



Longleaf Pine Climate Change Workshop Summary

October 2009



SERPPAS
Southeast Regional Partnership for Planning and Sustainability



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Introduction

Why Longleaf and Climate Change?

Longleaf pine (*Pinus palustris*) once ranged from southeastern Virginia to eastern Texas, covering more than 90 million acres in the Southeast. To date, approximately 8 million acres of this forest ecosystem remains (about 3% of the pre-settlement range). In a recent report published by the National Wildlife Federation (NWF 2009), it was proposed that longleaf pine restoration could support forest-based climate adaptation and carbon sequestration efforts in the Southeast. The NWF report, which was briefed prior to publication at our workshop, summarized how global warming would affect Southeastern forests and how longleaf pine can be resilient to many of these anticipated changes (see *Appendix—NWF Report*). More intense weather and climate extremes (e.g., increased frequency and severity of fires, hurricanes, sea-level rise, droughts, etc.) will directly impact forests and continue to stress natural ecosystems. Communities and governments will need to re-evaluate how to manage forests, water supply, and other natural resources. As a step towards addressing these needs, Secretary of Agriculture Tom Vilsack has spoken of an “all lands” approach to landscape conservation and tasked the Regions and Research Stations of the Forest Service to develop landscape level conservation plans. Some examples of how longleaf can address these challenges in the Southeast include:

1. **Longleaf pine ecosystems are naturally resilient to climate extremes.** Longleaf pine grows under very dry and very wet conditions, and is tolerant of and even dependent upon frequent fire. Longleaf pine is better adapted to weather severe storms and is more resistant to southern pine beetle infestations likely to be exacerbated by warmer and drier conditions (NWF 2009).
2. **Longleaf pine restoration can be a global warming adaptation strategy.** Investments in conservation strategies likely to help wildlife adapt to rapid habitat changes and maintain natural resources local communities depend upon is imperative. Restoring and expanding healthy longleaf pine forests can ensure long-term economic returns for landowners, provide important wildlife habitat, and enhance natural retention of fresh water on the landscape. Recent experiences with Hurricane Katrina (2005) and wildfires in Myrtle Beach (2009) SC illustrate how longleaf pine forests can retain much of

their economic value and help protect communities from devastating natural disasters (NWF 2009).

3. **Longleaf pine ecosystems can support land-based carbon sequestration.** Improved forest management will be an important tool in the effort to reduce the amount of carbon dioxide in the atmosphere, and thus limit the overall amount of warming during the coming decades. Longleaf pine ecosystems are well suited for long-term storage of carbon. Longleaf lives longer than other southern pine species, is less susceptible to fire, pests, and storms, and produces wood more likely to be used in long-lasting structures (NWF 2009).

Workshop Background

Efforts to accelerate place-based longleaf conservation have gained momentum in recent years. A challenge in these restoration activities is accounting for and understanding the impacts of environmental factors with a changing climate. Research can serve to guide and make better informed management decisions in longleaf restoration. A workshop was held November 2, 2009 in Atlanta, Georgia to discuss opportunities and strategies for coordinating longleaf pine and climate change research. The Longleaf Pine/Climate Change workshop was hosted by the Southeast Regional Partnership for Planning and Sustainability (SERPPAS), the Piedmont South Atlantic Coast and Gulf Coast Cooperative Ecosystem Studies Units, Department of Defense (DoD), National Oceanic and Atmospheric Administration (NOAA), and USDA Forest Service (USFS). Workshop sponsors share a strong interest in restoring longleaf pine in the Southeast and research that could further aid in that restoration.

America's Longleaf Restoration Initiative (hereafter *America's Longleaf*) is a voluntary collaborative effort of more than 20 organizations and agencies that seeks to support and coordinate longleaf pine restoration. The “roadmap” for *America's Longleaf* is a Range-wide Longleaf Pine Conservation Plan, which calls for 80+ actions to restore the longleaf ecosystem (www.americaslongleaf.org). SERPPAS established a Longleaf Subcommittee to identify specific actions that would be appropriate for SERPPAS to lead. Seven areas were identified by the subcommittee, including the need to coordinate climate change research as it relates to longleaf pine. One recommended strategy from the Longleaf Pine/Climate Change action team was to host a one-day workshop.

Thus, the goal of the workshop was to bring together a small group of experts (see *Appendix B Meeting Participants*) to gain a better understanding of current research taking place on the nexus between longleaf pine and climate change, and to identify issues and opportunities to further promote research coordination on this topic.

Workshop Structure

This report is a product of the one-day workshop and includes workshop highlights and recommendations/actions. The goals of the Longleaf Pine/Climate Change Workshop were to (1) identify strategies to coordinate longleaf pine/climate change research, and (2) prioritize research needs related to the topic. The workshop was divided into two parts. First, workshop participants reviewed current or ongoing research, and from this review, identified research gaps and priorities directly related to the longleaf restoration and climate change (see *Appendix A Workshop Agenda*). In addition to workshop discussion, “homework” questions sent prior to the workshop served to frame and identify gaps and priorities (see *Appendix C Homework Questions*). The second half of the workshop reviewed key partners not present at the workshop that needed to be engaged in the process, implementation strategies for further coordination, potential funding sources, and recommended policy changes.

Main Conclusions

1. Six research priority areas emerged from workshop discussion and break-out groups:
 - a. Carbon sequestration
 - b. Insects and pathogens
 - c. Growth dynamics
 - d. Prescribed fire
 - e. Restoration effects
 - f. Ecosystem services
2. Two broad recommendations and follow-up actions emerged from the workshop:
 - a. **Communication**—improve through (1) follow-up one-day workshop, (2) webpage “portal”, and (3) Longleaf Pine/Climate Change workgroup.
 - b. **Priority Research Areas**—prioritize list of research projects for SERPPAS to endorse.

Workshop Highlights

PART I

Current Research

Workshop participants from federal/state agencies, universities, and NGO's briefly reviewed ongoing or current research being conducted in the Southeast related to longleaf pine forests' role in adapting to or mitigating effects of expected climate change. Main themes of research being conducted included research in carbon sequestration, prescribed fire use/effects, climate/environmental factors, modeling and monitoring, threatened and endangered species, general ecology and ecosystem functions, and policy and economics. A sample of research projects and agency/organization conducting the research is included in the report (see *Appendix D Current Research*).

Gaps and Priorities

Six research priority areas emerged from workshop discussion and break-out groups: (1) carbon sequestration, (2) insects and pathogens, (3) growth dynamics, (4) prescribed fire, (5) restoration effects, and (6) ecosystem services. In many cases, some of these research priority areas were overlapping (*e.g.*, carbon sequestration and prescribed fire). A description of each priority area and sample research questions is provided.

1. Carbon Sequestration

Improved forest management will be an important tool in reducing the amount of carbon dioxide in the atmosphere, limiting the overall amount of warming in coming decades. Longleaf pine ecosystems can serve to support land-based carbon sequestration efforts in the Southeast (NWF 2009); however, an understanding of the carbon cycle in longleaf pine ecosystems to include effects from management practices like prescribed fire is lacking. Three focus areas were identified under the carbon sequestration research priority.

- ▶ **Distribution and Storage**—Research on the distribution and storage of carbon in the various components of the longleaf pine ecosystem needs to be conducted. We need to know, for example, if longleaf pine forests are overall net storers or emitters. How is carbon partitioned above and below ground and how does carbon cycling differ between these partitions? How do climate-induced changes in the availability of water, essential nutrients, and light affect carbon sequestration above and below-ground? Research studies should provide an accurate estimation of biomass accumulation across all ecosystem types, including estimation of carbon cycling relative to herbaceous layers and associated soil carbon cycling processes.

- ▶ **Species Comparison**—Future research should quantify the ecological advantages of longleaf pine forests over other southern pines, particularly with predicted increases in warming and drought frequency and severity. These studies should include the integration of carbon sequestration with economic goals and other ecosystem services. Research studies to be conducted include how will the range of longleaf pine, for example, expand as good seed crops become more frequent?
- ▶ **Prescribed Fire Effects**—Given that longleaf pine forests must be periodically burned to be maintained, we need to know the total life cycle of carbon in the longleaf pine ecosystem in terms of overall flux and among system components. Research studies to be conducted should include, for example, the construction of a total carbon budget model to aid in addressing management practices like prescribed fire. Prescribed fire releases CO₂ and other pollutants into the atmosphere but we do not know the difference in the release of pollutants between a series of prescribed fires versus intense and extensive wildfires. Studies to increase our understanding of these potential impacts need to be conducted.

2. Insects and Pathogens

Previous research suggests longleaf pine is more resistant to pathogens and insect damage. Southern pine beetle infestations are predicted to increase with warmer and drier conditions (NWF 2009). Research studies to be conducted include how will climate influence the occurrence and impacts of native and invasive pathogens and insects? How will longleaf pine defenses hold up against such infestations? Research should address these questions to better understand the benefits of longleaf restoration compared to other pine species.

3. Growth Dynamics

Understanding the long-term impacts of climate change to longleaf pine and other southern pines is imperative in successfully implementing forest management strategies. Research of growth and yield of longleaf to include physiology, timber growth models, and species regeneration will be needed for model forecasting and accounting. Three focus areas were identified under the growth and yield research priority.

- ▶ **Physiological Response/Limits**—Longleaf pine is considered the least resource-demanding and most stress-tolerant of the southern pines (NWF 2009). This is attributed in part to the adaptability of the species to tolerate or avoid stressful environmental conditions. Research is needed to better understand what environmental and physiological conditions are required for these mechanisms to function effectively. How far have these mechanisms, for example, been “pushed” in existing environments (*e.g.*, xeric sites)? How much species adaptation can be expected with

more frequent and severe water deficits and elevated air temperatures? How will a warmer and drier or wetter climate affect the patterns of photosynthesis, respiration, and reserve synthesis in longleaf? How do changes in water availability and air temperature associated with climate change affect carbon allocation to the root system, and soil constraints to root system expansion? Collectively, research should address these various questions to allow managers to make better and more informed management decisions.

- ▶ **Growth Rates**—A second aspect to the broad growth and yield research area is improving or updating growth and yield models. Existing growth and yield information on longleaf pine is limited; growth and yield models for a variety of sites and stand conditions are needed. Much more information is needed to inform private landowners that longleaf is economically attractive, and should include identification of existing data to use in models (*e.g.*, Escambia data) and completing various, broad-based longleaf pine growth and yield models. This effort would provide the basis for integrating strategic habitat conservation planning with carbon sequestration planning efforts. Due to the potential for significant physiological differences across sites and more broadly, across the range of longleaf, the supporting information must be broad-based. Research also should evaluate the direct effects of elevated CO₂ and elevated temperature on longleaf pine growth.
- ▶ **Regeneration**—The final area of emphasis in the growth and yield research area is increasing our understanding of longleaf regeneration. Research addressing how climate change, for example, influences longleaf pine cone crops is needed. What causative mechanisms account for the relationship between changing climate and the increasing frequency of good cone crops during the past 20 years? In anticipation of climate change, new longleaf seed orchards also need to be established. Over 80% of planting stock is containerized seedlings; however, it remains to be seen if container-grown seedlings are capable of withstanding strong winds from intense hurricanes without toppling becoming a problem.

4. Prescribed Fire

Fire is an important element in the maintenance of longleaf pine ecosystems. A changing climate will impact the ability to implement prescribed fire due to changes in fuel loads, fire ecology and dynamics, and practical application in forested landscapes. Two focus areas were identified under the fire impacts research priority.

- ▶ **Fuel Dynamics**—An understanding of how climate change will affect fuel loads is imperative in the use of fire as a management tool. A predicted warmer and drier climate will increase the numbers of invasive plant species and promote fires that are more frequent and higher in soil/ground temperatures. Research is needed to determine how the effectiveness of prescribed fire, for example, would be different with these changing fuel dynamics? How do fuel beds influence fire intensity and subsequently longleaf pine root and cambium injury and mortality? Do invasive understory plants alter fuel bed structure and fuel loads? This is an important area of research to better use prescribed fire in longleaf restoration.
- ▶ **Fire Dynamics**—A warmer and drier climate may result in more intense and extensive wildfires with adverse effects on forest health (*e.g.*, FL, GA, and LA wildfire seasons). Research is needed to update fuel and smoke dispersal models to improve model predictions relating to fire severity and vegetation effects with a changing climate. What will be the effect of more frequent and extensive prescribed burning on the release of CO₂ and other pollutants into the atmosphere? Is the release of pollutants by prescribed burns preferred to the release of pollutants from more intense and extensive wildfires as the climate continues to warm and drought frequency/severity increases? This issue has to be modeled over long time periods to include wildfire occurrence versus periodic prescribed fire. The frequency of prescribed burning needs to be increased in longleaf pine forests (*e.g.*, 2-3 years) to maintain healthy open longleaf pine forests. The introduction of repeated fire as stands are converted to longleaf pine as well as the application of fire in existing longleaf pine stands will change the understory composition. How will soil structure and nutrient loadings be affected by concurrent changes in understory composition? How will stand production and vigor respond to soil composition under a more intense fire regime? In an environment where water deficits are more frequent and severe and air temperatures are elevated, will it be more difficult to maintain leaf area and re-establish leaf area after crown scorch? If so, will an increase in the level of prescribed fire exacerbate leaf area limitations and impact other ecosystem functions (*e.g.*, carbon sequestration, tree growth, root system expansion, defense mechanisms? Collectively, the role of fire in longleaf restoration needs to

be addressed *via* research, particularly due to changes in predicting outcomes from management practices under a changing climate.

5. Restoration Effects

The Conservation Plan identifies various strategies to accelerate longleaf restoration throughout the range of the species. These strategies will eventually serve to implement placed-based restoration projects. Research is needed to identify the most suitable areas for restoration to occur over the long-term. We need to identify, for example, potential changes in species distribution and how these distribution shifts relates to proposed restoration areas. What effects may occur on understory species related to these shifts? We need to complete and maintain a range-wide mapping effort for supporting strategic planning of longleaf restoration efforts that provide the greatest benefits (*i.e.*, conservation benefits, carbon sequestration benefits, *etc.*). Have those benefits been articulated clearly and are strategies being developed to maximize those identified? The challenge in longleaf restoration includes looking at climate and longleaf through uncertainty analysis and multilateral outputs. Thus, traditional approaches to research modeling will need to account for this uncertainty at various spatial and temporal scales.

6. Ecosystem Services

The vast majority of forestlands potentially available for restoration across the longleaf range are privately-owned. In addition, significant holdings of the industrial timber companies have been acquired by timber investment management organizations (TIMO's) or real estate investment trusts (REIT's) over the past decade. The success of the Conservation Plan will require "making the case" for retaining and restoring longleaf with these landowners and consulting foresters who serve them. A research priority area identified by workshop participants includes the area of "ecosystem services" (*e.g.*, recreation, green space, water, *etc.*). Non-timber income sources such as hunting leases, carbon credits, pine straw production, and silvopasture strategies can serve to encourage or incentivize private landowners to manage for longleaf pine. Research is needed on the economic benefits of longleaf pine compared to other southern pines and under various management practices to include the capture of these other "ecosystem credits". Research to aid in the development of market standards and frameworks is needed. Finally, research or a synthesis of existing information on landowner demographics and behavior in relation to incentives can serve to provide a complete picture into the economics of longleaf restoration and provide further justification for longleaf restoration.

Workshop participants recognized the need to promote interdisciplinary research in addressing the aforementioned six research priority areas. In our review, an overlap in

research priority areas became evident; thus, interdisciplinary research can serve to ensure the interaction affects are accounted for in future research studies.

PART II

In the second half of the workshop, participants reviewed (1) key partners not present at the workshop that needed to be engaged, (2) implementation strategies for further coordination, (3) potential funding sources, and (4) recommended policy changes to promote coordination of research. Workshop participants were divided into groups to discuss each of these four topics. Following the group breakouts, group leaders presented findings. The following were reoccurring items presented during the group presentations.

Key Partners

Workshop participants identified other partners (not represented in the workshop) who need to be engaged in future meetings. These partners included the Jones Ecological Research Center, Forest Landowners Association, State Foresters, and the Southeastern Association of Fish and Wildlife Agencies (SEAFWA). These groups are either active in longleaf research and/or can serve to further identify and refine research priority areas.

Implementation Strategies and Mechanisms

Workshop participants discussed what models or frameworks might serve to coordinate LLP/CC research. Some possible models to consider in the future include the Forest Practices Board's Cooperative Monitoring, Evaluation, and Research (CMER), National Council for Air and Stream Improvement (NCASI), or further development of the CESU-SERPPAS partnership. Other strategies to coordinate research included a website or database clearing-house and a possible follow-up workshop to further refine a research agenda for the group.

Funding and Policy Changes

Several possible funding sources were identified by workshop participants including agency programs (*e.g.*, USFS, SERDP), private foundations/companies (*e.g.*, Turner Foundation, Southern Company), and NGOs (*e.g.*, NFWF, NWTF). The general consensus was a lack of regional coordination with a group or individual tasked with tracking progress, and clear objectives and milestones to ensure accountability. Some recommendations included an interagency advisory group to support the continued effort of the LLP/CC action team and the development of a "joint" research agenda to guide agency priority research areas and existing RFP efforts.

Recommendations and Action Items

Based on workshop input, the LLP/CC action team identified two key broad actions for implementing the coordination of climate change research:

1. **Communication**—information-sharing of current research efforts is important to research coordination. The team identified several strategies to improve and continue communication among scientists and funding agencies:
 - a. Host a follow-up one-day workshop to (1) develop a prioritized list of research projects based on findings in this report, and (2) identify 1-2 high-priority research projects SERPPAS could endorse for funding.
 - b. Establish a webpage “portal” to act as a clearinghouse of information including current research projects, scientific publications, and funding sources.
 - c. Establish a Longleaf Pine/Climate Change workgroup to meet periodically. Meeting can be in conjunction with suitable forums (*e.g.*, LLA biennial meeting) that can serve to further advance coordination. One function of the working group might include development of joint regional proposals (*i.e.*, multi-state) that includes multiple university PIs or agency partners.
2. **Priority Research Areas**—Priority research areas will be identified prior to the spring SERPPAS meeting. Specific follow-up actions include:
 - a. Develop a prioritized list of research projects based on findings in this report (see above follow-up workshop).
 - b. Identify 1-2 high-priority research projects that SERPPAS could endorse for funding.

Accomplishments

Some noteworthy accomplishments in promoting longleaf research on the nexus of climate change include:

- ▶ National Wildlife Federation’s report—“Standing Tall: How Restoring Longleaf Pine Can Help Prepare the Southeast for Global Warming.”
- ▶ Carbon Sequestration in Longleaf Pine Ecosystems: Current State of Knowledge and Information Needs Workshop. Workshop was hosted by the Center for Longleaf Pine Ecosystems and U.S. Fish and Wildlife Service East Gulf Coastal Plain Joint Venture on February 16–17, 2010 at the School of Forestry and Wildlife Sciences, Auburn University.
- ▶ LLP/CC Website Portal design. A group of 6 graduate students at George Mason University as part of a class project are designing a LLP/CC research portal as recommended by workshop participants. Portal is scheduled to be launched later this semester.

Appendix A: Workshop Agenda

**Longleaf Pine/Climate Change (LLP/CC) Workshop
Meeting Agenda
November 2, 2009
Atlanta, Georgia**

Time	Topic
8:45	Continental Breakfast
9:20	<p>Welcome</p> <p>Introductions and workshop purpose</p> <ol style="list-style-type: none"> 1. Identification of key and current research findings. 2. Identification of research gaps and priorities. 3. Identification of implementation strategies for coordinating LLP/CC research.
10:00	<p>Presentation by Amadou Diop:</p> <p>Longleaf Pine and Global Warming: How Investing in Restoration Can Help Prepare the Southeast for Global Warming</p>
10:15	Goal 1 discussion (entire group)
11:00	Break
11:15	Goal 2 discussion (entire group)
12:00	Lunch
12:30	<p>Review of Goal 2 and Prioritization</p> <p>- Assignment</p>
1:00	Goal 3 Discussion (group breakouts)
1:55	Break
2:10	Group reports (5-10 minutes) and strategy discussion
3:30	Wrap-up
4:00	Adjourn

Appendix B: Meeting Participants

Last Name	First Name	Title	Affiliation
Arndt	Deke	Chief Climate Monitoring Branch	National Oceanic and Atmospheric Administration
Brockway	Dale	Project Leader on Longleaf Pine	US Forest Service
Brown	Otis	North Carolina Director Cooperative Institute for Climate and Satellites	National Oceanic and Atmospheric Administration
Cabbage	Fred	Professor of Forest Policy, Economics, & Certification	NC State University
Culpepper	Jack	Refuge Forester Carolina Sandhills National Wildlife Refuge	US Fish and Wildlife Service
Darden	Tom	Contract Support for DoD	Department of Defense/BAH
Diop	Amadou	Southern Forest Restoration Manager	National Wildlife Federation
Fenwood	Laurie	IBWO Coordinator	US Fish and Wildlife Service
Gerken	Catherine	Contract Support for DoD-OSD	Department of Defense/ManTech
Hall	John	Program Manager for Sustainable Infrastructure DoD Strategic Environmental Research and Development Program & Environmental Security Technology Certification Program	SERDP/ESTCP
Hayes	Lark	Support for Longleaf Pine	Southern Environmental Law Center
Herbert	Nancy	AD-Research, Threats to Forest Health	US Forest Service
Klepzig	Kier	Assistant Director of USFS Southern Research Station	US Forest Service
Larimore	Bob	Army Installation Management Command-Southeast	Army
Lazenby	Bob	Cooperative Ecosystem Studies Unit Support to SERPPAS	SERPPAS
Lee	Danny	Director, Eastern Forest Env. Threat Assessment Center	US Forest Service
Lopez	Roel	Associate Director Texas A&M Institute of Renewable Natural Resources Cooperative Ecosystem Studies Unit Support to SERPPAS	Texas A&M University
McDearman	Will	RCW Recovery and Longleaf Pine Coordinator	US Fish and Wildlife Service

Last Name	First Name	Title	Affiliation
Norman	Steve	Eastern Forest Env. Threat Assessment Center	US Forest Service
Reinman	Joe	Wildlife Biologist St. Marks National Wildlife Refuge	US Fish and Wildlife Service
Rimer	Linda	Region 4, Environmental Protection Agency	Environmental Protection Agency
Samuelson	Lisa	Director, Center for Longleaf Pine Ecosystems (CLPE)	Auburn University Longleaf Alliance
Sweeney	Jim	Associate Dean, Research and Service	University of Georgia
		Warnell School of Forestry and Natural Resources	
		Cooperative Ecosystem Studies Unit Support to SERPPAS	
Teskey	Bob	Distinguished Research Professor Forest Ecology & Physiology Warnell School of Forestry & Natural Resources	University of Georgia
Uss	Jaime	Contract Support for DoD-OSD	Department of Defense/ManTech
Weiss	Jonathan	Contract Support for DoD-OSD	Department of Defense/ManTech

Appendix C: Homework Questions

LLP/CC Workshop Attendee

“Homework” Questions

In preparation for LLP/CC Workshop, the planning committee solicits your input to aid in identifying (1) on-going research directly related to longleaf restoration and climate change, and (2) research gaps and priorities. Please review and submit your responses by October 27th *via* email (roel@tamu.edu). We anticipate short answers and less than 20-30 minutes of your time. Thank you in advance for your assistance.

1. From your academic experience or from your agency’s perspective, list critical research priority areas directly related to longleaf restoration and climate change? Please list.
2. What critical or key gaps exist in understanding the role of longleaf restoration and management in carbon sequestration and adaptation? Please list.
3. What critical or key gaps exist in understanding the potential climate change impacts from the increased level of prescribed burning needed to restore and maintain healthy longleaf ecosystems? Please list.
4. List potential funding sources that could support longleaf pine and climate change research? These RFPs should be specific and beyond general RFPs (*e.g.*, NSF, *etc.*).
5. Any other key issues that should be discussed at the workshop? Please list.

Appendix D: Current Research Projects

Category	Research Area/Topic	Agency
Carbon Sequestration	<ul style="list-style-type: none"> ▶ Carbon management on public lands ▶ Updated region-wide growth and yield tables ▶ Carbon pools/fluxes in montane and coastal plain LLP 	Auburn, Jones Center, SERDP USFS
Prescribed Fire	<ul style="list-style-type: none"> ▶ Prescribed fires effects on carbon sequestration ▶ Predicted changes in fuels ▶ Role of increase prescribed fire on southern forests 	Auburn, Jones Center, USFS
Environmental Factors	<ul style="list-style-type: none"> ▶ Catastrophic storm effects (e.g., hurricanes) on LLP ▶ Dendrochronology studies ▶ LLP climate factors (genetic) 	Auburn NC State USFS
Modeling/ Monitoring	<ul style="list-style-type: none"> ▶ LLP prediction modeling (e.g., tree atlas) ▶ FIA monitoring 	USFS
T&E Species	<ul style="list-style-type: none"> ▶ Gopher tortoise population ecology ▶ RCW population ecology ▶ Impacts of sea-level rise on T&E species 	Army, Auburn, Jones Center SERDP, USFS, USFWS
Ecology/ Ecosystem	<ul style="list-style-type: none"> ▶ LLP mycorrhiza and taproot function ▶ Southern pine health ▶ LLP mapping and long-term biodiversity trends ▶ LLP Biodiversity—long-term (inc GT) (Auburn) ▶ Research to produce containerized seedlings ▶ Water use and LLP ecosystems 	Army, Auburn, Jones Center, NC State, SERDP, UGA, USFS
Policy/ Economics	<ul style="list-style-type: none"> ▶ Landowner opinions and incentives ▶ Forest economics for landowners and LLP – comparison of LLP to other forestry options ▶ Pine-straw harvesting (ecosystem services) ▶ Economic impact of carbon sequestration (southern pine) ▶ Economics of silvopasture, understory, pinestraw 	Auburn, Jones Center, NC State, USFS

Appendix E: National Wildlife Federation Report

Standing Tall: How Restoring Longleaf Pine Can Help Prepare the Southeast for Global Warming