve activities that are not expected to have a significant adverse effect on the quality of the human environment. The environmental effects of specific actions will be considered during the development of all study plans, at which time the existence of extraordinary circumstances related to the proposed action and any categorical exclusions will be documented as a part of the study plan as described in FSH 1909.15, Chapter 30. Study plans developed for field research or treatments conducted on public lands, especially Experimental Forests and NFS Research Natural Areas, will comply with with relevant environmental regulations and policies expressed in FSM 4060, FSM 4080, and other relevant directives. Any other SRS-4159 study installations or treatment activities that are determined to have sufficient environmental consequences will receive the appropriate level of environmental assessment. For research involving the use of toxicants, environmental considerations will be further evaluated through Environmental Assessments or Environmental Impact Statements prepared with, and reviewed by, the cooperating National Forest System staff and line officers. For research having the potential to affect a plant or animal species that is federally listed as endangered or threatened or proposed for such listing, SRS-4159 will consult with National Forest System biologists and the U.S. Fish and Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended.

Key Cooperators:

We will collaborate with professional resource managers and academic colleagues from public and private organizations across the southern United States to address the effects of management practices on pine- and pine-hardwood-dominated forest structure, function, and processes. We will collaborate with research scientists and land managers to study, manage, restore, and protect threatened and endangered species, alternative management approaches, and the production of various ecosystem goods and services, such as pollinator habitat, biofuels, carbon sequestration, ecotourism, water quality and quantity, and wildlife habitat. We will collaborate with government and private organizations to develop tours, field trips, and publish brochures and other written and web-based materials. Some of the key cooperators include the following:

USDA Forest Service

Southern Research Station:

SRS-4156—Center for Forest Disturbance Science
SRS-4157—Upland Hardwood Ecology and Management
SRS-4158—Restoring and Managing Longleaf Pine Ecosystems
SRS-4160—Forest Genetics and Ecosystem Productivity
SRS-4353—Center for Forest Watershed Research
SRS-4552—Insects, Diseases, and Invasive Plants of Southern Forests
SRS-4703—Forest Operations
SRS-4704—Utilization of Southern Forest Resources
SRS-4801—Forest Inventory and Analysis
SRS-4804—Forest Economics and Policy
SRS-4854—Eastern Forest Environmental Threat Assessment Center
SRS-4855—Center for Integrated Forest Science
SRS-4952—Integrating Human and Natural Systems

Northern Research Station

Research Unit 3: Ecology and Management of Invasive Species and Forest Ecosystems
Research Unit 5: Forest Inventory and Analysis
Research Unit 6: Climate, Fire, and Carbon Cycle Sciences

- Research Unit 11: Sustainable Management of Central Hardwood Ecosystems and Landscapes
- Research Unit 13: Institute for Applied Ecosystem Studies
- Southern Region, Regional Office, Atlanta (GA)
- Forest Health Protection, State and Private Forestry (various locations)
- National Forests in: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas
  - Angelina National Forest
  - Kisatchie National Forest
  - Ouachita National Forest
  - Ozark-St. Francis National Forest
- National Agroforestry Center (NE)
- Savannah River Forest Station, New Ellenton, SC

Other Federal Agencies:

- USDA Natural Resource Conservation Service
  - East Texas Plant Materials Center, Nacogdoches, TX
- US Department of Defense
  - Fort Benning
  - Fort Chaffee
  - Fort Stewart
  - Fort Gordon
  - Fort Polk JRTC
  - Eglin AFB
  - Camp Lejeune MCB
  - Army Corps of Engineers
- US Department of the Interior, Fish and Wildlife Service
  - Regional Office in Atlanta (GA)
  - Ecological Services (for Arkansas, Texas, Louisiana)
  - Felsenthal National Wildlife Refuge
- US Department of the Interior, Geological Survey

Universities:

- Alabama A&M
- Arkansas-Fayetteville
- Arkansas-Monticello
- Arkansas State
- Arkansas Tech
- Auburn
- Central Arkansas
- Clemson
- Florida (at Milton and Gainesville)
- Florida A&M
- Florida International
- Indiana
- Louisiana State (includes the LSU AgCenter and Louisiana Cooperative Extension Service)
- Louisiana Tech
- Minnesota
- Mississippi State

Oklahoma State
Rice
Stephen F. Austin State
Texas A&M
Texas Tech
Tuskegee
Virginia Tech

State Agencies:

Alabama Cooperative Extension Service
Alabama Forestry Commission
Arkansas Archeological Survey
Arkansas Forestry Commission
Arkansas Game and Fish Commission
Arkansas Natural Heritage Commission
Florida Forest Service
Louisiana Department of Agriculture and Forestry
Louisiana Department of Wildlife and Fisheries
Mississippi Department of Wildlife, Fisheries, and Parks
State Forest and Research Stations Division
North Carolina Dept. of Agriculture and Consumer Services: Research Stations Division
Oklahoma Department of Wildlife Conservation
Oklahoma Forestry Services
South Carolina Forestry Commission
Texas A&M Forest Service
Texas Department of Transportation
Texas Parks and Wildlife Department

Private organizations or companies:

Alabama Forestry Association
Arkansas Forestry Association
Bat Conservation International
Big Thicket Association
Campbell Global
Environmental Solutions and Innovations, Inc.
Georgia-Pacific
Hancock Forest Management
International Forestry Company
Joseph Jones Ecological Research Center
Louisiana Forestry Association
Longleaf Alliance
Lower Mississippi Valley Joint Venture
National Council for Air and Stream Improvement, Inc.
Native Tree Society
PotlatchDeltic
Roundstone Native Seed
Shortleaf Pine Initiative
Southeastern Partners of Amphibians and Reptiles
Tall Timbers Research Station
Tangled Bank Conservation

Texas Forestry Association
Texas Longleaf Taskforce
The Nature Conservancy
Weyerhaeuser Company

12/13. STAFF AND COSTS:

This Research Work Unit Description (RWUD) describes an ambitious five-year plan of work. Based on a proposed staffing level of four scientists and about $2.1 million per year, we expect to implement the majority of research described in the RWUD (and should get more done through collaboration with key cooperators). Additional (new lines of) work would be possible (especially in Problem Area 3) with a higher level of funding and more staff.

Staffing Plan: RWU Staffing and Funding

Problem Area	*Scientists* per year of the RWUD				
	2020	2021	2022	2023	2024
1	1.0	1.0	1.0	1.0	1.0
2	2.0	2.0	2.0	2.0	2.0
3	1.0	1.0	1.0	1.0	1.0

SRS-4159 currently consists of three permanent full-time research scientists, four permanent full-time professional wildlife biologists, one permanent full-time professional forester, three permanent full-time forestry/biological technicians, one permanent part-time statistician, and two permanent full-time support services specialists. In addition, SRS-4159 has an emeritus scientist (stationed at Pineville, LA) and several other contracted scientists, support staff, and student workers. Our record of accomplishments and ability to sustain long-term studies and datasets depend heavily on the expertise of our permanent technical staff and the maintenance of three experimental forests (Crossett, Stephen F. Austin, Alum Creek). Several scientists and technical staff are at or approaching retirement age within the timeframe of this RWUD. Temporary technicians are hired for summer and short-term appointments using soft money. SRS-4159 budgets over the last five years have been flat or slightly declining; budgets for future years are projected as declining. The unit is engaged in leveraging strategies with partners to expand our research resource base. Unless projections change, future flexibility and accomplishments will depend on external funding. Presently the unit brings in between $100,000 - $200,000 annually in outside funding.

SRS-4159 is responsible for maintaining three experimental forests: the Crossett, located in Ashley County, southeastern Arkansas, the Stephen F. Austin, located on the Angelina National Forest near Nacogdoches, TX, and most recent, the Alum Creek, near Jessieville, AR. The Crossett EF was established in 1934 through an agreement with the Crossett Lumber Company, with a permanent and final land transfer to the federal government occurring in the late 1970s. The 1,675-acre tract contains a forest dominated by naturally regenerated loblolly and shortleaf pine, with only a few areas planted to pines, and a relatively minor hardwood component in multiple compartments. To date, research and demonstration on the Crossett EF has focused on low-cost, low-impact silvicultural practices in naturally regenerated pine-dominated stands, loblolly and shortleaf pine regeneration, uneven-aged and even-aged silvicultural options in loblolly and shortleaf pine forests of the Gulf Coastal Plain, and forest genetics/tree improvement. The Crossett EF has substantial infrastructure related to the research and demonstration work done there over the years, including multiple office, laboratory, workspace, storage, and lodging buildings in a main headquarters compound, an all-season road network, and an eddy flux tower. Currently, one permanent SRS-4159 employee (Forest Manager) is duty stationed at Crossett; another permanent SRS-4159 employee (Forestry Technician) travels almost daily from his Monticello duty station to assist in Crossett operations. An additional SRS employee (with FIA) has a duty station at

Crossett. Up to four staff of the Arkansas Forestry Commission are stationed in the Crossett office building. The Stephen F. Austin EF consists of 2,560 acres of upland forest dominated by shortleaf and loblolly pine, with numerous hardwood species, and a large parcel (about 2/3 of the Forest) of mature bottomland hardwood forest. Although less active than the Crossett EF in recent years, some building infrastructure is available in association with the East Texas Plant Materials Center of the USDA Natural Resources Conservation Service (NRCS). Currently, no SRS staff are duty stationed on the Stephen F. Austin EF, but a number of NRCS staff are located at the East Texas Plant Materials Center. Historically the home of pine silviculture, game species management, and other wildlife ecology research, the future management and research directions for the Stephen F. Austin EF are fluid but will likely emphasize shortleaf pine-dominated ecosystem restoration in the uplands. The Alum Creek EF was added to the inventory of SRS-4159 in late 2019 following the retirement of the previous scientist in charge. This 4,658-acre experimental forest is part of the Ouachita National Forest and has hosted watershed, wildlife, and silvicultural research. This shortleaf pine-hardwood forest has some limited hydrology-based infrastructure, but no on-site staff. The prominence of mature, natural-origin and older growth (>120 years) shortleaf pine at Alum Creek EF will add to SRS-4159's portfolio of research on this declining species.

APPENDIX A. Shared Research Priorities - Southern Region (RS) & Southern Research Station (SRS)

Adapted from memo signed by SRS Station Director Robert L. Doudrick and Southern Region Regional Forester Ken Arney date January 17, 2020.

1. Southern Forest Futures Outlook

SRS and Region 8 are working together to develop the Southern Forest Futures Outlook {SFFO) for three specific issue areas: fire, markets, and water. Social, market, and biophysical dynamics continue to change the South's forest sector. The SFFO will inform forest sector decision makers and the interested public about observed trends, anticipated futures, and critical issues based on synthesis and interpretation of existing science, data, and projections. The SFFO will be question driven and linked to 2020 RPA projections of land use change, forest conditions, timber supply and demand, and forest product markets. These projection will inform a southern assessment of land use and forest conditions as well as issue analysis on 1) water and forests, 2) fire in a changing ecological and social landscape, and 3) timber market conditions and futures.

Leaders for each of these three chapters have identified key questions from previous assessments that will be revisited in the SFFO. New issues will also be addressed, including how to deal more effectively with catastrophic forest disturbances, particularly salvage, on national forests and other lands in the South. The SFFO is in the process of determining audiences, products, deadlines, and approaches for public engagement. The SFFO leadership team will meet with the Southern Group of State Foresters Committees on water, fire, management, and utilization this winter to discuss research questions and engage state partners. The study plan will be completed in the summer of 2020, followed by a public comment period, and research will begin in the fall of 2020.

2. Keeping Forests Initiative

The Keeping Forests initiative is a broad coalition of partners identifying ways to retain 245 million acres of forest across the South. Forests and water are inextricably linked, and people are dependent on forested lands to provide clean, reliable water supplies for drinking and to support local economies. Water supplies in the region are at risk of degradation from continued conversion of privately-owned forests to other land uses to support a growing population. A key component of maintaining this "green forest infrastructure" is ensuring that healthy forests are maintained using sustainable forest management.

SRS scientists are partnering with the Ecosystem Services team of Keeping Forests to develop a model-based approach to quantifying the ecosystem service value of forest water resources. The effort will highlight the benefits of sustainable forest management for downstream water quantity and quality and the potential to generate water markets associated with sustainable forest management. The intent is to use the best available science to both measure and assign (tax parcel) water related ecosystem services accruing from private forestlands and their management; then translate that information into a web application that enables governments, utilities, NGOs, and private landowners to understand the water-related values of private forests.

3. Improving Fire Management

SRS and Region 8 are working together to improve fire management in the South. SRS is working with other Research Stations and NGOs to finalize a framework and implement a coupled fire-atmosphere prediction system jointly developed with Los Alamos National Laboratory. The system integrates 3-D fuels, fire behavior, ecological fire effects, and smoke emissions in a high-resolution system accessible to fire managers in support of fire operations. The tool will improve firefighter safety, human health, and resource management outcomes.

SRS is collaborating with the Centers for Disease Control to quantify differences in human health impacts

due to acute and chronic smoke exposure from wildfires and prescribed fire. A five-year regional retrospective analysis combines CDC health assessment tools with USFS smoke modeling tools. The analysis is expected to improve understanding of relative differences in health outcomes due to different levels of smoke exposure. Future research will integrate health outcomes into daily smoke forecasting products.

SRS currently develops forecasts of annual suppression spending by the Forest Service and USDI at various lead times {1, 2 and 3 years). New research focuses on downscaling these forecasts to provide regional, monthly suppression information for policymakers, wildfire managers, and planners to respond to the uncertainties of future fire seasons.

SRS is working with forest managers to develop a prescribed fire prioritization model to identify forest stands that are good candidates for treatments that will maintain desirable species assemblages, slow the transition from xeric to mesic tree species composition, and sustain native fire adapted systems.

4. Water Supply from Forested Lands

In 2014, SRS completed a project quantifying the role of National Forest System lands in providing water supply to downstream communities and populations across the South, and is working on a similar project for the conterminous United States. SRS recently completed a project supported by SGSF that quantifies the role of state and private forests in providing water supply across the South. State and private forest lands comprise 44.2% of the total land area and contribute 44.3% of the region's water supply {836 billion cubic meters per year). Approximately 55 million people derived some portion of their drinking water supply from these forests. This project supports States by providing forest managers and landowners with data and maps that show the proportion of drinking water supply originating in forests they manage and what specific communities are served by that water. National Forest managers will benefit from this information as they work with communities to identify needs/opportunities to improve watershed conditions across the South. SRS will work with Region 8 national forest planners to integrate results of this work into NEPA projects to help forest managers improve watershed conditions.

5. Forest Markets and Ecosystem Services

SRS is developing a national forest timber harvest feasibility modeling system that seeks to identify the factors affecting successful timber sales. The modeling system, currently being prototyped for Region 1 and to be adapted subsequently to other national forest regions, will also be linked to a US and global forest sector modeling system being used in the 2020 Resources Planning Act Assessment. SRS leads the markets and trade components of the 2020 Resources Planning Act Assessment and related novel research concerning the effects of future changes in market conditions on timber harvests, forest conditions, and product manufacturers in the South and nationally.

Additional research led from the Station addresses role of taxes and regulations on timber management and the income of forest landowners in the South. Research in the Station has identified the effects of the production and export of wood pellets for energy on markets for traditional wood products. SRS continues to lead in research that quantifies how changing economic conditions, populations, wildfire prevention education, and other factors affect the occurrences of human-ignited wildfires in the South, on both public and private lands. The Station provides forecasts of wildfire suppression spending for all national forests, including those of the South, and all Department of Interior agencies, at different lead times in advance and during wildfire seasons. SRS continues to lead research on the economics of forest health, with a focus on spread of invasive species and bark beetle epidemics that affect national forests and private lands in the South and nationally.

SRS is working with Region 8 and SGSF to incorporate this type of information into plans and projects at the national forest level, and state and private entities, through activities such as the upcoming Forest

Economics Summit in New Orleans.

6. Forest Restoration. SRS, Region 8, and many others are partnering in efforts to restore longleaf pine, shortleaf pine, and white oak forests across the South.

A. Longleaf Pine Restoration

Longleaf pine forests once covered more than 90 million acres from southeastern Virginia to eastern Texas. They now occupy only 4.3 million acres, due to land conversion and fragmentation, intensive silvicultural practices, and fire suppression over the last century. Longleaf pine ecosystems provide high-quality wood products and habitat for numerous federally listed and culturally important species. For private landowners, longleaf pine offer product diversity and lower the risk of timber loss by some natural causes. In 2009, a collaborative effort emerged among more than twenty federal anô€€ state agencies, stakeholders, and non-government organizations to promote longleaf pine. The resulting America's Longleaf Restoration Initiative includes a Range-wide Conservation Plan to increase longleaf pine acreage from 4.3 to 8.0 million acres by 2024.

Region 8 recently issued a Million Acre Challenge to its forest land managers to restore longleaf pine on one million acres of national forest land. The effort targets areas that are suitable habitat for longleaf pine but currently intermixed with or completely occupied by other tree species. Current SRS research to support the success of these restoration efforts includes improving knowledge about the timing and intensity of management practices, including prescribed fire; regenerating longleaf pine while retaining the habitat values associated with mature trees; maximizing the establishment of planted seedlings and minimizing disturbance of the ground layer; and helping landowners transition back to longleaf pine stands using a variety of restoration tools.

B. Shortleaf Pine Restoration

Shortleaf pine is a widely distributed but rapidly declining species with important economic and ecological roles in the eastern United States. The Shortleaf Pine Initiative has started as an effort among federal, state, and local government agencies, universities, and non-governmental organizations determined to arrest the decline of shortleaf pine across its range. SRS is working with Region 8 and other partners to support shortleaf pine restoration. Research and technology transfer is focused on refining silvicultural treatments that can produce stands of mixed species composition; understanding factors that affect southern pine genetics and hybridization; and silvicultural options to develop and sustain a variety of desired ecosystem conditions and management outcomes.

The SRS Experimental Forest Network is well-positioned to support a wider effort to recover shortleaf pine: it is found on 16 of the 19 experimental forests, on sites ranging from the Atlantic, Lower, and Upper Gulf Coastal Plains to the elevations of the Appalachians, Cumberland Plateau, Piedmont, and Interior Highlands. This broad geographic distribution of the species creates a wide range of conditions related to structure and function of shortleaf pine ecosystems that can be assessed, measured, and modeled across the Network. SRS has initiated a project to better delineate the shortleaf resource across its range and then project future shortleaf habitat and population trends under a number of scenarios. This information will provide forest managers and policy makers with a comprehensive assessment of shortleaf's past, present, and future to focus and guide restoration and conservation efforts.

C. White Oak Improvement

Oak is highly valued for its economic and ecological attributes. Increasing demand for white oak requires active forest management to provide adequate, sustainable supply. SRS, Region 8, and State Foresters are working to identify ways to protect and improve white oak. SRS scientists are helping managers incorporate management practkes most likely to help improve white oaks stands. Scientists at the Forest Health Center in Lexington, Kentucky are sequencing the white oak genome as part of this tree improvement program. The partners are also establishing a network of demonstration forests across the hardwood region to help forest landowners and practitioners understand changes in forest composition, regeneration, productivity, and habitat quality to meet their management and restoration goals.

A broad-scale study of applied silviculture to improve forest health and resiliency on the Daniel Boone National Forest in Kentucky continues to bring together researchers and managers to address restoration goals. SRS is working with national forest managers and other partners in the Cold Hill project area to examine treatments to create conditions that sustain oak trees amid changes in disturbance regimes and forest dynamics. Researchers will examine forest response as the silviculture prescriptions are applied; provide continuity for long-term monitoring; and add analyses related to American chestnut restoration, the impact of forest pathogens, and the consequences of prescribed fire.

7. Shared Stewardship

Region 8 has forged strong partnerships with southern states through Shared Stewardship agreements. These agreements allow the Forest Service to work collaboratively with partners to identify priorities for landscape-scale treatments. Region 8 and SRS are working with the Georgia Forestry Commission to share information with private landowners in north Georgia about restoring fire-adapted communities and reducing the risk of wildfire; identifying, managing, and reducing threats to forest and ecosystem health; and maintaining a sustainable use model to ensure that their forests meet the present and future demands for natural resources and conserve working lands. SRS is providing research findings related to smoke impacts, insect and disease infestations, and priorities for improving forest and watershed conditions.

SRS is assisting Region 8 and the state of Georgia in efforts to develop shared stewardship projects to help private landowners build capacity for sustaining healthy forests, markets and incentives for retaining forests rather than converting to other uses.

8. Gulf Restoration Pilot Project in Alabama and Mississippi

SRS is working with State foresters in MS, AL, and FL, Region 8, NRCS and other stakeholders to develop a proposal Enhancing Gulf Waters through Forested Watershed Restoration for the Gulf Coast RESTORE program. The project includes a SRS-developed science-based decision support tool using hydrologic models and other data to inform restoration priorities, assess and monitor project impacts, and support adaptive-management decisions as they relate to water quantity and quality. The project would combine data synthesis and modeling to assess current watershed conditions. The team is also modeling how forest restoration efforts will affect water quantity and quality parameters across large watersheds that contribute to water quality in the Gulf of Mexico. SRS is the lead for writing the pre- and full-proposal and for conducting the analyses for the effort if funded. This project would provide important science support for the Gulf Coast Restoration across the variety of ownerships in the Gulf coast states.

9. Rapid Response to Hurricane Impacts

SRS scientists are collaborating with Region 8 and SGSF to develop tools that improve rapid response to hurricanes. Damage assessments are crucial in the immediate wake of extreme hurricanes. The destruction caused by severe storms like Hurricane Michael, which struck the southeastern U.S. in late

2018, typically restricts accessibility, and this, along with the huge scale of the impacted area, makes accurate and rapid assessments from ground observations impossible. Newly available high-frequency, high-resolution satellite technology is a game changer for rapid forest assessment. High-resolution forest maps can identify damage in hardwood and conifer areas. SRS scientists worked with state and federal forestry agencies to develop repeated assessments after Hurricane Michael and refine on-the-ground understanding of the damages. This collaborative effort improves the way storm damage can be quantified. This technology can also document forest recovery and post-storm salvage logging and the effects of multiple disturbances as part of a systematic landscape monitoring approach. For more information: https://hiform.org/.

10. Region 8, IITF and SRS support to SGSF summer meeting in Puerto Rico, June 2020

IITF has been a long standing partner for forest managers in Puerto Rico and the El Yunque National Forest, providing a sound research base for forest management. IITF, Region 8, and SRS will work together to support and serve as joint advisors for the SGSF's 2020 summer meeting in Puerto Rico. The meeting focus is resilience and restoration. SRS, R8, and IITF have committed staff to serve on the SGSF Incident Management Team organizing the meeting and organize a tour of the El Yunque National Forest. IITF and SRS will showcase research tools and science applications that can help Puerto Rico and El Yunque restore ecosystems and manage for resilient forests in the future.

11. Water Quality and Watershed Health

Extreme precipitation events threaten inadequately designed forest roads. Daily precipitation is a common factor in designing roads, but recent work has shown that rainfall intensity affects runoff and flooding. SRS is evaluating rainfall intensity and providing the basis for new tools to better understand flood hazards and improve forest road design. SRS and Region 8 are partnering to incorporate new information into forest road design and maintenance.

Sea level rise affects ecosystem processes and the provision of forest ecosystem services in the lower Atlantic coastal plain. A collaborative effort with the Francis Marion National Forest is underway to gauge a freshwater tidal stream and quantify water fluxes associated with the tidally mediated discharge. The measurements of stream discharge will be used with water quality data to assess carbon and nutrients entering the estuary. The gauging site will also be used to testing flood hazard prediction tools and to augment forest monitoring capabilities. A related study is examining the export of carbon in dissolved and gas from tidal wetlands in order to reduce uncertainties in forest carbon budgets.

12. Insect and Disease Impacts on Forest Resources

Diseases and insects, particularly those that are non-native and invasive, threaten North American forests. Tree species differ in life-history strategies and population dynamics, which could drive varying responses to these threats. To address this challenge, SRS scientists implemented a national framework to prioritize forest tree species for conservation, management, or monitoring:

https://www.srs.fs.usda.gov/pubs/58289)

Many of the most vulnerable species occur in National Forests of the South. Some have decades-long projects focused on resistance and restoration, such as American chestnut. Allegheny chinquapin and Ozark chinquapin are also highly susceptible to chestnut blight and would benefit from efforts to improve blight resistance. Red bay and Sassafras are two species that are being decimated by laurel wilt disease. Florida torreya is a rare species that has declined precipitously as the result of a canker disease. Carolina ash, pumpkin ash, Port-Orford-cedar, Carolina hemlock, butternut, and tanoak are generally more sensitive to their threats because of their limited distributions or relative rarity. Eastern hemlock and white, black and green ash are facing severe threats from hemlock wooly adelgid and emerald ash borer, respectively, but may have more breathing room with their broad geographic distributions. SRS is working

with Region 8, and state and university partners, to identify possible mitigation strategies to conserve these species.

One of the most destructive native insect species in the South is the southern pine beetle. Broad scale outbreaks can last several years if not suppressed and have resulted in more than a billion dollars in timber losses over the past few decades. SRS in cooperation with R8 Forest Health Protection developed a new tool to help managers anticipate and reduce damage from southern pine beetle. This model predicts the location of new southern pine beetle outbreak areas with 72 percent accuracy, as early as nine months in advance. This tool was initially used during the 2019 growing season in high and moderate risk areas. It will be provided to forest managers across the South in 2020. For more information: https://www.climatehubs.usda.gov/hubs/southeast/topic/forecasting-short-and-long-term-southern-pine-beetle-risk-southeastern-us.