

USDA-Forest Service  RESEARCH WORK UNIT DESCRIPTION Ref: FSM 4070	<b>1. Number</b> FS-SRS-4158	<b>2. Station</b> Southern Research Station
<b>3. Unit Locations</b> Monticello, AR; Pineville, LA; Auburn, AL; Clemson, SC		
<b>4. Research Work Unit Title</b> SRS-4158: Restoring and Managing Longleaf Pine Ecosystems		
<b>5. Project Leader (Name and Address)</b> Don C. Bragg, USDA Forest Service, P.O. Box 3516 UAM, Monticello, AR 71656		
<b>6. Area of Research Applicability</b> Regional; National	<b>7. Estimated Duration</b> 5 years	
<b>8. Mission</b> To provide knowledge, strategies, and tools for restoring, managing, and sustaining longleaf pine ecosystems, develop better understandings about the ecology and silviculture of longleaf pine and other affiliated southern pines in the southern United States, and foster insights about ecosystem restoration.		
<b>9. Justification and Problem Selection Summary</b> Longleaf pine ecosystems are a distinct part of the forest landscape in the southern United States, and these longleaf pine-dominated systems offer critical ecosystem goods and services, from habitat to water quality to high-value wood products. Once dominant over 90 million acres but now occupying only 4.3 million acres, longleaf pine ecosystems have been lost to land conversion and fragmentation, intensive silvicultural practices, and fire exclusion. The 2009 establishment of America's Longleaf Restoration Initiative and the development of the Range-wide Conservation Plan (an multi-party initiative to increase longleaf pine acreage from 4.3 to 8.0 million acres by 2024) led to the formation of the Regional Longleaf Partnership Council and numerous Local Implementation Teams to systematically coordinate this conservation effort. In 2010, the U.S. Departments of Agriculture (USDA), Interior, and Defense supported the Range-wide Conservation Plan by signing the Longleaf Pine Initiative Memorandum of Understanding. More recently, the Million Acre Challenge of the USDA Forest Service's Southern Region put in place an effort to restore longleaf pine on one million acres of National Forest land in the region by 2025. All of these initiatives (and other shared research priorities) require supporting science to ensure the appropriate restoration and management for longleaf pine ecosystems. SRS-4158 and the Southern Research Station's Center for Forest Restoration and Management will play a fundamental role in developing the science needed to help the Forest Service, the USDA, and the American public answer questions related to longleaf pine ecosystems.		
<b>Signature</b>	<b>Title</b>	<b>Date</b>
Recommended:	Assistant Station Director	5/22/2020
Recommended:	Staff Director	
Approved:	Station Director, Southern Research Station	
Concurred:	Deputy Chief for Research and Development	

## **SRS-4158—Restoring and Managing Longleaf Pine Ecosystems**

**Monticello, AR**

**Pineville, LA**

**Auburn, AL**

**Clemson, SC**

**Project Leader: Don C. Bragg**

SRS-4158, the Southern Research Station's (SRS's) Restoring and Managing Longleaf Pine Ecosystems research work unit (RWU) includes two experimental forests (the Palustris and Escambia EFs) and staff assigned to four duty stations in Alabama, Arkansas, Louisiana, and South Carolina. This geographic distribution, staffing, and previous research emphasis on resource issues related to longleaf pine (*Pinus palustris*) ecosystems means this RWU is well placed to study a range of management and restoration-related topics. Today, SRS-4158 is 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-4158 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 the longleaf pine ecosystem.

### **9. JUSTIFICATION AND PROBLEM SELECTION**

As the principal feedstock of the early southern forest industry and a source of livelihood for many communities, longleaf pine is a high-quality timber species that provided logs, poles, pilings, posts, peelers, pulpwood, and naval stores for the building and transportation needs of Euroamerican settlers in the southern United States. These forests encompassed over 90 million acres from southeastern Virginia to eastern Texas. Longleaf pine trees grew in a range of habitats, from hydric and mesic flatwoods and uplands to xeric sandhills of the Southeastern Coastal Plain up to an elevation of 2,000 feet on the rocky ridges of the Southern Appalachian Mountains. Demand for longleaf timber and other commercial products led to widespread exploitation of this resource, especially following the expansion of railroads into southern forests in the late 19<sup>th</sup> and early 20<sup>th</sup> centuries and development of steam-engine logging. These industrial advances, coupled with the spread of agricultural land uses and alterations to historical fire regimes resulted in the disappearance of longleaf pine forests from much of the landscape by 1950. Widespread adoption of increasingly intensive silvicultural practices further accelerated the decline of longleaf pine. Millions of acres once dominated by longleaf pines were planted to loblolly (*Pinus taeda*) and slash (*Pinus elliottii*) pines for a variety of reasons, including the difficulty of regenerating longleaf pine and longleaf pine's slower growth rate and typically lower short-term economic return than intensively managed loblolly and slash pines.

By the end of the 20<sup>th</sup> century, it was recognized that the once vast longleaf pine-dominated forests had been reduced to less than 5 percent of their original extent and had become one of the most threatened ecological systems in the United States. This is a major conservation challenge, as longleaf pine communities are biologically rich and diverse ecosystems that harbors dozens of rare plant and animal species and represent an important cultural resource. Interest in restoration of longleaf pine ecosystems has grown through time, as evidenced by the 2009 Range-wide Conservation Plan for Longleaf Pine (<http://www.americaslongleaf.org>). This plan, developed cooperatively with federal, state, and private partners, proposed an increase from 3.4 to 8 million acres in longleaf pine area by 2024. Mandates to conserve federally listed threatened or endangered species have translated into large-scale efforts to restore longleaf pine on public lands. With recent strategic emphasis placed by the USDA on using research to strengthen private land stewardship and help ensure the productivity and sustainability of

National Forest System (NFS) lands, the scientific study of longleaf pine ecosystems by the Southern Research Station (SRS) has much to contribute. For example, landowner support is key to successful restoration of longleaf pine ecosystems if the 8-million-acre goal is to be achieved, but little restoration has occurred on privately held land to date. In support of the Range-wide Conservation Plan, the Southern Region of the USDA Forest Service embarked on a “Million-Acre Challenge” in 2017 to more than double NFS longleaf pine acreage, but key knowledge gaps affecting that challenge remain. For example, the management of public and private land differs with regard to inputs, outputs, the duration of time for outputs to be achieved, and regulations, with private land generally managed over relatively short periods to maximize products or values that are financially quantifiable. Regardless of ownership, more study into the complex nature of longleaf pine ecosystems is warranted. Providing this longleaf pine-based research support to meet Forest Service and USDA strategic goals will also help improve the condition of the Nation’s forests and grasslands and enhance recreational opportunities.

Although much has been learned, much remains to be discovered. While early research produced guidelines to manage longleaf pine for wood products, the interaction between management practices and other societal values of longleaf pine forests (e.g., income generation, biodiversity conservation, watershed protection, recreation uses, cultural heritage) was rarely addressed. Because these factors add to the complexity and variability of management goals, the applicability of this early research is limited. Future scientific investigations must address the challenges of longleaf pine restoration on both public and private lands. Conventional approaches to restoration problems will often prove effective, but new and perhaps unconventional approaches may be needed to meet landowner expectations, minimize risks, and accommodate societal demands. In response to requests for more options, research should focus on efforts that expand the longleaf pine manager’s toolbox, simplify treatment options, increase the net worth of outputs by increasing value and/or decreasing the time horizon, and decrease the risk of failure. For example, private landowners often depend on revenue generated from their ownerships. Any effort to foster a long-term commitment to longleaf pine restoration on private land must be supported by information on the costs and benefits of management activities, recognizing that expectations and benefits may differ among owners and across geographic scales. At any stage of stand development, research that minimizes the natural loss of established longleaf pines not only maximizes monetary value, but reduces the risk of inaccurate predictions of stand outputs. Knowledge about non-timber products such as pine straw, silvopasture, and understory cash crops could also contribute to market development and in time, landowner commitment to re-establishing longleaf pine forests.

The complex and complicated nature of these pineywoods makes research into basic and applied questions about longleaf pine (and related) ecosystems especially challenging. As an example, ecological needs to support these ecosystems are affected by societal needs and preferences. As a fire-adapted species in fire-dependent ecosystems, longleaf pine responds well to frequent surface fires and struggles when burning is excluded for prolonged periods, as does a whole host of associated plant and animal species. Unfortunately, the widespread implementation of prescribed fire as a silvicultural tool continues to be challenging, especially on private lands. The expansion of human populations in the southern United States has increased concerns about the health, safety, and environmental hazards of smoke and fire, especially among an increasingly urban population less familiar with this management practice. Also, forest managers have had increasing difficulty conducting prescribed burns because of the limited number of days available each year when fire can be applied within the parameters of an appropriate burning prescription. Hence, restoring longleaf pine near population centers presents challenges that are more complex and socially intractable than those on rural lands of low population density. By developing guidelines for the socially acceptable conversion of undesirable forest types to longleaf pine ecosystems and developing low-cost methods that either diminish the need for very frequent prescribed fires or achieve the effect of prescribed fire without risks of damage to private property, research can contribute to longleaf pine restoration near populated areas.

Longleaf pine communities represent both a conservation challenge and opportunity in the southern United States. Because of the past dominance of longleaf pine forests and their dramatic decline, many affiliated plant and animal species and their habitats have also declined precipitously. As a result, numerous dependent species have become threatened or endangered. It is believed that the restoration of longleaf pine ecosystems, especially at larger scales, will help recover these troubled species. Hence, research into the most effective restoration strategies offers great potential for the recovery of these increasingly rare species. For instance, stand management guidelines are needed for publicly owned land that is mandated to contain habitat for federally listed, threatened or endangered species such as the red-cockaded woodpecker (RCW; *Dryobates borealis*). These birds rely on mature pines for nesting and foraging. Gradual conversion from loblolly or slash pine to longleaf pine, while supporting the RCW, requires a suitable level of overstory retention. This information is in particularly high demand on military installations under the mission-critical directive to simultaneously retain large stands of mature pines for the RCW and conduct mission-related activities.

Although some previous research has explored relationships between understory plants and overstory longleaf pine trees, managers need to know how to regenerate longleaf pine while retaining the habitat values associated with mature trees. Research has documented how organisms in the understory perform critical functions which sustain entire longleaf pine ecosystems. Vigorous and diverse ground layer plant communities play a key role in the fire ecology of these ecosystem. Where there is no natural seed source, restoring longleaf pine requires artificial regeneration. However, many conventional site preparation methods can be detrimental to native herbaceous vegetation. Research that maximizes the establishment of planted seedlings and minimizes disturbance of the ground layer will likely accelerate the trajectory of longleaf pine ecosystem restoration on a range-wide basis. Further, where the natural herbaceous community has been eliminated, suitable plant materials and reintroduction methods are needed if restoration goals are to be achieved. Another concern is the establishment of native ground layer plants that do not readily seed into an area. Once again, ground layer seed and seedlings and economically viable ground layer establishment alternatives must be available for the success of large-scale ecosystem restoration efforts.

Another challenge and opportunity in longleaf pine-dominated ecosystems is how they are affected by, and can influence, a changing environment. Altered climate patterns and associated disturbance regimes are likely to impact longleaf pine management, with restoration offering opportunities to moderate their influences. Among the southern pines, longleaf pine is the most tolerant of drought and nutrition limitations, the most resistant to insect attack and disease, and the least damaged by wildfire when managed appropriately. Preliminary observations also suggest that longleaf pine trees without RCW cavities may be more resistant to hurricane-force winds and that longleaf pine may sequester more carbon when compared to the other southern pines. Longleaf is clearly a species that offers promise in the event of rising atmospheric carbon dioxide levels, elevated air temperatures, shifting rainfall patterns, and more frequent and severe tropical storms that are predicted with global climate change. There are, however, unknowns that must be resolved before longleaf pine establishment and ecosystem restoration can be wholly endorsed as the superior choice for forests for the future. To increase the probability of restoration success in a changing climate, an understanding of the relative influence of genetics and environment on the establishment success and resilience of longleaf pine and its ecosystem functional groups is vital in guiding genetic improvement efforts. Additionally, sustained adaptation to climate change will only be possible if whole-crown carbon fixation is adequate to support above- and belowground structural, energy, and other process needs (e.g., seed production). Research that evaluates the balance among leaf area, light availability, soil resource supply and acquisition, and longleaf pine vigor across its range will help reveal the role of longleaf pine in a changing climate.

By definition, longleaf pine ecosystem restoration requires that all components—not just the dominant tree species—receive attention from land managers. Integrating these challenges with a

continued need for stemwood production requires a more holistic research strategy. SRS-4158 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-4158 and SRS-4159 (Ecology and Management of Southern Pine Ecosystems) research work units represent an integrated effort to study various components of pine- and pine-hardwood ecosystems, including those dominated by longleaf pine. As a part of the CFRM, SRS-4158 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 longleaf pine-dominated ecosystems; 2) delivering longleaf-related benefits 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 longleaf pine ecosystems; and 4) facilitating excellence in the Station through improvements to longleaf pine-focused 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-4158 to support the science needs of a close partner. SRS-4158'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-4158 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-4158 MISSION:**

#### **TO PROVIDE KNOWLEDGE, STRATEGIES, AND TOOLS FOR RESTORING, MANAGING, AND SUSTAINING LONGLEAF PINE ECOSYSTEMS, DEVELOP BETTER UNDERSTANDINGS ABOUT THE ECOLOGY AND SILVICULTURE OF LONGLEAF PINE AND OTHER AFFILIATED SOUTHERN PINES IN THE SOUTHERN UNITED STATES, AND FOSTER INSIGHTS ABOUT ECOSYSTEM RESTORATION**

To accomplish our program of research to support the above mission, the tasks in SRS-4158's RWU Description (RWUD) have been organized into the following Problem Statements:

#### **Problem 1. Develop the fundamental knowledge needed to improve our ability to effectively restore and manage longleaf pine and associated understory communities.**

Many challenges underlie the large-scale restoration of longleaf pine ecosystems, as called for in the America's Longleaf Restoration Initiative, the Million Acre Challenge, the recently signed Shared Research Priorities of SRS and the Southern Region (Appendix A), and other initiatives. Our knowledge of past environmental conditions and the internal and external dynamics of longleaf pine ecosystems is incomplete, thus limiting manager's abilities to restore to, manage for, or adaptively respond to system needs and changing context. An emphasis on functional restoration and fostering conditions where desired species can complete their entire life cycles may be more effective under a changing climate or when faced with invasive species or other threats. Potential limitations to the annual production of longleaf pine seedlings are also of concern, starting with the looming challenge of developing a reliable supply of longleaf pine seed. Longleaf pine is characterized by a dynamic seedfall pattern with multiple years passing between productive years. Better knowledge of what controls male (pollen) and female (conelet) strobili production, cone development and retention, and seed maturity, and how these factors

can be manipulated to benefit the availability of seed is needed. Further, high-quality longleaf pine seedling stock is critical for the success of artificially establishing longleaf pine forests. In addition to first-year seedling survival, percent of seedlings initiating accelerated height growth (i.e., emergence from the grass stage) two to three years after planting should also be included in the evaluation of early field performance. Information about the vertical stability of planted longleaf pine stock types once they become saplings (5 to 10 years in field) is needed in areas prone to tropical storms and hurricanes.

Longleaf pine communities are more than just their dominant pines. We need to better understand the processes that affect the fecundity, establishment, and development of other native tree and ground layer plant components of longleaf pine ecosystems. We will then better understand how native vegetation responds to disturbance and management in terms of growth, vigor, genetic variability, hybridization potential, disease and insect resistance, and longevity. Efforts will provide private landowners and public land managers with high-quality longleaf pine seedlings, excellent rates of seedling survival, and seedlings and saplings exhibiting accelerated and uniform height growth and windfirmness. In doing so, we will reduce the risk of lost revenue from wind-impacted trees or slow-growing seedlings. We will also monitor silvicultural treatments and stand conditions for insight about the factors controlling cone and seed production in even-aged and uneven-aged forests. This improved understanding will enable us to better restore and sustainably manage longleaf pine ecosystems.

We will use our expertise in the biology of seeds, seedlings, trees, and native plants, including at-risk species, to study the basic biology, physiology, and ecology of longleaf pine and its associated plant species. Specific problems are as follows:

**Problem 1a. Advance understanding of ground layer species biology and systems ecology to ensure persistence or growth of key understory species.** We will discover and develop knowledge of the population biology, seed dispersal dynamics, and habitat relationships of common and at-risk ground layer plant species found in the plant communities of longleaf pine ecosystems. Systematic, incremental accumulation of species-based knowledge provides a foundation for understanding the persistence of these species-rich, fire-associated plant communities. Priority will be given to taxa that have widespread application in restoration (e.g., native grasses, legumes, perennial forbs) and to formally recognized conservation target species (e.g., rare species in sensitive habitats).

**Problem 1b. Advance understanding about longleaf pine reproductive biology and seedling development to improve our ability to successfully regenerate and restore longleaf pine ecosystems.** We will develop an improved understanding of the genetic, physiological, and environmental factors that influence longleaf pine cone crops, seed production, and unique juvenile development. Knowledge about how to improve and predict seed production from natural stands and seed orchards, and how to enhance early height growth in planted seedlings is needed. This will contribute to the resilience of the commercial nursery industry by more reliable sources of longleaf pine seed, and the ability to produce high-quality seedlings with accelerated and uniform height growth and root systems that ensure sustained tree growth and vertical anchorage. We will also use this knowledge to develop better seed production, seedling culture, and establishment protocols to meet the demand for superior planting stock and innovative, site-specific establishment techniques. These actions should lead to greater acceptance of longleaf pine as a species of choice to plant under many circumstances.

**Problem 1c. Understand the physiological and developmental strategies that sustain longleaf pine vigor.** We will develop an improved understanding of the physiological and developmental processes that sustain longleaf pine in frequently burned forests and across a diversity of stand conditions. Aspects of root system function, crown physiology, and soil and canopy environments will be assessed to understand how longleaf pine adapts to its environment and how these processes may be affected by potential changes in climate.

SRS-4158 has the facilities and equipment to engage in research in Problems 1a-c. This work will be

achieved using SRS-4158 scientists, scientists in other SRS units, and collaboration with external partners (e.g., NFS staff, university faculty, other state and federal agencies).

**Problem 2. Develop the tools to manage and restore longleaf pine ecosystems, including the full array of ecosystem goods and services associated with sustainable longleaf pine forests.** Restoration of longleaf pine ecosystems continues to be recognized as a high research priority for the SRS and the Southern Region (acknowledged as Shared Research Priority #6, Appendix A). To this end, we will use our expertise in the structure and function of longleaf pine ecosystems to conduct an integrated research program for restoring longleaf pine across a range of conditions. This will include studies designed to help landowners transition their forests back to longleaf pine communities using a variety of silvicultural and ecological restoration tools. For example, the conversion of established loblolly or slash pine forests to longleaf pine ecosystems requires straightforward alternatives for establishing a relatively low stem density that allows sunlight to reach the forest floor and an understory that can carry low-intensity surface fires every two to three years. However, alternatives such as clearcutting and/or burning may be unacceptable under some circumstances. Therefore, development of the means to gradually reduce stem density and slowly foster a desirable understory using a minimum amount of prescribed fire could appeal to landowners who reject stand conversion by clearcutting and planting or who are unwilling to accept the risks associated with prescribed fire. Specific problems are as follows:

**Problem 2a. Develop and test protocols for restoring ground layer communities across the gradients characteristic of longleaf pine forests.** Knowledge of all aspects of restoration is needed. These include the harvest, viability testing, and storage of seeds, as well as site preparation and planting, and maintenance of restoration sites. Information and technology needs are extensive, but early attention will be given to developing knowledge that supports increased availability of native plant materials, integrating ground layer restoration and canopy management, and using established tools (e.g., prescribed fire, chemical applications, and seed harvesting technologies) to achieve restoration of the ground layer vegetation.

**Problem 2b. Improve knowledge about the silvicultural methods and tools needed to regenerate, sustain, and improve longleaf pine forests and related communities.** We will develop science-based silvicultural approaches for converting stands of less desirable overstory species to longleaf pine, produce open stand conditions when justified, and refine methods for using mechanical, chemical, and fire treatments to encourage the development of ground layers dominated by native plants. This could include management of longleaf in mixed-composition stands, and the influence of different understory-related fuel conditions on the application of prescribed fire. We will also study the growth and yield of existing longleaf pine stands to better understand the long-term influences of stock origin (natural versus bareroot versus container) on this important attribute. Researchers will compile information so that it is straightforward and applicable on public and private landholdings regardless of size. This will allow us to comprehensively address the silviculture of longleaf pine ecosystems and provide private landowners and public forest managers with effective tools for sustaining healthy, diverse, and productive longleaf pine ecosystems.

**Problem 2c. Develop knowledge about the full suite of ecosystem goods and services provided by longleaf pine ecosystems and design the corresponding silviculture and restoration tools needed by landowners.** We will use our expertise in the ecology and management of longleaf pine ecosystems, plus the expertise of others, to refine and expand upon the functionality and productivity of these natural systems. Such an effort will depend on the documentation of historical vegetation conditions in longleaf pine ecosystems in order to provide benchmarks for guidance, and better identify the full range of goods and services these systems are capable of producing. This will also entail considering both traditional outputs (e.g., timber products such as dimensional lumber, poles, and veneer, and wild game species) and non-traditional goods and services (e.g., carbon sequestration, water quantity

and quality, pollinator habitat, declining or threatened/endangered species habitat, aesthetics, recreation), and using novel approaches to assess past, present, and future production.

SRS-4158 has the facilities and equipment to engage in research in Problems 2a-c. This work will be achieved using SRS-4158 scientists, scientists in other SRS units, and collaboration with external partners (e.g., NFS staff, university faculty, other state and federal agency personnel).

**Problem 3. Research the integration of longleaf pine-dominated ecosystems in the broader southern pine and pine-hardwood forests, with a particular emphasis on the restoration of system functionality, community resilience, and improvement of affected human systems.** Beyond simple restoration of longleaf pine (Shared Research Priority #6, Appendix A), a complex suite of ecosystem processes, goods, and services need to be studied to help land managers meet societal needs. Related research priorities include improvements to fire management (Priority #3) in the fire-dependent longleaf pine ecosystem, water supply as a function of forest cover (Priority #4), developing new and novel forest markets and ecosystem services from longleaf pine (Priority #5), shared stewardship opportunities to increase longleaf pine cover and resilience (Priority #7), and hurricane recovery and ecosystem resilience (Priority #9). We will transfer the knowledge and expertise gained through our research in longleaf pine ecosystems to managers, landowners, the scientific community, and policymakers across the southern United States to develop and improve upon restoration practices and tools 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, and sustainable resource conservation. Specific problems are as follows:

**Problem 3a. Investigate how local plant communities and longleaf pine-dominated landscapes are affected by interacting biotic and abiotic factors, particularly in support of large-scale restoration efforts.** We will develop knowledge of the spatially variable biotic and abiotic factors and their interactions that influence the structure, distribution, and condition of longleaf pine communities across landscapes. Variables with spatial aspects include site quality (e.g., soil structure, water holding capacity, fertility), natural disturbances (e.g., fire, wind, drought, insects, pathogens), open forest structure and patterns, and reproductive processes such as pollination, hybridization, and seed dispersal. We expect to find differences in these spatial variables among longleaf pine communities in the Atlantic Coastal Plain, the Lower Gulf Coastal Plain, the Sandhills, the Piedmont, and in the Southern Appalachians as well as interactions between physiographic region and management history. Understanding these effects will be key to helping the National Forest System move ahead with large-scale restoration efforts, and should support their activities related to the Million Acre Challenge and our Shared Research Priorities.

**Problem 3b. Increase our understanding of longleaf pine and associated forest communities through the development, application, and improvement of ecological models.** Simulation models offer a tool 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 longleaf pine is a dominant canopy species. Improvements in resource conservation resulting from more viable and sustainable restoration efforts will help public land managers do their jobs more efficiently as well as improving the stewardship of privately held lands.

**Problem 3c. Expand expertise on the socioeconomic costs and benefits of longleaf pine restoration.** We will establish research partnerships to assess the costs and benefits of restoring longleaf pine ecosystems. To deliver the most complete information possible, an analysis of economic benefits and risks should be performed. The analysis should consider both the accruable benefits and risks associated with public and private investment and changes in land use. Risks should include practical problems such as not being able to use prescribed fire as planned. Such an analysis would include

markets for products from current and changing land uses, and 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 wildlife habitat (including its potential to support hunting leases as a revenue stream), the values of the quantity and quality of water produced, the presence of federally listed (threatened or endangered) or known declining species, and impacts of air quality regulations. This will provide landowners and managers with information about revenue streams and resource obligations 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 through the years. On these experimental forests, we will seek new opportunities to partner with other Forest Service research units and working groups, university collaborators, other government agencies, non-governmental organizations, and corporate partners to leverage existing research support, develop new research questions, install new technologies and better utilize existing ones, expand/broaden the scope of studies from local to regional, national, or even international scales, and join in appropriate science-based networks. In addition to serving as large-scale field laboratories and repositories of biological diversity, experimental forests have always, and will continue to, serve as demonstration areas to better inform fellow academics, professional resource managers, and the general public about the long-term history of various treatments as well as the opportunities presented by new management approaches. The SRS has developed an Experimental Forest Network (EFN) consisting of 19 experimental forests, and has undertaken a series of connected, large-scale, network-driven research projects on topics ranging from shortleaf pine (*Pinus echinata*) conservation to pollinator studies to intensive forest plot monitoring by Forest Inventory and Analysis (FIA) staff, and SRS-4158 will work to become a key participant in this EFN.

SRS-4158 has the facilities and equipment to engage in research in Problems 3a-d. This work will be achieved using SRS-4158 scientists, scientists in other SRS units, and collaboration with external partners (e.g., NFS staff, university faculty, other state and federal agency personnel).

## **10. APPROACH TO PROBLEM SOLUTIONS**

**Problem 1. Develop the fundamental knowledge needed to improve our ability to effectively restore and manage longleaf pine and associated understory communities.**

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

**Problem 1a. Advance understanding of ground layer species biology and systems ecology to ensure persistence or growth of key understory species.**

- 1. Intensive management and ground layer species.* Understanding the composition, structure, and function of the ground layer of longleaf pine ecosystems has been a SRS-4158 research focus for over a decade. We will continue to build on early trials that evaluated direct seeding and aspects of management such as season of burning and roller drum chopping on the ground layer plant community including selected, threatened or endangered plants. Increased emphasis will be placed on evaluating chemical treatment effects on native herbaceous species.
- 2. Factors that control seed production and seedling establishment of perennial grasses and forbs.* Field studies and greenhouse experiments will be used to investigate the effects of interacting biotic and abiotic factors that influence seed production and natural seedling establishment in longleaf pine plant communities. Factors to be manipulated include prescribed fire, water and mineral nutrient availabilities, and light. Efforts to understand the effects of canopy and herbaceous cover on seed production and seedling establishment among native warm season grasses will continue.

3. *Rare or sensitive plant species.* Because (a) there are so many rare plant species (formally recognized by state or national ranking systems) associated with longleaf pine ecosystems and (b) our staff includes expertise in the area of rare plant species, we will continue to design and implement studies when needed to address conditions or management actions that pose imminent threats to protected species. Monitoring will continue in a study of the habitat conditions required to successfully move a federally listed (endangered) plant (*Harperocallis flava*) from a heavily travelled roadside to a secure location in the Apalachicola National Forest along Florida's Gulf Coastal Plain. Other species-specific studies will be considered as resources permit and needs arise.

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

- Increased understanding of population and community processes that affect threatened and endangered plant species in the ground layer of longleaf pine ecosystems.
- Improved understanding of the effects of fire on the condition of ground layer plants in longleaf-dominated ecosystems.
- More reliable reference ecosystem information to help inform restoration objectives, including that of the understory.

**Problem 1b. Advance understanding about longleaf pine reproductive biology and seedling development to improve our ability to successfully regenerate and restore longleaf pine ecosystems.**

1. *Growth and establishment of longleaf pine seedlings.* Presently, morphological standards for container-grown longleaf pine seedlings are correlated with acceptable survival rates, but not post-planting growth. Little is known of the physiological quality at planting, or the potential to improve physiological quality and therefore, juvenile growth. Many soils in the natural range of longleaf pine are characterized by low phosphorus availability and soil physical properties that lower fertility and restrict normal root elongation. Research is underway to evaluate novel cultural treatments to enhance seedling performance after planting. Research is also underway to understand interactions between soil physical properties and root system development after planting. These efforts provide insight about the potential to improve post-planting juvenile longleaf pine growth by changing cultural or establishment environments. Furthermore, knowledge of relationships between seedling morphological variables at planting and seedling field performance will help define new pre-planting standards that reflect both survival and long-term growth after planting.
2. *Seedling root system development.* Forest industry in the southern United States modified and implemented the container technology that was developed in Canada for northern conifer species. While adequate for loblolly, slash, and shortleaf pines, these containers are often problematic for longleaf pine because of this species' taproot size and root system architecture. Field studies are underway to assess the effect of cavity variables such as size and chemical or air root pruning attributes on longleaf pine root system morphology over time and sapling vertical stability. Results will guide container manufacturers' efforts to design containers better suited to the root system of longleaf pine and use of these containers by the nursery industry.
3. *Cone and seed crop predictions.* To support the growing demand for longleaf pine nursery stock, a sustained, large supply of viable longleaf pine seed is needed. A shortfall of available longleaf pine seed is predicted for two primary reason. First, the efficiency of longleaf pine seed storage is inherently low, with seed viabilities less than 75 percent when storage exceeds two years. Second, patterns of longleaf pine cone and seed supply are erratic and often lead to more than two years between ample seed crops. Two efforts are underway to remedy longleaf pine seed

shortfalls. We are building upon a monitoring effort that quantified longleaf pine cone production at 10 locations for 55 years so that these cone data can be paired with climatic and edaphic information to investigate linkages among cone production, annual water deficit, soil series, chemical and physical properties, and available stand information. Second, four years of intensive female reproductive and vegetative phenology and nutrition measurements in a single clone of loblolly pine are recently complete. With this data set, carbon and nutrition drivers of *Pinus* cone and seed production are being investigated. Information from both of these efforts will be used to propose conceptual hypotheses about variables that control longleaf pine cone and seed production which may prove valuable for sustaining the supply of longleaf pine seed.

4. *Impacts of hybridization on longleaf pine seedling production.* A recent (2014) bumper longleaf pine seed crop in several seed orchards offered an opportunity to generate a large number of seedlings to plant on public and private lands. Initial morphological tests suggested that a significant percent of the germinants from this seed crop were “Sonderegger” pines (hybrids of longleaf and loblolly pine) and hence were unacceptable as planting stock. Further investigation of this event, including the use of DNA marker analysis, morphological assessments, and field tests of seedlings have been completed and preliminary genetic tests did not agree with standard morphological assessments and field tests. In addition to improving how hybrids are identified in the nursery, this work may also lead to better knowledge about the natural frequency of longleaf pine hybridization and the morphological plasticity of longleaf pine germinants.
5. *Longleaf pine sapling and tree toppling.* Planting seedlings is a practical method for establishing longleaf pine regeneration where no natural seed source exists. Container stock is generally favored over bareroot seedlings because bareroot stock has a narrow seasonal planting window and has to be planted soon after lifting, as seedling quality decreases rapidly after cold storage for more than one week. However, the isolated occurrence of toppling after strong wind events has been noted among saplings derived from container stock. Conventional containers change the natural root system architecture of longleaf pine and there has been little effort made to temper this effect. Studies are underway on the Palustris and Escambia EFs to evaluate longleaf pine root system architecture among seedlings, and saplings, and young trees in response to an array of container types. Ultimately, these results will minimize negative effects of container type on the field establishment, juvenile growth, and vertical stability of planted longleaf pine.

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

- Better comprehension of how seedling size and morphology, root system architecture at planting, and soil attributes control the establishment, growth, and release from the grass stage of longleaf pine seedlings.
- Identification of root system attributes and root-soil interactions that favor longleaf pine growth and vertical stability.
- Identification of the physiological drivers and environmental factors that control longleaf pine cone and seed production.
- Establish an understanding of the morphological plasticity of longleaf pine germinants, seedlings, and saplings, and outline criteria for distinguishing between the range of exhibited morphologies and Sonderegger hybrids of longleaf pine.

**Problem 1c. Understand the physiological and developmental strategies that sustain longleaf pine vigor.**

1. *Frequent fires and soil properties.* As a repeated fire regime is reestablished, shifts occur in proportions of woody and herbaceous understory vegetation. The loss of woody understory

species and the gain of herbaceous plants and grasses have the potential to change vertical rooting profiles and therefore, subsoil porosities and organic matter inputs. For soils dominated by silt and clay, these changes influence plant-available water holding capacity and strength in the subsoil and, therefore, may affect soil quality. A long-term assessment of the soil physical properties of a fine sandy loam in response to repeated fire or herbicide application during longleaf pine establishment is ongoing. Soil physical property measurements of the A, and upper and lower B<sub>t</sub>1 horizons will continue through eight cycles of biennial prescribed fire. From this long-term study, land managers will better understand the effects of repeated fire on the plant-available water holding capacity and strength of fine textured soils.

2. *Physiological adaptation to frequent fire.* Fire-adapted pines possess physiological characteristics that minimize growth loss after fire. An important adaptation of longleaf pine to fire that allows sustained stemwood growth is rapid foliage re-establishment after crown scorch. Foliage regrowth is controlled by interaction among developmental stage (e.g., seedling, sapling, tree), lateral branching pattern, amount of post-fire unscorched foliage, and reserve carbohydrate level. Research is underway to define seasonal windows and stand conditions that minimize negative effects of fire on the physiology and growth of longleaf pine across all developmental stages. This information will aid land managers in developing fire prescriptions that favor longleaf pine production.
3. *Adaptations that sustain tree vigor.* Longleaf pine health and vigor depend on physiological adaptations that support soil resource and carbon fixation demands for adequate allocation of fixed carbon above- and belowground. Shortfalls of water and soil fertility that reduce carbon-fixation have the potential to disrupt carbon allocation among the growth and maintenance of fascicles and roots and the production of defense chemicals. Failed adaptation leads to poor tree vigor and increased susceptibility to insect attack and disease. Field and greenhouse studies with longleaf pine continue in an effort to understand how soil fertility and water availability affect longleaf pine fascicle physiology, root system growth, and susceptibility to root pathogens.

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

- Improved understanding of the effects of fire on the physiology of longleaf pine, including repeated fire effects on sapling recruitment and growth performance.
- Identification of the basis of longleaf pine's tolerance of crown scorch which will ensure compatibility among the timing of prescribed fires, longleaf pine developmental stage, and management goals.
- Identification of adaptations employed by longleaf pine in response to soil, climate, and stand conditions, and establishment of thresholds for critical conditions beyond which adaptive mechanisms are challenged.
- Identification of the physiological drivers and environmental factors that control longleaf pine cone and seed production.
- Better comprehension of how seedling size and morphology, root system architecture, and nutrients control the establishment and growth, release from the grass stage, and soil resource utilization of longleaf pine seedlings.

**Problem 2. Develop the tools to manage and restore longleaf pine ecosystems, including the full array of ecosystem goods and services associated with sustainable longleaf pine forests.**

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

**Problem 2a. Develop and test protocols for restoring ground layer communities across the gradients characteristic of longleaf pine forests.**

1. *Seed sources and transfer zones.* The effort to restore the ground layer of longleaf pine communities is strongly limited by the lack of ecologically suitable native plant materials. Plant materials from outside the longleaf pine natural range are being used to fill this demand. In restoration, local seed sources are generally preferred because they are more likely to be successful and less likely to have negative effects on local populations. However, given that climate is changing, it is worth investigating if expanding beyond local seed sources to ones of the same species from other climatic envelopes may be a better ecosystem adaptation strategy. We will complete data analysis from a common garden study to evaluate the growth and reproduction of plant species representing populations from across the species' ranges. We will also collaborate with investigators in a related study to propose and evaluate seed transfer zones for ground layer species desired for longleaf pine ground layer restoration.
2. *Ground layer establishment guidelines.* Across the longleaf pine range, managers have implemented various restoration projects; however, documentation of protocols and results are scarce. We will continue to monitor and report the results of restoration plantings established at various locations and opportunistically launch additional trials collaboratively with land managers. Because most existing projects have been installed on upland sites, new trials will emphasize wet sites.
3. *Ground layer vegetation dynamics.* We are renewing ground layer inventory projects on the Kisatchie National Forest in Louisiana to determine temporal changes in the ground layer composition of longleaf pine forests.

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

- Practices that will improve the restoration and sustainability of diverse understory plant communities in longleaf pine forests.
- Plant material and seed transfer guidelines for common herbaceous plant groups that comprise the ground layer vegetation.
- Increased confidence in the identification of ecologically appropriate seed sources for native herbaceous species.
- Technologies for artificially restoring ground layer vegetation.
- Development of reliable management practices for both even-aged and uneven-aged regeneration systems to restore natural understory plant community richness and production.
- Development of even-aged and uneven-aged management methods and guidelines that encourage sustainable forest structure, minimize wildfire risk, and provide habitat for native plants and animals.
- Narratives of historical examples of longleaf pine ecosystems, including ground layer communities, and assessments of current examples of functional and dysfunctional stands.
- Broader assessment of the ecosystem goods and services of longleaf pine ecosystems.
- Brochures and other written and web-based outreach materials targeted for private landowners that provide information on longleaf pine understory community restoration and management.
- Field tours and workshops tailored for private landowners, but also useful for public land managers, to help them solve longleaf pine understory restoration problems.

**Problem 2b. Improve knowledge about the silvicultural methods and tools needed to regenerate, sustain, and improve longleaf pine forests and related communities.**

1. *Regeneration methods.* While continuous-canopy management is best achieved through the

irregular shelterwood method and selection systems, these techniques need further study before they are widely applied in longleaf pine. We will continue comparative analysis of uneven-aged and even-aged regeneration methods across gradients of site quality to better understand the efficacy of each approach in various forest environments. We will supplement traditional management approaches, such as uniform shelterwood, with new knowledge about the irregular shelterwood method and selection systems.

2. *Proportional-Basal Area.* A new approach developed by SRS-4158 and cooperator Auburn University for applying selection silviculture, the Proportional-Basal Area (Pro-B) method is being tested and refined in longleaf pine forests. The Pro-B method for implementing selection systems makes uneven-aged management a practical option for forest managers, because it is a low-cost and easy to learn and apply approach. We plan to rigorously field test the Pro-B method to discern its value in longleaf pine management. We will translate results into web-based tools, to aid forest managers seeking a user-friendly approach for managing naturally regenerated longleaf pine stands and other forest types where selection systems are appropriate.
3. *Hurricane damage.* The natural range of longleaf pine lies mostly within the hurricane zone of the southern United States. Although this species is more resistant than other southern pines to damage from tropical storms, it can be blown down by extremely high winds. When the worst happens, and all trees in a stand must be salvage-logged, restoring the longleaf pine forest becomes the top priority. We will continue the study of intensive management practices to aid the recovery of hurricane-damaged longleaf pine and develop guidelines that identify the most effective practices to restore longleaf pine forests following recurrent natural disturbances. This work can be linked into the EFN, which should provide both baseline (pre-event) and post-storm conditions and system response.
4. *Long-term fire studies.* Fire favors longleaf pine because it kills the regeneration of competing pine species, curtails the growth of shrubs and hardwood sprouts, removes smothering litter, and helps control brown-spot needle disease, which stunts longleaf pine seedling growth. We will continue examining the interaction effects of time-interval and season for prescribed fire and their roles in even-aged and uneven-aged longleaf pine management. Additionally, we will evaluate the effectiveness of non-fire vegetation control methods (i.e., physical, chemical and biological techniques) when incorporated into stand management and burning plans. We will use newly emerging information to refine prescribed fire guidelines, suggest alternative methods for understory manipulation where appropriate, and supplement longleaf pine growth and yield models with anticipated stemwood responses to repeated fire. Studies will be developed to better understand the dynamics of seed dispersal in longleaf pine communities that experience repeated prescribed fires. We will continue the long-term study of longleaf pine cone crops to predict seed availability to forest and nursery managers and contribute data to the long-term record of longleaf pine cone production.
5. *Stand replacement.* Gradual conversion of loblolly or slash pine stands to longleaf pine dominance requires a suitable level of overstory retention to provide continuous nesting and foraging habitat for critical fauna. We will seek funding to remeasure experiments installed at Fort Benning, Georgia, and Camp Lejeune, North Carolina, to determine the optimal silvicultural practices for converting loblolly pine stands to longleaf pine ecosystems. Experimental treatments included canopy treatments of stand thinning or gap creation, and sub-plots of cultural treatments that alter seedling survival and growth (i.e., post-planting competition control, fertilization, increasing fine fuels with native grass establishment).
6. *Pairing stock type with stand replacement methods.* Using knowledge about juvenile longleaf

pine root system and shoot growth when seedlings are grown in different container types and sizes, we will assess the performance of planted longleaf pine in stand replacement settings that include three stock types planted in gaps or in post-thinning stand basal areas of 40 or 60 square feet per acre. The study will be replicated in recently thinned, mature stands of slash and loblolly pine. In addition to evaluation of nursery stock performance, we will monitor the effectiveness of biennial prescribed fire for the control of volunteer slash and loblolly pine.

7. *Revision of seedling quality and planting guidelines.* Desirable post-planting traits include high seedling survival rates, earlier and uniform release from the grass stage, sapling windfirmness, and accelerated height growth. We will compile new information about the relative roles of stock type, genotype, and environment on the juvenile growth of longleaf pine, and the morphological standards that reflect these traits. With incorporation of this new information, recommendations with regard to standard longleaf pine seedling quality, seed source, site preparation, and establishment treatments will be revised with a focus on the importance of financial return to the private landowner.
8. *Legacy growth and yield studies.* Longleaf pine of natural- or planted-origin often grows differently, depending on seedling source (natural seedfall versus bareroot stock versus container stock), site conditions (e.g., old field or forest), genetics, stand density, competition control, fertilization, water availability, and numerous other factors. Long-term studies of longleaf pine growth and yield are of particular interest to those considering this species as a management option, and reliable data are often hard to find. We will continue to maintain, measure, and publish studies of southern pine growth and yield.

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

- Practices that will improve the restoration and sustainability of longleaf pine forests, especially in the context of a changing climate, invasive species, and land-use change.
- Development of reliable management practices for both even-aged and uneven-aged regeneration systems to restore natural longleaf pine ecosystems.
- Development of even-aged and uneven-aged management methods and guidelines that encourage sustainable forest structure, minimize wildfire risk, and provide habitat for native plants and animals.
- Improved understanding of how seed dispersal interacts with silvicultural treatments.
- Assessments of the impacts of large-scale natural disturbances (e.g., hurricanes, droughts, wildfires, insects and disease, ice storms) on longleaf pine ecosystems, including management recommendations.
- Recommendations on improving sapling resilience to repeated prescribed fires.
- Demonstration areas that provide landowners with a visual understanding of potential outcomes from longleaf pine establishment in a stand conversion setting.
- Nursery and field protocols to increase the quality of longleaf pine planting stock and longleaf pine field performance including early accelerated height growth and sapling windfirmness.
- Narratives of historical longleaf pine ecosystems, assessments of current examples of functional and dysfunctional ecosystems, and future (expected/predicted) longleaf pine-dominated ecosystems.
- Growth and yield information on longleaf and other southern pines.
- Brochures and other written and web-based outreach materials targeted for private landowners that provide information on longleaf pine restoration and management.

- Field tours, workshops, webinars, and other knowledge transfer materials tailored for private landowners, but also useful for public land managers, to help them solve their longleaf pine restoration and management problems.

**Problem 2c. Develop knowledge about the full suite of ecosystem goods and services provided by longleaf pine ecosystems and design the corresponding silviculture and restoration tools needed by landowners.**

1. *Documentation of historical conditions in longleaf pine ecosystems.* Ecosystem restoration is a process of serial approximation and dynamic adjustment to management practices that can be guided by comparison with reference state(s), historical ranges of variability, and projected future conditions. Reference conditions are one of several types of information needed to guide managers. Whether found in functional examples of existing stands, contrasts with dysfunctional examples of existing stands, scientific inferences about past conditions using modern-day measurements or observations, and/or assessments of historical documentation for similar inferences of previous conditions, reference conditions provide broad indications of potential natural vegetation composition, openness and structure, and function and can therefore be useful for evaluating the relative success of restoration efforts. Using a reference condition as a benchmark for success implies that these conditions are known, but that is often not the case. While some assume these ecosystem references and their historical range of variability will be applicable in the future (i.e., longleaf pine ecosystems will be shaped in the same fashion by the patterns and processes of the past), changing circumstances will make this unlikely. Hence, we will use our familiarity with the literature, existing forest conditions, and ability to project future environmental conditions to better understand the utility (strength and weaknesses) of longleaf pine reference states as a supporting guide to restoration efforts.
2. *Identification of the full range of goods and services from longleaf pine ecosystems.* The most prominent traditional goods produced in longleaf pine ecosystems—conventional timber products and harvested wild game —have been well understood and described for many years. These traditional outputs (e.g., dimensional lumber, poles/pilings, veneer, mass timbers, deer, turkey, quail) are only a portion of the goods and services which can be produced by longleaf pine ecosystems. When included in forest management decisions, the other “non-traditional” goods and services (e.g., carbon sequestration; watershed protection including water quantity and quality; habitat for pollinators, declining/threatened/ endangered species, and game and non-game wildlife; aesthetics; recreation including gathering edible and non-edible products; and others yet to be documented) provide a more complete accounting of the ecological and socioeconomic values of longleaf pine ecosystems in supporting the welfare of human society. We will continue to research and identify the non-traditional ecosystem goods and services of longleaf pine and make these known to private landowners and public forest managers.
3. *Use novel approaches to assess the past, present, and future production of longleaf pine ecosystems.* A unique suite of environmental conditions and influencing factors determine the abundance, distribution, and persistence of longleaf pine communities on southern landscapes. Conventional silvicultural and restoration approaches that may work in other ecosystems (e.g., those not dependent on periodic surface fire) may not prove effective—or ideal—in longleaf pine. To encourage forest managers, especially private landowners, to embrace longleaf pine ecosystem restoration, novel approaches to gauge restoration success need to be developed. Having described and refined the fuller suite of ecosystem goods and services provided by functioning longleaf pine communities, we will use this information to improve upon the accounting of silvicultural tools and restoration options landowners need to implement longleaf pine ecosystem restoration.

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

- Development of even-aged and uneven-aged management methods and guidelines that encourage sustainable forest structure, minimize wildfire risk, provide habitat for native plants and animals, and favor other goods and services of longleaf pine ecosystems.
- Demonstration areas that provide landowners with a visual understanding of potential multiple-use outcomes from longleaf pine establishment in a stand conversion setting.
- Study mixed pine stands of the past to understand the implications of converting current mixed composition examples to longleaf pine-dominated forests.
- Brochures and other written and web-based outreach materials targeted for private landowners that provide information on longleaf pine restoration and management.
- Field tours, workshops, webinars, and other knowledge transfer materials tailored for private landowners and public land managers to help them understand the potential goods and services arising from longleaf pine restoration and management.

**Problem 3. Research the integration of longleaf pine-dominated ecosystems in the broader southern pine and pine-hardwood forests, with a particular emphasis on the restoration of system functionality, community resilience, and improvement of affected human systems.**

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

**Problem 3a. Investigate how local plant communities and longleaf pine-dominated landscapes are affected by interacting biotic and abiotic factors, particularly in support of large-scale restoration efforts.**

1. *Longleaf pine trees on poorly drained sites.* Except for ongoing long-term studies in flatwoods environments, most current research is directed at understanding the response of longleaf pine community dynamics to management and disturbance on upland sites. Ongoing studies are investigating these dynamics in poorly drained habitats and will provide a basis for developing much-needed restoration approaches and protocols where soil drainage and dense shrub cover (e.g., saw-palmetto, *Serenoa repens*) hinders establishment success.
2. *The effects of fire on longleaf pine plant communities.* In the absence of frequent prescribed fire (e.g., typically on a two- to three-year cycle and a little longer on more xeric sites), accumulation of forest fuel reaches a point where wildfire can be very destructive. Prescribed burning is considered necessary for the management of longleaf pine, because it is the best means for controlling unwanted fuel buildup and promoting the growth of desirable herbaceous plants. Even prescribed burning, however, can negatively affect the growth and persistence of fire-dependent longleaf pine (e.g., when flame temperatures become too high and overstress trees and seedlings). In addition to a reduction in carbon fixation by crown scorch and woody root and stem damage caused by fire, post-fire conditions can attract insects that feed and brood in the roots and stems and may introduce pathogens. Research has been ongoing for several decades to discern how fire season and return interval and age of initial application interact with tree and understory vigor and ground layer diversity. 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 longleaf pine ecosystems.
3. *Assessment of the longleaf pine component of forest types classified as other southern pines or pine-hardwood.* Although longleaf pine is best known as a community dominant tree species across much of its distribution, it was historically present as a minor and varying component of mixed-composition forests, and can still be found in that condition today. The extent of that minor and varying role in the past, its management prospects in current forests, and its potential

opportunities for future restoration efforts needs further study. We know little about how to regenerate longleaf pine in these mixed-composition forests, how resilient longleaf pine may be in hardwood-dominated stands, and how to refine prescribed burns in these forests with a range of species of differing fire tolerances.

4. *Restoring longleaf pine communities in areas outside of the Coastal Plains.* Many of the best opportunities for restoration of longleaf pine in the Coastal Plain have already been started—or even completed—and public agencies such as the USDA Forest Service will need to look for new opportunities to meet their restoration objectives. Studies of regions outside the Coastal Plain will be needed, especially in the Piedmont and southern portions of the Blue Ridge Mountain, Ridge and Valley, and Cumberland Plateau physiographic provinces that had historically been longleaf pine-dominated ecosystems. This research will help to support restoration efforts by development of more knowledge on overstory structure, understory conditions, and the dynamics of these upland systems (both past and present).

Outcomes in Problem 3a 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.
- Determination of the past abundance and role of longleaf pine in mixed-composition forests.
- Improvements to the management of mixed-composition forests to increase longleaf pine success, and how this may affect established restoration targets.
- Restoration management guidelines for private landowners outside of the Coastal Plains.
- Development and refinement of prescribed burning guidelines in pine-hardwood mixtures in the Cumberland Plateau.
- Assessments of forest health and productivity in pine-hardwood mixtures, including field tours and webinars to transfer knowledge.

**Problem 3b. Increase our understanding of longleaf pine and associated forest communities through the development, application, and improvement of ecological models.**

1. *Modeling tree growth and yield as an ecosystem output.* Through the years, work at the Escambia and Palustris EFs (and elsewhere) has generated a large quantity of growth and yield data for naturally regenerated and planted longleaf pine under a number of different management controls and interventions (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 ecosystem goods and services (e.g., sequestered carbon) produced by longleaf pine-dominated forests.
2. *Predicting the influence of poor drainage.* Models of the ecological effects of poor drainage during the course of longleaf pine ecosystem restoration will be new and powerful planning and management tools. The well-documented conditions of experimental plots established in these studies will help in the development of such models.

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 longleaf pine stands.
- New or improved ecological models of biomass, ecosystem production, and the goods and services produced by longleaf pine ecosystems.

**Problem 3c. Expand expertise on the socioeconomic costs and benefits of longleaf pine restoration.**

1. *Cost-benefit analysis.* We will pursue 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 longleaf pine. These may include (but are not limited to) understanding the ecological tradeoffs between restored longleaf pine stands and the other forest types that they replace; the impacts of prescribed fire as a management tool versus its impacts as an influencer of air quality; the socioeconomic impacts of longleaf pine restoration following conversion of slash or loblolly pine-dominated stands on water quality and quantity; the value of non-traditional ecosystem goods and services to human communities, public land managers, private landowners, and the timber industry; and the relative impacts of climate change on restored vs. unrestored longleaf pine-dominated landscapes.
2. *Ability of longleaf forest restoration to address global climate change through carbon sequestration while boosting other ecosystem goods and services.* The strong, high-density wood produced by longleaf pine offers multiple opportunities to improve upon the traditional timber-related component of ecosystem goods (e.g., dimensional lumber, poles, pilings, veneer) and develop markets for new wood product options (e.g., cross-laminated panels and other mass timbers) that could lead to increased profitability for these forests at both the domestic and international scales. The properties of longleaf pine wood are also amenable to increasing carbon sequestration, particularly if this wood is incorporated into durable products. We will examine the potential of longleaf pine stands—especially planted ones—as an opportunity to produce long-term climate benefits through carbon storage throughout the entire life-cycle of this species (seedling, sapling, standing tree to consumed wood product).
3. *Identify opportunities to combine restoration and management treatments of longleaf pine 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 logging debris 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 longleaf 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 longleaf 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 longleaf 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.
- New or improved ecological models of biomass, ecosystem production, and the goods and services produced by longleaf pine ecosystems.
- Measures of socioeconomic impacts of longleaf pine restoration on human communities.

- A new strategy for long-rotation longleaf 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.
- Provide landowners with an uneven-aged management system (e.g., Pro-B, BDq, etc.) that will accrue carbon through an extended time, produce periodic outputs of high-quality timber products, utilize natural regeneration to minimize investment costs, and maintain a continuous forest cover through time that will foster the maintenance of wildlife habitat beneficial to game and non-game animal species and a diversity of native plant species.
- Linkage of longleaf pine restoration and management actions with opportunities to use resulting woody residues for bioenergy and emerging material science developments in industry.
- 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 longleaf pine.

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

1. *Experimental Forest Network (EFN) 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 (because of fundamental ecological differences and resource requirements), it should be possible to expand upon some topics in which the experimental design is controlled (kept constant) with the exception of geographic location.
2. *Expanding longleaf pine restoration to more private landowners.* Although most research work to date on longleaf pine ecosystem restoration has been conducted on public lands with the intent of its findings being useful to both public and private landowners, implementation efforts and resulting gains in acreage appear to be higher in the public sector. However, since most forestland in the South—including that historically occupied by longleaf pine—is held by private landowners, it is essential that greater emphasis be placed on developing information for and providing assistance to the private sector. For restoration of longleaf pine communities to be most successful, these landowners—ranging from owners of small parcels to industrial landowners—will need to be much more involved in the effort.

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

- Installation of FIA-based intensified inventory plots to develop long-term data on composition, structure, and dynamics of longleaf pine-dominated stands (both natural and planted) on unit EFs.
- Development of restoration management guidelines for private landowners based on decades of research and demonstration on unit EFs.
- Development of baseline data via intensified FIA-style plots across the EFN to address both ecosystem responses to large-scale natural catastrophes such as hurricanes, droughts, and ice storms.
- Production/demonstration of applications of research studies to real-world challenges of national forest and private land managers and to use these as the basis for published management recommendations.

## **11. ENVIRONMENTAL CONSIDERATIONS:**

Most of the studies covered in this RWUD to be conducted by SRS-4158 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-4158 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-4158 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 natural resource managers and academic colleagues from public and private organizations across the southern United States to address the effects of management practices on longleaf pine ecosystem structure, function, and processes. We will collaborate with research scientists and land managers to study threatened, endangered or declining species; alternative management approaches such as agroforestry; and the production of various alternative commodities and services, such as pine straw, pollinator habitat, bioenergy, 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-4159—Ecology and Management of Southern 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

Southern Region, Regional Office, Atlanta (GA)  
Forest Health Protection, State and Private Forestry (various locations)  
National Forests in: Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina,  
South Carolina, and Texas  
Calcasieu and Winn Ranger Districts of the Kisatchie National Forest, Louisiana  
Conecuh Ranger District of the National Forests in Alabama  
DeSoto Ranger District of the National Forests in Mississippi  
Tuskegee Ranger District of the National Forests in Alabama  
Savannah River Forest Station, New Ellenton (SC)  
National Agroforestry Center, Lincoln (NE)

Other Federal Agencies:

USDA Agricultural Research Service  
USDA Natural Resource Conservation Service  
East Texas Plant Materials Center  
US Department of Defense  
Fort Benning (GA)  
Fort Stewart (GA)  
Fort Gordon (GA)  
Fort Polk JRTC (LA)  
Eglin AFB (FL)  
Camp Lejeune MCB (NC)  
US Department of Interior, Fish and Wildlife Service  
Regional Office in Atlanta (GA)  
Panama City Field Office (FL)  
Asheville Field Office (NC)  
Charleston Field Office (SC)  
Carolina Sandhills National Wildlife Refuge (SC)  
US Department of Interior, National Park Service  
Congaree National Park

Universities:

Auburn  
Alabama  
Alabama A&M  
Berry College  
Clemson  
Florida (at Milton and Gainesville)  
Florida A&M  
Georgia  
Louisiana State (includes LSU AgCenter and Louisiana Cooperative Extension Service)  
Louisiana Tech  
Missouri  
Mississippi State  
North Carolina State  
Southern Mississippi  
Stephen F. Austin State  
Texas A&M  
Tuskegee

State Agencies:

Alabama Cooperative Extension Service  
Alabama Forestry Commission  
Florida Forest Service  
    Goethe State Forest  
    Blackwater River State Forest  
Georgia Forestry Commission  
Louisiana Department of Agriculture and Forestry  
Louisiana Department of Wildlife and Fisheries  
Mississippi Department of Wildlife, Fisheries, and Parks  
North Carolina Forest Service  
    Bladen Lakes State Forest  
    Sandhills Gamelands  
North Carolina Department of Agriculture and Consumer Services  
    Research Stations Division  
South Carolina Department of Natural Resources  
    Aiken Gopher Tortoise Preserve  
    Peachtree Rock Heritage Preserve  
South Carolina Forestry Commission  
    Sandhills State Forest  
South Carolina Cooperative Extension Service  
Texas A&M Forest Service  
Texas Parks and Wildlife  
Virginia Department of Forestry

Private organizations:

Alabama Forestry Association  
Cedar Creek Land and Timber Company (Brewton, AL)  
International Forestry Company (Moultrie, GA and Evans, LA)  
The Jones Center at Ichauway (Newton, GA)  
Louisiana Forestry Association  
Longleaf Alliance  
Longleaf Partnership Council and Local Implementation Teams  
RoyOMartin Timber Company  
National Audubon Society (Silver Bluff Preserve)  
Norfolk Southern Railways Corporation (Brosnan Forest, SC)  
Shortleaf Pine Initiative  
Silvia Terra, Inc. (New Haven, CT)  
Southern Group of State Foresters  
Roundstone Native Seed  
Tall Timbers Research Station (Tallahassee, FL)  
The Nature Conservancy

**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 \$1.5 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	<i>Scientists per year of the RWUD</i>				
	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-4158 currently consists of three permanent full-time research scientists (and three emeritus scientists), four permanent full-time forestry/biological science technicians, one permanent full-time statistician, one permanent full-time resource information specialist, and one permanent full-time professional forester. Additionally, SRS-4158 operations are supported by a part-time, term office automation assistant, and business administration from staff in SRS-4159. Our record of accomplishments and ability to sustain long-term studies and datasets depend heavily on the expertise of our permanent technical staff and maintenance of two experimental forests, the Escambia and Palustris. Some 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. Our budget over the last five years has continued to decline, and is expected to remain limiting into the next five years. The unit is engaged in leveraging strategies with partners to expand our research resource base. Unless projections change, future research and accomplishments will depend more on external funding. Currently, the unit brings in \$100,000-\$200,000 annually in outside funding.

SRS-4158 is responsible for maintaining two experimental forests (EFs), the Escambia EF, located in Escambia County, southwestern Alabama, and the Palustris EF, located on the Kisatchie National Forest, near Pineville, LA. The Escambia EF was established in 1947 through a 99-year lease agreement with the T.R. Miller Mill Company. The 3,000-acre tract constitutes a unique example of longleaf pine ecosystems in various stages of development, and research involves all aspects of longleaf pine natural regeneration, as well as artificial regeneration following hurricane impact and assessment of stock type effects on longleaf pine seedling and sapling performance. Long-term studies and demonstrations include stand management for large and small forest tracts and even-aged and uneven-aged management alternatives, growth and yield of even-aged naturally regenerated stands, and fire ecology. The Palustris EF consists of two tracts totaling about 7,500 acres: The J.K. Johnson tract, established in 1935, site of numerous long-term studies, including a longleaf pine thinning regime study that is now over 75 years old, and the Longleaf Tract, established in 1951, site of some of the most intensive multi-resource research in the South and studies of longleaf pine responses to fire and non-fire management. The experiments on these EFs and the data they yield are valuable assets for the RWU and for the entire longleaf pine research community. SRS-4158, with assistance from Kisatchie NF employees, supports maintenance activities on the Palustris EF, including mowing and prescribed burning activities. The Escambia and Palustris EFs are no longer the duty station of any SRS employees.

## **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 and 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 practices most likely to help improve white oak 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 SGFS 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 torreyia 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>.