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	3. Unit Location Auburn, AL	

4. Reseach Work Unit Title

SRS-4158: Restoring and Managing Longleaf Pine Ecosystems
(Auburn, AL; Clemson, SC; Pineville, LA)

5. Project Leader (Name and Address)

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6. Area of Research Applicability	7. Estimated Duration
Regional (longleaf restoration); global (principles/methodology)	5 years

8. Mission

To provide knowledge, strategies, and tools for restoring, managing, and sustaining longleaf pine ecosystems in the United States and foster insight about ecosystem restoration globally.

9. Justification and Problem Selection Summary

Longleaf pine ecosystems are a distinct part of the forest landscape in the southeastern United States. To landowners, longleaf pine may offer product diversity and lower the risk of timber loss by some natural causes. The species is an important component on many Department of Defense landholdings in the region. These biologically diverse ecosystems are also the native habitat of numerous federally listed and culturally valued species. Once dominating over 90 million acres but now occupying only 3.4 million acres, longleaf pine ecosystem area has been reduced during the past century by urbanization, ineffective management choices, and by economically more profitable forest types and land uses. In 2009, a collaborative effort emerged among over 20 federal and state agencies, stakeholders, and non-government organizations to promote longleaf pine, resulting in the *Range-wide Conservation Plan for Longleaf Pine* which is a science-based approach to increase longleaf pine acreage from 3.4 to 8.0 million acres in 15 years. In 2010, the U.S. Departments of Agriculture, Interior, and Defense acknowledged their support of this plan by signing the Longleaf Pine Initiative Memorandum of Understanding. Scientific information that helps solve the problems encountered by private and public efforts to restore and manage these ecosystems is imperative to the success of this plan. The fundamental science of longleaf pine restoration will also be valuable to ecosystem restoration efforts on a global scale.

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SRS-4158 -- Restoring and Managing Longleaf Pine Ecosystems
Auburn, AL; Clemson, SC; and Pineville, LA
Project Leader: Kristina Connor

9. JUSTIFICATION AND PROBLEM SELECTION

As the backbone of the early southern forest industry and a source of livelihood for southern communities, longleaf pine (*Pinus palustris*) is a high quality timber species that provided logs, poles, pilings, posts, peelers, pulpwood, and naval stores for the building and transportation needs of early European settlers in the southeastern 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 the rolling, sandy hills of the Carolinas to the flatwoods of Florida, Alabama, Mississippi, and Louisiana. Found at sea level along the Gulf Coast and the ridges and flats of central Florida, longleaf pine ecosystems also reached up to an elevation of 2,000 feet on the rocky hills of northern Alabama and northwestern Georgia.

The expansion of railroads into southern forests in the late 19th and early 20th centuries and development of steam-engine logging accelerated the harvest of longleaf pine trees. These industrial advances and the exclusion of fire from these fire-dependent woodlands resulted in the disappearance of longleaf pine forests from much of the landscape. Millions of acres once dominated by longleaf pines were planted to loblolly (*P. taeda*) and slash (*P. elliottii*) pines for a variety of reasons including difficulty in regenerating longleaf pine, and rapid growth rates and economic value of loblolly and slash pine. Longleaf pine ecosystems were reduced to 3.4 million acres and are now among the most threatened ecological systems in the United States.

Longleaf pine ecosystems are now recognized as rich sources of biological diversity harboring dozens of rare plants and animals. Interest in their restoration has grown through the last decade, as evidenced by the release in 2009 of the *Range-wide Conservation Plan for Longleaf Pine* (http://www.americaslongleaf.org). This plan, developed cooperatively with federal, state, and private partners, proposes an increase from 3.4 to 8 million acres in longleaf pine area during the next 15 years. Governmental mandates to conserve federally listed, threatened or endangered species have translated into efforts to restore longleaf pine on portions of most public lands within this species' range, with restoration occurring on relatively few privately held parcels. Thus, private landowner support is key to the restoration of longleaf pine ecosystems on 4.6 million acres by 2024. 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. Research should focus on efforts that expand the longleaf pine manager's toolbox, simplify management actions, increase the net worth of outputs by increasing value and/or decreasing the time horizon, and decrease the risk of failure.

While early research produced guidelines to establish and manage longleaf pine, the interaction between management practices and the inherent values of longleaf pine forests (e.g., income, biological diversity, recreation) were rarely addressed. Because these factors add to the complexity and variability of management goals, the applicability of this early research is limited. New scientific investigations must address the challenges of longleaf pine restoration on both public and private lands. Conventional approaches to restoration problems may be effective in theory, but new and perhaps unconventional approaches will be necessary to meet private landowner expectations, minimize risks, and accommodate societal demands. Private landowners often depend on revenue generated from their ownerships. Any effort to foster a long-term commitment to longleaf restoration on private land must be supported by information on the costs and benefits of management activities, recognizing that expectations and benefits may differ across ownership 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 contibute to market development and in time, landowner commitment to establishing longleaf pine.

Conversion of established 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 fires every 3 to 5 years. However, contentional approaches often include practices like clearcutting and burning that may be rejected in some settings. A means to gradually reduce stem density and slowly foster a desirable understory using a minimum amount of prescribed fire could be appealing to private landowners who reject stand conversion by clearcutting and planting or who are unwilling to accept the risks associated with prescribed fire. Research can contribute to longleaf pine restoration near populated areas by providing guidelines for the asthetically acceptable conversion of other pine forests to longleaf pine ecosystems, and low-cost methods that achieve the effect of prescribed fire wihout risks of unwanted smoke and fire damage to private property.

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). These birds rely on mature pines for nesting and foraging. Gradual conversion from loblolly pine to longleaf pine, while supporting the RCW, requires a suitable level of overstory retention. Although some previous research has explored relationships between understory and overstory longleaf pine trees, managers need to know how to regenerate longleaf pine while retaining the habitat values associated with mature trees. 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.

Changing climate patterns and associated disturbance regimes are likely to impact longleaf pine restoration. Among the southern pines, longleaf pine is the most tolerant of drought and nutrition limitations, the most resistant to insect attack and disease infestation, and when managed appropriately, the least damaged by wildfire. 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. It is clearly a species that offers promise in the event of rising atmospheric carbon dioxide levels, elevated air temperatures, shifts in rainfall patterns, and more 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. 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 to guide genetic improvement efforts and therefore, increase the probability of restoration success in a changing climate. Additionally, sustained adaptation to climate change will only be possible if whole-crown carbon fixation is adequate to support above-ground and below-ground energy needs. Research that evaluates the balance among leaf area, light availability, and the supply and acquisition of soil resources across the longleaf pine range will help to quantify longleaf pine's role in a changing climate.

The long-term application of repeated prescribed fire is viewed as fundamental to the restoration and management of longleaf pine ecosystems. Ongoing research indicates that repeated fire may change the distribution and composition of understory plant roots, old root channels, and soil physical properties that influence sustainability on some soils. Assessing this phenomenon on appropriate soils where climatic extremes are first expected will help determine if alternatives to repeated prescribed fire are needed where soil sustainability may be threatened by global climate change.

Collections of organisms in the understory perform critical functions which sustain the longleaf pine ecosystem. Vigorous and diverse ground-layer plant communities play a key role in fire ecology of the ecosystem. Where there is no natural seed source, restoring longleaf pine requires artificial regeneration, but 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 rangewide 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.

Potential limitations to the annual production of longleaf pine seedlings is a subject of concern. One looming problem is the reliable supply of longleaf pine seed. Longleaf pine is characterized by a dynamic seedfall pattern with many years passing between productive years. Knowledge of what controls flower and cone development and retention, and seed maturity, and how these factors can be manipulated to benefit the availability of seed are needed. 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 longleaf pine ecosystem restoration efforts.

To accomplish our program of research, tasks have been organized into two broad Problem Statements described under the mission:

Provide knowledge, strategies, and tools for restoring, managing, and sustaining longleaf pine ecosystems in the southeastern United States.

Problem 1. Develop the fundamental biological knowledge needed to design sound management practices for establishing and maintaining longleaf pine ecosystems. We need to better understand the processes that affect the fecundity, establishment, and development of native trees and ground-layer plant communities in longleaf pine ecosystems. We will then better understand how native vegetation responds to disturbance and management in terms of growth, vigor, disease and insect resistance, and longevity. 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:

<u>Problem 1a</u>. Advance understanding of ground-layer species biology to ensure persistence or growth of key understory species. We will discover and develop knowledge of the population biology 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).

<u>Problem 1b</u>. Advance understanding about longleaf pine reproductive biology and seedling development to improve our ability to sucessfully regenerate 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 will contribute to the resilience of a commerical nursery industry benefitting from reliable sources of seed, and the ability to produce high quality seedlings with root systems capable of sustained tree growth and anchorage. This will lead to greater acceptance of longleaf pine as a species of choice.

<u>Problem 1c</u>. 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.

<u>Problem 1d</u>. Investigate how plant communities and the landscape ecology of longleaf pine ecosystems are affected by interacting biotic and abiotic factors. 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 plant communities across landscapes. Increased understanding will lead to improved ecological models to develop restoration and management protocols suited to the diverse environmental conditions where longleaf pine is a dominant canopy species. Factors with spatial aspects include site quality variables (e.g. soil strength, water holding capacity, fertility), natural disturbances (e.g., fire, wind), and reproductive processes such as pollination and seed dispersal.

The unit has the facilities, personnel, and equipment to successfully analyze and solve Problem 1a-c. However, any new research, such as entering the field of landscape ecology, as in 1d, will require new personnel and funding.

<u>Problem 2</u>. Develop planning and implementation tools that achieve successful restoration

and other outcomes for longleaf pine ecosystems characterized by outputs of traditional forest products, and the array of land uses and values associated with sustainable longleaf pine forests.

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. Specific problems are as follows:

Problem 2a. Develop and test protocols for restoring ground cover communities across the soil moisture and fertility gradients characteristic of longleaf pine forests. Knowledge of all aspects of restoration is needed. These include the harvest, viability testing, and storage of seeds, 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 even-aged and uneven-aged silvicultural methods for regenerating longleaf pine forests. We will develop science-based silvicultural approaches for converting stands of less desirable overstory species to longleaf pine, and refine methods for using mechanical, chemical, and fire treatments to encourage the development of ground layers dominated by native plants. Researchers will compile information so that it is straightforward and applicable on 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. Enhance knowledge about the regeneration of longleaf pine. Using knowledge of seed and seedling biology and physiology, we will develop protocols for seedling production, and field establishment and maintenance to meet the demand for superior planting stock and innovative, site-specific establishment techniques. Efforts will provide landowners and 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.

Problem 2d. Expand expertise on the economics of longleaf pine. 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 done. 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 currently traded in existing markets, cost-share payments, the presence of federally listed, threatened or endangered species, and air quality regulations. This will provide landowners and managers with information about revenue streams and resource obligations associated with various management activities and strategies.

The unit has the facilities, personnel, and equipment to successfully analyze and solve Problem 2a-c. However, entering any new fields, such as 2d, will require new personnel and funding.

10. APPROACH TO PROBLEM SOLUTION

<u>Problem 1</u>. Develop the fundamental biological knowledge needed to design sound management practices for establishing and maintaining longleaf pine ecosystems.

Research and Accomplishments Planned by Emphasis Area:

a. Advance understanding of ground cover species biology to improve our ability to effectively maintain 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 research focus for over a decade. We will continue to build on early studies that evaluated direct seeding trials 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.
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, nutrients, and light. Efforts to understand seed production by native warm season grasses and the effects of canopy and herbaceous cover on seedling establishment 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 the longleaf pine ecosystem 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 iminent threats to protected species. Currently underway is 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. Experimental moves involve multiple translocation sites and schedules. Other species-specific studies will be considered as resources permit and needs arise.

b. Advance understanding about longleaf pine reproductive biology and seedling development to improve our ability to sucessfully regenerate longleaf pine ecosystems.

1. *Nutrient-loading 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, nor the potential to improve physiological quality and therefore, growth after planting. Soils in the natural range of longleaf pine are generally low in available phosphorus (P). Studies at the Palustris Experimental Forest (EF) are underway to determine if P loading during seedling production or nutrient amendment in the field enhances seedling growth. Research will evaluate the potential to improve seedling growth by changing cultural or establishment environments. Relationships between seedling morphological variables at planting and seedling field performance will be assessed in an effort to define pre-plant standards that reflect both survival and growth after planting.

2. *Seedling root system development.* Forest industry in the southern U.S. 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. Several field studies are underway on the Palustris EF and Escambia EF to assess the effect of container type on longleaf pine root system morphology and overall seedling quality at planting, seedling development in the field, and sapling vertical stability. Results will guide container manufacturers' efforts to design containers more suited to the root system of longleaf pine and uses of these containers by the nursery industry.
3. *Cone and seed crop predictions*. At best, 75% of longleaf pine seeds stored for up to 20 years may be viable, but greater than 75% viability is anticipated when longleaf pine seeds are stored for less than two years. Since the annual production of large amounts of longleaf pine nursery stock requires a large supply of viable seed and longleaf pine seed is generally in short supply, storing longleaf pine seeds for no longer than two years is desired. Unfortunately, longleaf pine is characterized by an erratic pattern of cone production and seed supply that often leads to more than two years between ample seed crops. Building upon a monitoring effort that has quantified longleaf pine cone production at 10 locations for up to 55 years, we will pair the cone data with climatic and edaphic information and investigate linkages among cone production, annual water deficit, soil series, chemical and physical properties, and available stand information. If warranted, conceptual hypotheses about the variables controlling longleaf pine cone production will be developed and tested. Information may prove valuable for sustaining the supply of longleaf pine seed.

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

1. *Frequent fires and soil properties.* Land managers need assurance that frequent fire does not negatively affect the soil physical properties that influence pine root elongation and root system expansion. Furthermore, on fine textured soils, as the amount and frequency of precipitation decrease with climate change, the risk to pine roots of mechanical impedence by soil strength increases. A long-term assessment of soil physical properties and the variables that control these properties in response to frequent prescribed fire is ongoing. This work also serves as a basis of understanding how interaction between the soil physical environment and pine root system growth could interact on fine textured soils with an increasing water deficit. Concentrations of hydrophobic and hydrophilic compounds in the surface mineral soil of burned and

unburned areas were quantified after the first burn, and soil physical properties at three depths have been monitored four times. From this long-term study, land managers will better understand the effects of repeated fire on the productivity of fine textured soils and the role that understory vegetation plays in buffering these effects.

2. *Physiological adaptation to frequent fire.* Fire-adapted pines possess physiological and growth characteristics that minimize growth loss after fire. The application of prescribed fire outside these parameters risks an unnecessary setback in growth between fire intervals, and a loss of stemwood production during the rotation. In the event of a hotter and drier setting with global climate change, multiple fires during a rotation that are applied when trees are vulnerable to a growth loss could reduce tree vigor and lead to stand decline. In collaboration with Louisiana Tech University, research is underway to define a window of time during the year when the physiology of longleaf pine minimizes the potential loss of fixed carbon. This information will be made available to private landowners interested in maximizing the stemwood growth of planted longleaf pine, to public land managers whose goal is forest sustainability, and to scientists working to model the impacts of fire on the forest landscape in a changing climate.

3. *Adaptations that sustain tree vigor.* Longleaf pine health and vigor depend on physiological adaptations that assure two basic needs. These are carbon to provide adequate energy above-ground and below-ground, and sufficient soil resource uptake to maintain corresponding levels of carbon fixation. Energy deficits and shortfalls of water and essential nutrients have the potential to disrupt this balance between carbon fixation and soil resource acquision leading to inadequate carbohydrate for the maintenance of fascicles and roots. In some situations, this imbalance may indirectly cause nutritional problems that expand exisiting physiological problems. Either condition can lead to poor tree vigor and increased susceptibility to insect attack and disease. Field observations and a series of greenhouse studies with longleaf pine continue in an effort to understand relationships among nutrient and water availabilities, fasicicle physiology, root system growth, and susceptibility to root pathogens. Key associations will be validated *in situ*, and remedial measures will be investigated as warranted.

d. Investigate the biotic and abiotic factors affecting plant communities and the landscape ecology of longleaf pine ecosystems.

1. *Longleaf pine trees on poorly-drained sites.* Most current research directed at understanding the response of longleaf pine community dynamics to management disturbance focuses on upland sites. A study continues to investigate these dynamics in poorly drained habitat and will provide a basis for developing much needed restoration approaches and protocols where soil drainage hinders establishment success. 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 this study will serve the development of such models.

2. *The effects of fire on longleaf pine plant communities.* In the absense of prescribed fire, fuels reach a point when wildfire can be very destructive. Prescribed fire is considered necessary for the management of longleaf pine because it is the best means to control unwanted fuel and promote the growth of desirable herbaceous plants. Even prescribed

fire, however, can negatively affect the growth and persistance of longleaf pines in some settings. In addition to a reduction in carbon fixation by crown scorch, woody root and stem damage by fire can attract insects that feed and brood in the roots and stems and introduce pathogens. Research on how fire season and interval, and the age of its initial application interact with tree and understory vigor and ground cover diversity has been ongoing for several decades. These efforts will continue with a focus on obtaining information about prescribed fire methods that respond to problems encountered by private landowners interested in restoring longleaf pine ecosystems.

Anticipated outcomes in Problem 1:

-Increased understanding of population and community processes that affect threatened and endangered plant species in the ground layer of longleaf pine ecosystems.
-More reliable reference ecosystem information to help inform restoration objectives.
-Identification of the basis of longleaf pine's seasonal tolerance of crown scorch which will ensure compatibility between the timing of prescribed fires and management goals.
-Improved understanding of the effects of fire condition on the longleaf pine trees and ground-layer plants of longleaf pine ecosystems.
-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 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 planning and implementation tools that achieve successful longleaf pine ecosystem restoration and management outcomes characterized by traditional forest products and an array of land uses and values associated with sustainable longleaf pine forests.

a. **Develop and test protocols for restoring ground cover communities.**

1. *Seed sources and transfer zones.* The effort to restore the ground cover of longleaf pine communities is strongly limited by the lack of ecologically suitable native plant materials. Plant materials from outside the longleaf 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 any local populations. We will complete the establishment of a network of common gardens to evaluate the growth and reproduction of plant species representing populations from across the species' range. Plant selections include representative grasses, legumes, and other forbs with extensive geographic ranges, and with demonstrated consumer demand.
2. *Ground cover 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. Additionally, a synthesis of

published data plus previously unpublished lessons learned by restoration practitioners will be completed.

3. *Ground-layer vegetation dynamics.* We are renewing ground-layer inventory projects on the Kisatchie National Forest, LA, to determine temporal changes in the ground-layer composition of longleaf pine forests.

b. Improve knowledge about even-aged and uneven-aged silvicultural methods for regenerating longleaf pine forests.

1. *Regeneration methods.* While continuous-canopy management is best achieved through irregular shelterwood and selection methods, 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, like uniform shelterwood, with new knowledge about the irregular shelterwood and selection methods.
2. *Proportional-B.* A new approach developed by the Unit and cooperator Auburn University for applying selection silviculture, the Proportional-B (Pro-B) method is being tested and refined in longleaf pine forests. The Pro-B selection method makes uneven-aged management a practical option for forest managers by its low cost, simplicity to learn and ease of application. 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 to natural longleaf pine stand management.
3. *Hurricane damage.* The natural range of longleaf pine lies mostly within the hurricane zone of the southeastern U.S. Although the 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.
4. *Long-term studies.* Fire favors longleaf pine because it kills the regeneration of other pine species, keeps brush in check, removes smothering litter, and helps control brown-spot needle disease that stunts longleaf pine seedling growth. We will continue examining the interaction effects of time-interval and season for prescribed fire and their role 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. 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 pollen and cone production.
5. *Loblolly pine stand replacement.* Gradual conversion of loblolly stands that support RCWs requires a suitable level of overstory retention to provide continuous nesting

and foraging habitat. Although some previous research has explored relationships between understory and overstory longleaf pine trees, little is known about regenerating longleaf pine under a loblolly pine overstory. We will continue experiments at Fort Benning and Camp Lejeune to determine the optimal silvicultural practices for converting loblolly pine stands to longleaf pine ecosystems, while retaining mature trees for RCW use and enhancing the herbaceous ground layer. Experimental treatments include canopy treatments of thinning or gap production, 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).

c. Enhance our knowledge about artificial regeneration of longleaf pine.

1. *Longleaf pine sapling and tree toppling.* Planting seedlings is a practical method to establish longleaf pine regeneration where or when no natural seed source exists. Reasons for switching from bareroot stock to container stock are that the latter has too narrow a seasonal planting window and the seedlings have to be planted soon after lifting because they do not store well. While container stock is preferred to bareroot stock for its greater survival, it has been accompanied by isolated occurrences of toppling after strong wind events. Although currently used containers change much of the natural root system architecture of longleaf pine, there has been little effort made to improve this aspect of the containers. We have studies underway on the Palustris and Escambia EFs to minimize negative effects of container attributes on the field establishment, growth, and vertical stability of sapling longleaf pine trees.
2. *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 genotype and environment in the juvenile growth of longleaf pine, and 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.

d. Explore the economics of longleaf pine.

1. *Modeling tree growth.* (1) A growth and yield study for naturally regenerated longleaf pine was started at the Escambia EF in 1964 and later was expanded region-wide. The objective of this study which continues today, was to quantify the growth and yield of natural, thinned longleaf pine forests spanning a range of ages, site types, and residual stand densities. Plots are remeasured every 5 years, with the 45-year remeasurement taking place in 2009. Since 1974, new 18-year-old stands have been added every 10 years. (2) The collection of another long-term data set began in 1935 on the Palustris EF and continues today. It contains information on the stemwood production of artificially regenerated longleaf pine in response to burning, planting spacing, pruning, and thinning to different stand densities. From these two efforts, a large growth and yield modeling project grew to include numerous university, and state and federal agency partners. This effort not only addresses the prediction of overstory tree stemwood yield, but also pine straw production, and carbon sequestration. These data

are available for the economic analysis of longleaf pine management options across the species' range.

2. Cost-benefit analysis. We will pursue developing research partnership(s) to develop tools for economic analysis of the benefits, costs, and potential risks associated with public and private investment and changes in land use when establishing large areas of longleaf pine on the landscape.

<u>Anticipated outcomes in Problem 2</u>:
-Practices that will improve the restoration and sustainability of diverse understory plant communities in open longleaf pine forests.
-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.
-Production of a decision tool or key for assessing the restoration potential and costs of restoration on target sites.
-Plant material guidelines for use in expanding longleaf pine acreage.
-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.
-Measurement of long-term field installations to provide growth and yield information for modeling stemwood yields and associated commodities from longleaf pine stands.
- 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.
- Brochures and other written and web-based outreach materials targeted for private landowners that provide information on longleaf pine restoration and management.
-Conduct field tours and workshops tailored for private landowners, but also useful for land management professionals, to help them solve their longleaf pine restoration and management problems.

11. ENVIRONMENTAL CONSIDERATIONS

The RWU-4158 program of research includes 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 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. 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 District or Forest staffs. 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, RWU-4158 will consult with District or Forest biologists and the U.S. Fish and

Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended.

Key Cooperators: We will collaborate with professional resource managers and academic colleagues from public and private organizations across the Region to address the effects of management practices on longleaf pine forest structure, function, and processes. We will collaborate with research scientists to study threatened and endangered species, alternative management approaches like agroforestry, and the production of various alternative commodities and services, such as pine straw, biofuels, carbon sequestration, ecotourism, 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. Key cooperators include the following organizations:

Southern Research Station:
- SRS-4156--Center for Disturbance Science
- SRS-4159--Southern Pine Ecology and Management
- SRS-4160--Forest Genetics and Ecosystem Productivity
- 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 Health Monitoring
- SRS-4854--Eastern Forest Environmental Threat Assessment Center
- SRS-4952--Integrating Human and Natural Systems

Federal Agencies:
- National Forests in:
  Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina, and North Carolina
- DeSoto Ranger District of the National Forests in Mississippi
- Calcacieu Ranger District of the Kisatchie National Forest, Louisiana
- USDA Natural Resource Conservation Service
- Region 8, Regional Office, USDA Forest Service
- Region 8, State and Private Forestry, Forest Health Protection
- Department of Defense – Fort Benning, Fort Stewart, Fort Gordon, Fort Polk JRTC, Eglin AFB, Camp Lejeune MCB
- USDI Fish and Wildlife Service – Panama City Field Office, Asheville Field Office, Charleston Field Office, Regional Office, Carolina Sandhills National Wildlife Refuge
- USDA National Agroforestry Center

Universities:
- Auburn
- Alabama A&M
- Clemson
- Florida (at Milton and Gainesville)
- Florida A&M
- Louisiana State
- Louisiana Tech
- Mississippi State
- Tuskegee

State Agencies: Alabama Cooperative Extension Service
Alabama Forestry Commission
Florida Forest Service
LSU AgCenter, Louisiana Cooperative Extension Service
Louisiana Department of Agriculture and Forestry
Louisiana Department of Wildlife and Fisheries
Mississippi Department of Wildlife, Fisheries, and Parks
North Carolina Dept. of Environmental Resources – Bladen Lakes State Forest and Research Stations Division
North Carolina Department of Agriculture and Consumer Services: Research Stations Division
South Carolina Forestry Commission – Sandhills State Forest

Private organizations: Joseph Jones Ecological Research Center
Tall Timbers Research Station
The Nature Conservancy
Alabama Foresty Association
Louisiana Forestry Association
Longleaf Alliance
Cedar Creek Land and Timber Company, Alabama
Martin Timber Company, Louisiana
Silvia Terra, Inc., New Haven, Connecticut
Roundstone Native Seed
International Forestry Company, Georgia

12/13. STAFF AND COSTS

The RWUD describes an ambitious five-year plan of work. Based on a proposed staffing level of 6 scientists and about 1.8 million per year, we expect to implement most areas of research described in the RWUD excluding Problems 1d and 2d. With a higher level of funding, and more staff, all the proposed the research could be accomplished sooner.

Staffing Plan: RWU Staffing and Funding

Problem Area	Scientist years per year of the RWUD				
	2013	2014	2015	2016	2017
1	3.65	3.65	3.10	3.10	3.10
2	2.35	2.35	1.90	1.90	1.90

The unit consists of six permanent full-time research scientists, one full-time support scientist, seven full-time technicians, one information technology specialist, one resource information specialist, one full-time project secretary (vacant), and two shared support personnel. 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. Many 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 for FY12 was flat and that of FY13 and future years are projected as declining. The unit is engaged in leveraging strategies with partners to expand our research resource base. Unless projections change, future flexibility and accomplishments will depend on external funding. Presently the unit brings in $223,000 annually in outside funding.

The unit is responsible for maintaining two experimental forests (EFs), the Escambia, located in Escambia County, southwestern AL, and the Palustris, 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. Long-term studies and demonstrations include stand management and management alternatives, growth and yield of even-aged natural 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. The experiments on these EFs and the data they yield are valuable assets for the Unit and for the entire longleaf pine research community. The Unit, with assistance from Kisatchie NF employees, supports maintenance activities on the Palustris EF, including mowing and prescribed burning activities, and has two full-time employees stationed on the Escambia EF. The manager of the Escambia EF is expected to retire later in FY13 and hopes are his position will be filled. We consider it essential to have two employees there to accomplish the work load necessary to meet conditions in the lease agreement and for safety purposes.