PINEMAP

Pine Integrated Network: Education, Mitigation, and Adaptation Project

Year 3 Annual Report | March 2013-February 2014

Mapping the future of southern pine management in a changing world

ACKNOWLEDGMENTS

This report highlights research results and programs from the PINEMAP project during year 3 (March 2013-February 2014). We acknowledge the dedication and hard work of the entire PINEMAP team throughout the year (see pages 53 through 55 for complete team list).

We especially would like to thank the 69 authors who contributed to this report (see chapters for details).

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PINEMAP

www.pinemap.org

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USDA United States Department of Agriculture
National Institute of Food and Agriculture

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PINEMAP Year 3 Annual Report | March 2013-February 2014

Introduction

Welcome to the third Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP) annual report. PINEMAP is a Coordinated Agricultural Project funded in 2011 by the United States Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA). PINEMAP focuses on the 20 million plus acres of planted pine forests managed by private landowners in the Atlantic and Gulf coastal states from Virginia to Texas, plus Arkansas and Oklahoma. These forests provide critical economic and ecological services to citizens of the United States. Southeastern forests contain one third of contiguous U.S. forest carbon and form the backbone of an industry that supplies 16% of global industrial wood, 5.5% of the jobs, and 7.5% of the industrial economic activity in the region.

NIFA funded PINEMAP to create, synthesize, and disseminate knowledge that enables southern pine landowners to

- manage forests to increase carbon sequestration;
- increase the efficiency of nitrogen and other fertilizer inputs; and
- adapt forest management approaches and plant improved tree varieties to increase forest resilience and sustainability under variable climates.

These goals require that the PINEMAP team conduct interdisciplinary research and integrate research, education, and Extension activities. To meet these goals, we have launched a number of synergistic and creative groups to build opportunities and facilitate integration.

In the past year, PINEMAP faculty, staff, and students have continued their disciplinary research and also worked to share and synthesize information and efforts seamlessly among institutions as we scale up our analyses from forest plots to regional landscapes. Multidisciplinary and multi-institution groups were formed to work on the application of new knowledge that will help bring about PINEMAP outcomes. The articles in this year's report reflect the progress of these integration groups and the disciplinary research that underpins them.

This report is written to convey the breadth and depth of PINEMAP research; the evolving integration of our science, education, and Extension efforts; and the clear connections to improved outcomes for southern pine forests.

Outcome Themes

PINEMAP is charged with producing real-world outcomes, and accordingly, the tasks are organized around a set of outcome themes. The articles in this report are tagged with icons symbolizing one or more of the outcome themes supported by the research they describe.

Increased carbon (C) sequestration from silvicultural and genetic enhancement of productivity and efficiency of fertilizer use, and resilience to climate variability and disturbance.
Planted southern pine forests already contribute to climate change mitigation by taking up and storing (sequestering) enormous amounts of atmospheric CO_2, both in trees and soil, and in long-lived wood products. PINEMAP produces knowledge necessary to increase the amount of CO_2 sequestered through enhancement of forest productivity, more efficient use of fertilizers, and management of forests for resilience to climate variability and disturbance.

Engaged and literate public with the capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management.
In a democratic society, rational public policy and decision making depend to a large extent on public understanding of and engagement with societal problems. PINEMAP's education programs are designed to help nonscientists better understand and grapple with the complex issues surrounding climate and forest management.

Public policy that supports sustainable management of planted pine under future climate scenarios.
The biophysical and human dimensions research produced by PINEMAP provides information critical for guiding the development of rational natural resource policy.

Enhanced capacity for regional, interdisciplinary collaboration among climate and forest scientists and Extension and education professionals.
PINEMAP's unprecedented coalition of more than 120 forestry researchers, educators, Extension professionals, and students is building new networks and new infrastructure for cutting-edge, collaborative, and outcome-based science.

Enhanced connections between corporate and noncorporate forest landowners and forestry and climate researchers and education and outreach professionals.
Research performed in isolation has little impact on society. PINEMAP strives to strengthen existing and build new connections to on-the-ground forest management so that the science can be quickly translated to outcomes that benefit society.

A more robust and resilient forest-based economy in the Southeast U.S.
PINEMAP research enables pine landowners in the Southeast U.S. to continue producing economic and ecological services that benefit society.

PINEMAP Team

- 57 principal investigators
- 25 research/technical staff
- 7 postdoctoral research associates
- 51 graduate students

Team members are associated with the USDA Forest Service and the following 11 southeastern land grant universities:

- Alcorn State University
- Auburn University
- Mississippi State University
- North Carolina A&T University
- North Carolina State University
- Oklahoma State University
- Texas A&M University
- University of Florida
- University of Georgia
- Virginia Polytechnic Institute and State University (Virginia Tech)
- Virginia State University

See Appendix A for a complete team list.

PINEMAP Partnerships and Networks

A key element of PINEMAP's success is the ability to leverage and expand existing, successful networks. PINEMAP partnerships and networks include the following:

State climate offices and the multi-state Southeast Climate Consortium
State climatologists, primarily located at participating universities, have a common mission to support the advancement of climate information, science application, and education. These scientists serve as local resources on climate. The Southeast Climate Consortium (SECC) is a multidisciplinary, multi-institutional team that uses advances in climate sciences to provide scientifically sound information and decision support tools for agricultural ecosystems, forests and other terrestrial ecosystems, and coastal ecosystems in the southeastern United States.

Southern Regional Extension Forestry
Southern Regional Extension Forestry (SREF) is working with the PINEMAP Extension team to disseminate emerging knowledge, practices, and decision support tools to enable corporate and noncorporate landowners to increase forest carbon sequestration, nitrogen fertilizer efficiency, and forest resilience under variable climates.

Project Learning Tree®
Project Learning Tree® (PLT), an award-winning national environmental education program, is partnering with PINEMAP to assist in the development and implementation of a new secondary module on climate change and southern pine forests.

University-Corporate-Governmental Forestry Research Cooperatives
Members of forestry research cooperatives in the Southeast have tremendous impact on the management of more than 20 million acres of planted forests in the region (about 55% of the privately owned planted southern pine forestland). Corporate members of research cooperatives also produce 95% of the pine seedlings planted in the region each year. Partnerships with these research cooperatives enable PINEMAP to translate research results into practical applications for industrial land managers in the Southeast. These research cooperatives also share data with PINEMAP to establish regional carbon, nutrient, and water baselines. Research cooperative partners include the following:

- *Cooperative Forest Genetics Research Program*
- *North Carolina State University (NCSU) Cooperative Tree Improvement Program*
- *Forest Biology Research Cooperative*
- *Forest Modeling Research Cooperative*
- *Forest Productivity Cooperative*
- *Plantation Management Research Cooperative*
- *Southern Forest Resource Assessment Consortium*
- *Western Gulf Forest Tree Improvement Program*

United States Department of Agriculture Forest Service
Researchers from the USDA Forest Service Southern Research Station Eastern Forest Environmental Threat Assessment Center, Southern Institute of Forest Genetics, and Southern Institute of Forest Ecosystems Biology assist with PINEMAP research efforts.

1. PINEMAP Monitoring Network

Timothy Martin

Professor, PINEMAP Project Director • School of Forest Resources and Conservation, University of Florida

The PINEMAP monitoring network generates the biological and ecological data that enables researchers to understand how pine forest productivity responds to soils, climate, and management, and to develop and test models that simulate forest dynamics under future climate conditions. By developing and using standardized measurement and data sharing protocols, forest scientists across the Southeast United States are better able to collaborate on important research questions now and in the future.

Establishment of a monitoring network to develop carbon, water, and nutrient storage and flux baselines and responses to climate and management is one of the primary requirements of the National Institute of Food and Agriculture (NIFA) grant that funds PINEMAP. The three-tiered monitoring network developed by PINEMAP leverages the enormous investments in cooperative research trials from the past several decades and creates an unprecedented resource for regional pine plantation research.

The Tier I legacy network (Figure 1.1) consists of hundreds of existing silviculture experiments and growth-and-yield plots that blanket the region and provide extensive, spatially explicit information on regional variability in productivity. The Tier II active experiments network (Figure 1.2) contains 127 existing silvicultural trials that cover the full range of climate and soils in the region on which detailed carbon (C) and nutrient balance will be measured. Finally, the Tier III throughfall reduction x fertilization network (Figure 1.3) was established on four sites situated at the edges of the loblolly pine range. In these studies, nutrients and water are manipulated through fertilization and ~30% reduction of rain falling through the forest canopy (throughfall). Table 1.1 summarizes the characteristics of the three-tiered monitoring network, including number of sites in each tier, treatments, measurements, and questions to be answered.

The PINEMAP monitoring network provides a wealth of data for model development and testing as well as improved understanding of how southern pine productivity responds to climate and soils now and in the future.

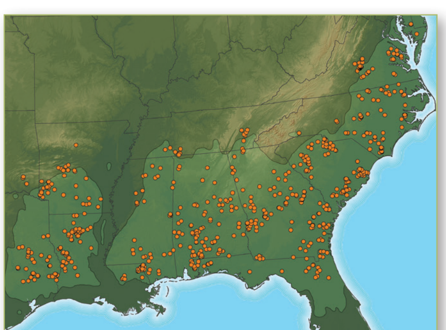

Figure 1.1. Tier I legacy network.

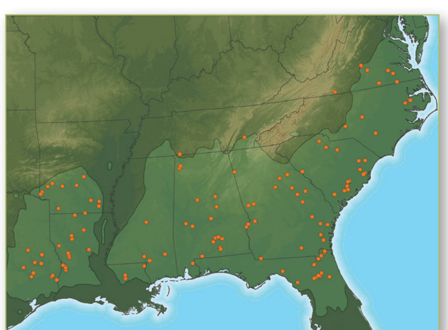

Figure 1.2. Tier II active experiments network.

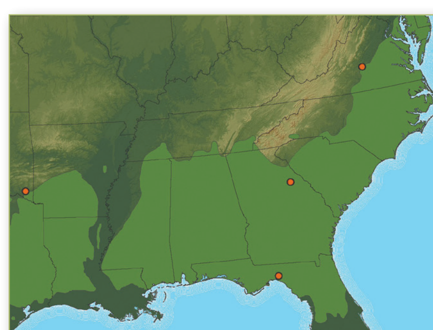

Figure 1.3. Tier III throughfall reduction x fertilization network.

Throughfall reduction structures at the PINEMAP Tier III site in Taylor County, Florida. Photo by Geoffrey Lokuta.

The PINEMAP monitoring network provides a wealth of data for model development and testing as well as improved understanding of how southern pine productivity responds to climate and soils now and in the future.

Network Level	# Sites	Treatments	Measurements	Questions to be Addressed
Tier I (legacy network)	~ 700	Combinations of fertilization, competition control, planting density, thinning, and stand age.	Existing inventory data shared among regional forestry research cooperatives.	How does tree productivity vary with climate, soils, stand development, and management factors?
Tier II (active experiments network)	~ 125	Combinations of fertilization, competition control, planting density, thinning, and stand age.	Inventory, carbon and nitrogen pools, soil greenhouse gas fluxes, and key ecophysiological model parameters on a subset.	How do aboveground and belowground carbon and nitrogen pools and fluxes, as well as key biological and ecological modeling parameters, vary with climate, soils, stand development, and management factors?
Tier III (throughfall reduction x fertilization network)	4	Factorial combination of fertilization (control and "optimum") and precipitation (rain fed and 30% reduction).	Same as Tier II, plus intensive carbon, nitrogen, and water ecophysiology.	Same as Tier II, plus exposure of loblolly pine to climatic conditions likely not experienced within the historic range.

Table 1.1. Summary of the characteristics of the PINEMAP monitoring network.

2. The Tier II Research Sites: A Regional Network for Understanding Loblolly Pine Plantation Carbon Dynamics

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This interdisciplinary, regional research is aimed at gaining a better understanding of how environmental factors and silvicultural treatments affect ecosystem carbon accumulation and storage, enabling us to develop a scientific analysis of the role of loblolly pine plantations in regional carbon dynamics. Research is being conducted on established research sites managed by the University-Corporate-Governmental Research Cooperatives partnering with PINEMAP, which enhances connections between researchers and corporate forest landowners.

How do environmental factors and silvicultural treatments affect ecosystem carbon accumulation and storage? This is the central question of PINEMAP'S effort to develop a scientific understanding of the role that loblolly pine plantations play in regional carbon dynamics. Forest scientists generally understand that the answer to this question depends on time and the rate of forest regrowth. After a forest is harvested, the decomposition of residual woody debris and soil organic matter causes the site to lose carbon; in other words, the ecosystem has a net loss of carbon to the atmosphere. However, as trees and understory plants regrow, the accumulation of a surface litter layer and soil organic matter eventually reverses this carbon loss. Thus, *time since harvest* is a critical component of ecosystem carbon dynamics. The rate at which trees grow is also critical, as this is the primary source of carbon accumulation in the ecosystem. Because tree growth is affected by *climate, nutrient, and soil water availability,* these dynamics are also critical to ecosystem carbon accumulation. Stand density, often expressed as number of trees per unit area, will also affect carbon inputs to the ecosystem, influencing the amount of time that a forest requires to offset the carbon lost after a harvest.

Silviculture in planted southern pine forests focuses on manipulating environmental resources and stand density to increase profitability. In most cases, increased profitability also corresponds to increased forest productivity. Greater forest productivity can be achieved through proper site preparation, fertilization, and herbaceous or understory competition control; these practices interact with stand density, as well as soil and climatic factors, to affect carbon accumulation and storage. Advanced loblolly pine genetics are also being incorporated into silvicultural systems in an effort to increase forest growth and disease resistance, which in most cases will also increase the rate of carbon accumulation and profitability. In some management systems, profitability increases by keeping stand density low so that individual trees achieve a desired size more quickly. This may mean that trees are planted at a low initial density and/or the stand is thinned to reduce the density. Making low stand density a silvicultural objective may slow the rate of ecosystem carbon accumulation as the stand may not fully occupy the site and stand-level productivity may be reduced.

The forestry research cooperatives partnering with PINEMAP selected 130 Tier II sites that represent a range of silvicultural and environmental conditions from a network of several hundred established experimental sites. The forests range from 6 to 25 years in age and are found throughout the natural range of loblolly pine (See Figure 1.2, page 6, for a map of the Tier II sites). Originally created to examine tree growth under specific silvicultural practices, the selected sites are now being sampled to estimate the carbon stored in the tree biomass, soil, forest floor, understory, and woody debris of the forests. These measurements will represent the full ecosystem carbon accumulation. Each research site will compare one or more silvicultural practices, but thinning and the level of fertilization will be the two most common practices studied.

An objective of PINEMAP is to compare estimates of ecosystem carbon accumulation at the Tier II sites with existing models of ecosystem carbon dynamics. One model currently being

Jill Qi and Aaron Joslin collect soil samples at a PINEMAP research site in Georgia. Photo by Madison Akers.

Originally created to examine tree growth under specific silvicultural practices, the selected sites are now being sampled to estimate the carbon stored in the tree biomass, soil, forest floor, understory, and woody debris of the forests. These measurements will represent the full ecosystem carbon accumulation.

employed is the Water Supply Stress Index (WaSSI) Ecosystem Services Model, which estimates ecosystem carbon cycling processes based on climatic factors and pine physiological processes. The model uses spatially explicit climate and soils databases as inputs to produce regional estimates of ecosystem carbon exchange. From this model's analysis of existing databases, we find that the Tier II network spans from 1077 to 1718 mm/yr in precipitation, and from 716 to 1200 mm/yr in potential evapotranspiration (a measure of annual evaporative demand) (Figure 2.1). The model also estimates a 30% range in gross ecosystem production (GEP, a measure of total plant photosynthesis) and net ecosystem exchange (NEE, a measure of net carbon accumulation) (Figure 2.2). These latter estimates are based on parameterizing the model for a 17-year old loblolly pine forest receiving very little silvicultural treatment.

A complementary objective is to compare this model parameterization to the actual field estimates of carbon pools collected under a range of silvicultural prescriptions. Using this approach, we will be able to develop a spatially explicit estimate of carbon accumulation across the range of managed loblolly pine ecosystems. Gradients in existing climate variables will provide insight into how carbon dynamics in different regions might respond to climate change and silvicultural prescriptions, providing regional modelers with validation for predictions of regional carbon balance.

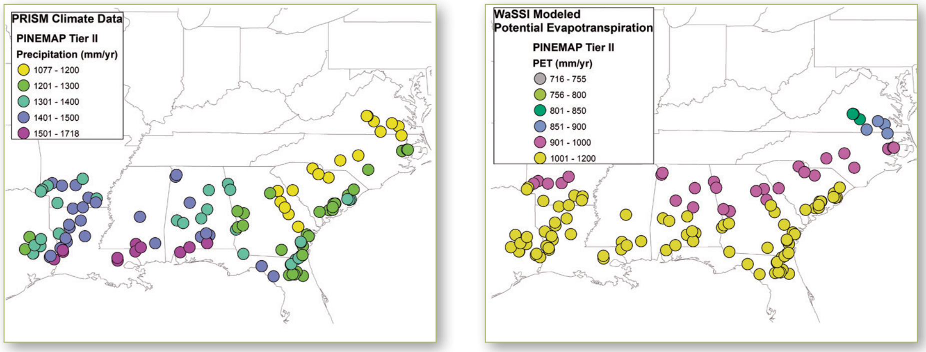

Figure 2.1. Precipitation estimated from PRISM historic climate data (left) and potential evapotranspiration estimates with the Water Supply Stress Index (WaSSI) Ecosystem Services Model (right) across the range of Tier II sites. Each dot represents a site, and the color of the dot relates to the amount of precipitation or potential evapotranspiration.

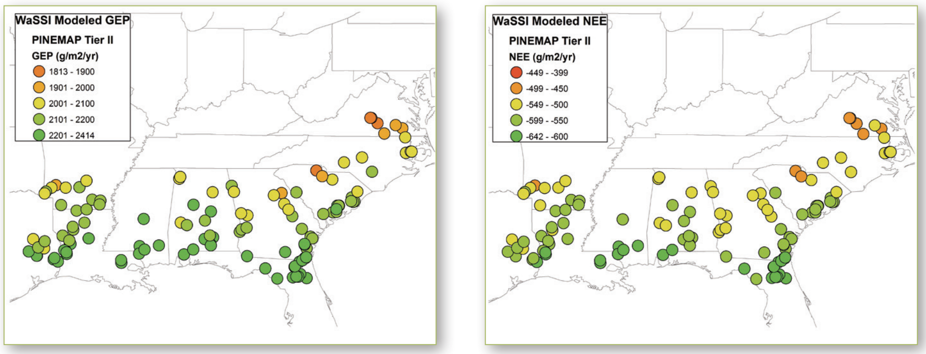

Figure 2.2. Potential gross ecosystem production (GEP) (left) and net ecosystem exchange (NEE) (right) from the Water Supply Stress Index (WaSSI) Ecosystem Services Model parameterized for a 17-year old loblolly pine forest across the range of Tier II sites. Each dot represents a site, and the color of the dot relates to the relative amount of GEP or NEE compared to the rest of the sites. For the NEE figure (right), larger negative NEE values correspond to greater rates of carbon accumulation.

3. Developing Scenarios to Use in Model Simulations

Robert Teskey

Distinguished Research Professor • Warnell School of Forestry and Natural Resources, University of Georgia

Scenarios are predictions that describe various combinations of possible events and likely outcomes. These simplified representations of the future will allow PINEMAP researchers to evaluate the best options for increasing carbon sequestration and decreasing nitrogen use in an organized and efficient manner.

PINEMAP will use region-wide models to understand how management, climate, and other factors collectively affect planted pine productivity in the future. To focus this effort, we are developing a series of scenarios of the most likely future conditions. We envision there will be four essential components to the PINEMAP scenarios: land use, productivity, environment, and disturbance. Land use describes the amount of land in loblolly pine plantations. Productivity is the amount of carbon sequestered by loblolly pine plantations. Environment describes the future climate and atmospheric carbon dioxide (CO_2) concentrations that could affect plantation productivity. Disturbance includes both biotic and abiotic disturbances that reduce plantation productivity.

Land use is affected by many economic and policy factors. The amount of land in loblolly pine plantations in the future could increase, decrease, or stay the same in response to timber and wood fiber prices, regional population growth, investments by forest industry, farm commodity prices, added economic value of sequestered carbon from new plantations (carbon markets), government economic incentives to plant loblolly pine on marginal farmland, or changes in forestry activities in other countries.

Because of improvements in silviculture and genetics over the last 50 years, productivity has increased in successive rotations of loblolly pine plantations and is likely to continue to increase in the future. In this case, an increase in productivity means an increase in the rate of biomass accumulation over time or an increase in carbon stored in wood products. There are many management options for increasing plantation productivity and carbon sequestration in forests. Wood products can also increase carbon sequestration; for example, if more wood is used in buildings, the carbon is sequestered in the structures longer, or new products can be developed that can use additional wood. An increase in the use of woody biomass for energy production, substituting wood for fossil fuels, is also a consideration.

With regard to climate, we expect temperatures to increase throughout this century. Changes in precipitation are less certain. In the near term, i.e., the 2014 to 2030 period that is the focus of the PINEMAP project, we can assume the climate will not be significantly different than the present condition. However, when we consider the remainder of the century, we can expect significant changes in temperature, precipitation, and atmospheric CO_2 concentration.

Major disturbances affecting loblolly pine plantations include hurricanes, tornadoes, insects, diseases, and fires. All of these disturbances reduce productivity and therefore have the potential to reduce carbon sequestration. Disturbance is the most uncertain scenario condition to predict. Because of this, both biotic and abiotic disturbances are being considered together as a category of change to regional plantation productivity.

Photo by Steve McKeand.

We envision there will be four essential components to the PINEMAP scenarios: land use, productivity, environment, and disturbance.

Twelve scenarios were developed for the near term time period up to 2030. These scenarios focus on changes in land use and productivity and assume that the effects of environment and disturbance will be similar to present conditions. In its simplest form (shown in Table 3.1), these scenario combinations can be visualized as combinations of a small increase (1) or decrease (-1), no change from the present (0), or a large increase (2). These factor levels represent various management options, policy decisions, and economic considerations that are feasible between now and 2030. These scenarios will allow collaborators in PINEMAP to have a standard basis through which they can evaluate the best ways to increase carbon sequestration and reduce nitrogen use. Because the number of scenarios is large and region-wide model runs consume large amounts of computer resources, large-scale simulations will probably focus on a subset of these scenarios.

What happens during the rest of the century, from 2030 to 2100, is also very important, so we are in the process of developing additional scenarios to address the likely conditions of the time period beyond the initial PINEMAP focus. This will allow us to predict productivity of loblolly pine plantations across the region and help managers and policy experts make informed decisions about growth rates, fertilizer use, and carbon sequestration.

Photo by John Seiler.

Land use	-1	-1	-1	0	0	0	1	1	1	2	2	2
Productivity	0	1	2	0	1	2	0	1	2	0	1	2

Table 3.1. Twelve scenarios, visualized as combinations of increasing (1 or 2), unchanging (0), or decreasing (-1 or -2) factor levels, represent likely combinations of changes in land use and productivity that could occur in the near term (2014 to 2030) PINEMAP focus period. Some combinations have a higher probability of happening than others. Because of the large number of scenario combinations, PINEMAP region-wide simulation assessments will likely focus on a subset of these scenarios.

4. Physiological Principles in Predicting Growth (3-PG) Regional Analysis

Randolph H. Wynne[1,7] • Evan Brooks[2,7] • Robert Teskey[3,8] • Ying Wang[4,8]
Valerie Thomas[5,7] • Quinn Thomas[5,7] • Harold E. Burkhart[6,7]

[1]Professor • [2]Postdoctoral Research Associate • [3]Distinguished Research Professor • [4]Ph.D. Student • [5]Assistant Professor • [6]University Distinguished Professor
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The regional biomass and carbon estimates resulting from the Physiological Principles in Predicting Growth (3-PG) regional analysis will inform economic models of product availability and will provide forest land managers with knowledge and tools necessary to make informed management decisions to ensure sustainable yield and increased carbon sequestration. Given that these models are being integrated into the project's decision support system, this information will also be useful to Extension specialists as they reach out to stakeholders.

Modeling is an essential component of PINEMAP activities, and there are several models being used in the project including Physiological Principles in Predicting Growth (3-PG) (Landsberg and Waring 1997). This process-based model uses mathematical representations of tree physiological processes such as carbon gain and loss, water use, and nutrient uptake, coupled with weather and soil information, to predict tree growth and stand productivity. 3-PG has been used by other research groups to predict plantation productivity of several *Eucalyptus* and conifer species with success. We have made several modifications to 3-PG to increase the model's accuracy in predicting productivity of loblolly pine plantations, including refinements in how it calculates leaf area index, basal area, and stem volume. Because we have optimized the model specifically for loblolly pine plantation growth, we call our modified version 3-PG_{lob}.

This year, using Tier I datasets (see Chapter 1, page 6), we tested the ability of 3-PG_{lob} to predict historical growth of loblolly pine plantations at sites in 10 southeastern states: Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, and Arkansas. For these simulations, we used the unique weather and soils information of each site. Figure 4.1 shows examples of the model's prediction of stem biomass growth compared to actual measured growth at three sites. We found that a single set of physiological model settings specific to loblolly pine was sufficient to estimate stand biomass and stem volume across the region. There are likely two main reasons for the robustness of these physiological settings. The first is that, due to many years of research by university, government, and corporate scientists, there is a wealth of information about the physiology of loblolly pine with which to determine the settings or parameter values needed in the model. The second is that maximum rates of physiological processes that are critical to growth, such as photosynthesis and respiration, change little across a wide range of soil fertility and climatic conditions. Our results give us confidence that the model can be used for more extensive regional assessments of plantation growth and productivity.

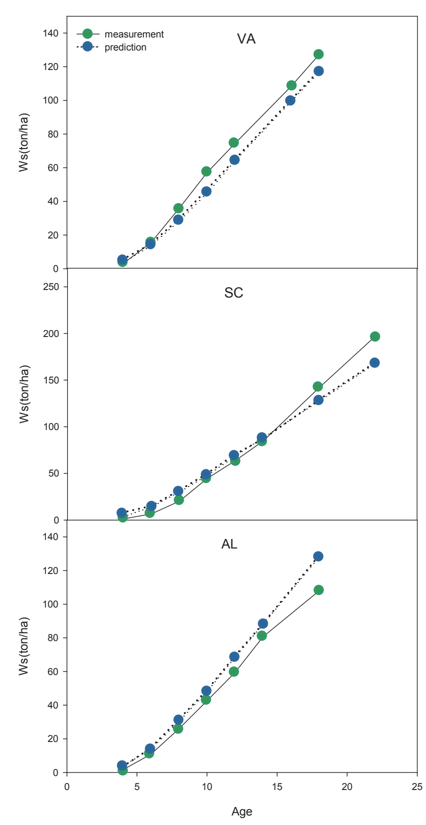

Figure 4.1. Physiological Principles in Predicting Growth (3-PG) simulations of stem biomass growth (blue circles) in loblolly pine plantations in Virginia (VA), South Carolina (SC), and Alabama (AL) compared to biomass estimated from measurements made at each site. Each green circle represents a year in which biomass was estimated from volume and wood density measurements.

Photo by Steve McKeand.

We have made several modifications to 3-PG to increase the model's accuracy in predicting productivity of loblolly pine plantations, including refinements in how it calculates leaf area index, basal area, and stem volume.

Ultimately, the 3-PG_{lob} model will be scaled up, or applied across the region, to thousands of individual grid cells so that we can predict variation in response specific to particular areas in the range. The regional scaling up of 3-PG_{lob} will mirror as closely as possible the scaling up of other models being used in PINEMAP to facilitate comparisons among the models' outputs. While the same set of physiological parameters will be used across the PINEMAP study area, the climate and soils data will vary by location. Accordingly, we will use the USDA Natural Resource Conservation Service Soil Survey Geographic (SSURGO) database and Multivariate Adaptive Constructed Analogs (MACA) climate model data as location-specific inputs into 3-PG_{lob}. We will also input the same site index (a measure of site quality) estimates derived from the process described in the growth and yield model report (see Chapter 5, page 14). By keeping the input variables as congruent as possible, we expect to be better able to compare the resulting model outputs.

In order to simplify data processing, the SSURGO soil inputs will be aggregated to a coarser scale associated with 12-digit hydrological unit code (HUC-12) features, a standardized unit often used in large-scale analysis. These HUC-level soil aggregates will be intersected with the 1/16 degree climate data grid to produce uniquely indexed features (in soil and climate values) with areas of no more than 16 square miles, sufficiently fine for subcounty analysis. This approach allows for more efficient construction of the climate-based input files used to drive the 3-PG_{lob} model. Within this framework, we will generate monthly outputs from 3-PG_{lob} for each feature, each available year, and each emissions scenario in the projected climate dataset (1950 to 2100). The results can then be displayed as a map of each 3-PG_{lob} model output, either at the finer level or re-aggregated to the HUC-12 level. A visual representation of this approach is shown in Figure 4.2.

The regional 3-PG_{lob} model represents an important synthesis of many aspects of PINEMAP. The revised model and parameter estimates use field data from PINEMAP. The model and parameter changes reflect our current understanding of the ecophysiological processes important to pine productivity in the Southeast. These processes are affected by changing carbon dioxide concentrations, climate, silvicultural practices, and growing stock improvements. The resulting regional biomass and carbon estimates will inform economic models of product availability and will be very helpful to Extension specialists as they reach out to stakeholders. Given that these models are being integrated into the project's decision support system, forest land managers will have the latest research results available as they make management decisions to ensure sustainable yield in a changing world.

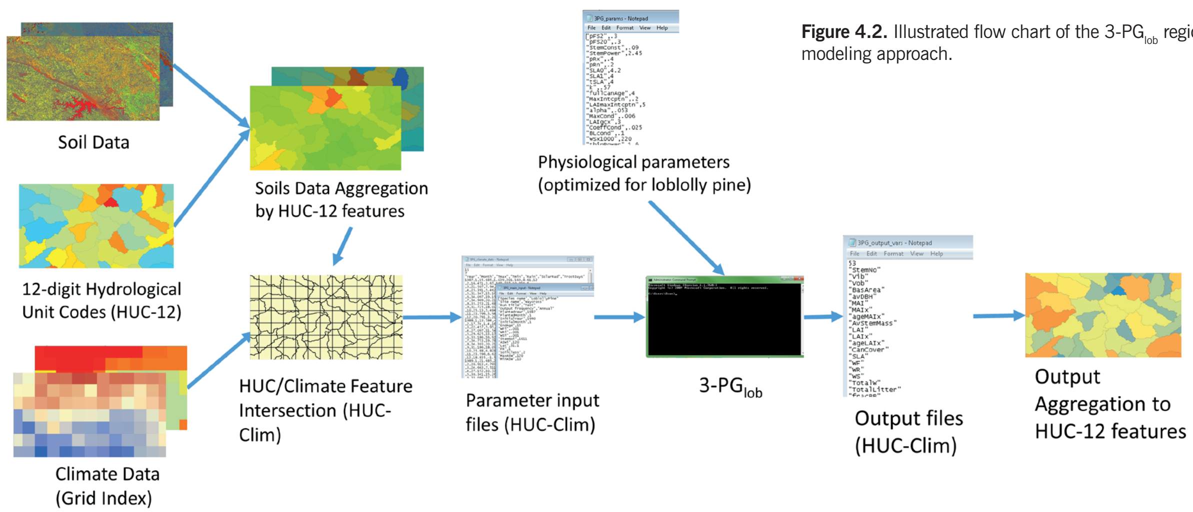

Figure 4.2. Illustrated flow chart of the 3-PG_{lob} regional modeling approach.

5. Regionalization of Growth and Yield Models

Harold E. Burkhart[1,5] • Randolph H. Wynne[2,5] • Nabin Gyawali[3,5] • Ram Thapa[3,5] • Charles O. Sabatia[4,5] • Evan Brooks[4,5]

[1]University Distinguished Professor • [2]Professor • [3]Research Assistant • [4]Postdoctoral Research Associate • [5]Department of Forest Resources and Environmental Conservation, Virginia Tech

Predicting future tree growth with growth and yield modeling systems is central to forest management planning and to PINEMAP's research goal of understanding how forest carbon sequestration responds to forest management and climate. We are using PINEMAP datasets to develop a new, region-wide growth and yield modeling system that incorporates the effects of advanced genetics, more intensive silviculture, and changing climate. From a research perspective, this system will enable us to test a range of modern management scenarios under predicted future climate conditions. In addition, this system will be a useful tool for corporate and noncorporate forest landowners.

Accurately predicting productivity of southern pines is essential for determining sustainability of the resource under various management options and future climate conditions. Management practices—such as developing genetically improved planting stock, controlling competing vegetation, thinning, and applying fertilizers—are commonly employed when growing southern pines. While a number of growth and yield models have been developed for specific physiographic areas and management practices, a region-wide modeling system is needed when projecting future productivity that will involve advanced genotypes, more intensive silvicultural inputs, and changing climate.

Stand-level Modeling

Our approach for developing a modeling system for long-term predictions of productivity for future southern pine stands has three components. These are (1) developing baseline, stand-level growth models; (2) formulating general response functions for silvicultural practices, including thinning, vegetation management, and fertilizer applications; and (3) relating exhibited site index (a standardized measure of growth potential of a particular site and management combination) to biophysical factors (soils and climate variables) so that, in concert with information on performance of present and anticipated genotypes, pine productivity can be estimated for various management inputs and climate scenarios.

Baseline models of stand dominant height growth, basal area, and tree survival of loblolly pine plantations were fitted using the Tier I network, region-wide data from permanent sample plots that were installed across the region and measured on multiple occasions (see Chapter 1, page 6). Response functions were then fitted to data from broad-scale studies of thinning treatments, competing vegetation control, and fertilizer applications. Stand productivity for various levels of silvicultural options is estimated by multiplying the baseline growth models with the modifier response functions. Effects of multiple silvicultural inputs are assumed to be additive.

We fitted and evaluated different types of statistical models for predicting loblolly pine plantation site index from biophysical variables. Tree and stand location data came from region-wide plot installations of the Virginia Tech Forest Modeling Research Cooperative (Figure 5.1). Climate data for each stand location were computed using the Oakridge National Laboratories' daily surface weather prediction models, while soils data were extracted from the USDA Natural Resource Conservation Service Soil Survey Geographic (SSURGO) database. Separate models were fitted for non-intensively managed and intensively managed loblolly pine plantations. Variable selection methods in both modeling approaches showed that the number of biophysical variables that were important in predicting site index of intensively managed loblolly pine was smaller than the number for non-intensively managed stands. Appropriate statistical models were selected based on both their fit to the input data, as well as their ability to produce consistent and reasonable predictions when used for extrapolation.

Photo by Larry Korhnak.

Baseline stand-level growth models, coupled with general response functions for thinning, competing vegetation control, and fertilizer applications, provided accurate estimates of pine plantation productivity for varying levels of management intensity.

Scaling Up

In order to extrapolate the stand-level parametric models to the regional level along historical and future timelines, we used regional-based climate and soil data. In particular, the Multivariate Adaptive Constructed Analogs (MACA) downscaled climate model outputs yielded temperature and precipitation data at 1/16 degree grid cells (areas of no more than 16 square miles for each cell), and the SSURGO database yielded water holding capacity and soil physical properties along polygons of varying size. In order to match these data efficiently, we intersected the soil polygons with the grids for the climate variables as polygons to produce "wall to wall" polygons containing both climate and soils data across the 15 states that encompass the PINEMAP study region. These polygons were then used as input to the stand-level models to produce site quality estimates for the different management conditions. An example of baseline site quality classes for a portion of Virginia is shown in Figure 5.2. We are in the process of producing region-wide site index maps, specific to each management scenario, for each year of available climate data.

We will use these site index maps in conjunction with stand age information from sources such as the Vegetation Change Tracker and reasonable assumptions about the level of management intensity to arrive at growth and yield estimates for each cell in the region. Results can be re-averaged, if necessary, to produce outputs at larger levels of aggregation for comparison to output from other PINEMAP modeling efforts.

Conclusion

Baseline stand-level growth models, coupled with general response functions for thinning, competing vegetation control, and fertilizer applications, provided accurate estimates of pine plantation productivity for varying levels of management intensity. A function that relates pine site index to biophysical variables (soils and climate) allows the model to incorporate the effects of climate on tree growth. These growth and site quality relationships provide a basis for scaling up from stand- to regional-level productivity under varying assumptions of silvicultural inputs and climatic influences.

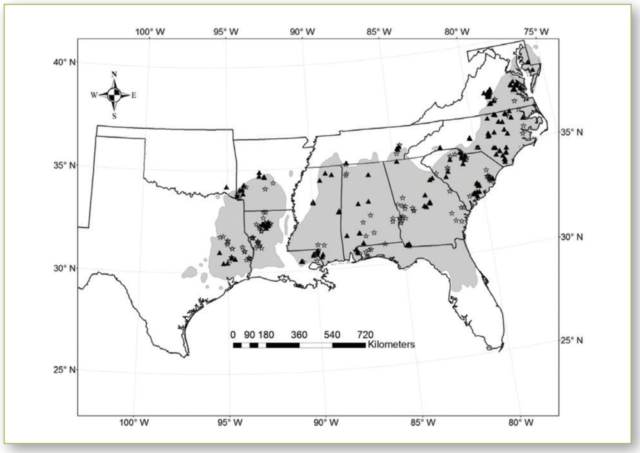

Figure 5.1. Location of Virginia Tech Forest Modeling Research Cooperative loblolly pine permanent research plots (186 non-intensively managed locations are represented by triangles and 170 intensively managed locations are represented by stars). The portion of the map shaded in gray is the natural range of loblolly pine.

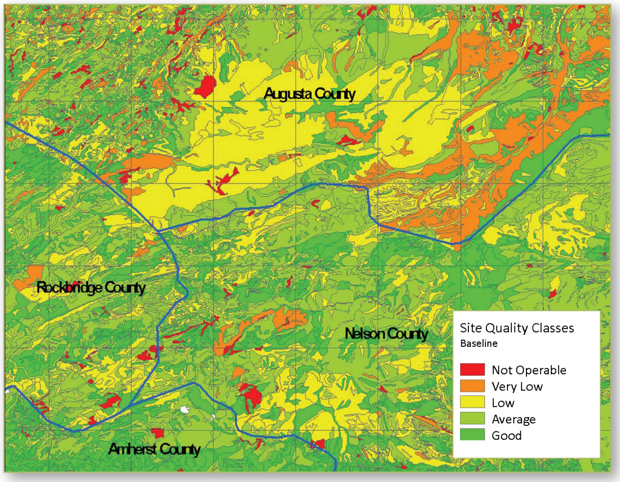

Figure 5.2. Baseline site quality classes for loblolly pine in a portion of four counties in Virginia.

6. Biology in Context: Linking Ecological and Economic Assessments

Robert Abt[1,4] • Steve McNulty[2,5] • Ge Sun[3,5]

[1]Professor • [2]Ecologist; Team Leader • [3]Research Hydrologist • [4]Department of Forestry and Environmental Resources, North Carolina State University
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This work directly contributes to a more robust and resilient forest-based economy in the Southeast United States by providing landowners and managers with the knowledge they need to better assess how climate change and economic drivers will impact the value of short- and long-term timber markets. The demand for forest products is as important for optimizing forest profitability as tree growth rates, and this combined modeling project provides much needed information for understanding how these factors may interact in the future.

PINEMAP's core focus is to produce, synthesize, and disseminate the knowledge necessary to better manage planted southern pine for mitigation and resilience to changing climate. Accordingly, most of PINEMAP's research focuses on loblolly pine plantations. However, pine plantations are only a small part of the southern forest landscape: urbanization and other forest and agricultural markets shape land use as well. It is important to remember that the impact of improved management information produced by PINEMAP will be tempered by planting decisions and policies driven by agriculture and other forest markets.

This article describes initial efforts to link loblolly pine plantations to this broader ecological and economic context. We are constructing preliminary links between biophysical models, which simulate how forest function (such as growth and water use) will respond to climate, and management and economic models, which simulate how land use and timber markets will respond to supply and demand.

PINEMAP is using two biophysical models: Physiological Principles in Predicting Growth (3-PG) (Landsberg and Waring 1997) and the Water Supply Stress Index (WaSSI) Ecosystem Services Model (Sun et al. 2011). 3-PG is a generalized process-based carbon allocation model that combines forest stand-level information with climate data to estimate the gross amount of carbon captured by forest stands, and then allocates that carbon to forest biomass components. PINEMAP researchers have calibrated 3-PG for loblolly pine and have implemented new routines to produce outputs in units useful for economic analysis, such as stem volume by product class (see Chapter 4, page 12). WaSSI is a water-centric model used to estimate climate change impacts on forest growth across the southeastern United States. WaSSI predicts forest growth response (measured as gross ecosystem production [GEP], or the total carbon gained by an ecosystem) to future changes in environmental conditions given established relationships between environmental conditions (e.g., soil type, water availability, solar radiation, air temperature, and leaf area) and tree water use. WaSSI exploits relationships found from eddy covariance measurements of forest carbon gain and water use that link tree water use and growth (Sun et al. 2011).

The Sub-Regional Timber Supply (SRTS) Model (Abt et al. 2012) is the regional economic model being used in PINEMAP. The SRTS Model uses empirical estimates of timber harvest response to changes in price to allocate harvest among ownerships, forest types, and age classes at substate levels. It provides a platform for examining the influence of product demand at the forest landscape scale. These changes include harvest patterns, plantation management intensity, and change in land use allocation between natural forests and agriculture. For PINEMAP, SRTS is being used to explore the forest market and land use change impacts on pine plantation productivity and resilience.

Changes in land use are a critical component of regional estimates of future climate related changes in southern pine carbon sequestration. For example, earlier analyses using SRTS showed that climate change could cause an increase in volume accumulation across the mid-Atlantic region of the South, but increased volume accumulation would be partially offset by the loss of timberland to urbanization (McNulty et al. 2000). The impact of land use change on timber resources also has been

We are constructing preliminary links between biophysical models, which simulate how forest function (such as growth and water use) will respond to climate, and management and economic models, which simulate how land use and timber markets will respond to supply and demand.

recently documented by Wear et al. (2013). PINEMAP will use updated economic, ecological, and climate models to explore the implications of changes in tree growth response on timber supply and associated changes in the amount of forest land (including plantation and non-plantation) in the region.

An integrated framework combining SRTS and WaSSI was developed where WaSSI estimates of county level GEP were aggregated to the USDA Forest Service Forest Inventory and Analysis (FIA) unit level. Survey units are large enough to contain sufficient plot samples to describe landscape growth, removals, area, and inventory. Figure 6.1 shows predicted future forest productivity estimates from the WaSSI model, expressed as GEP, for four regions across the Southeast U.S. The hotter and wetter predicted climates in the southeastern part of the range will likely create more favorable growing conditions with a tendency toward increasing GEP in Atlantic coastal Florida, Georgia, and South Carolina. However, the climate is predicted to become more variable in the south central region, with smaller positive responses or even negative productivity impacts projected in Oklahoma and Texas as growing conditions become less optimal.

The GEP estimates in each of the survey units in the Southeast were used to modify the growth rates for all forest types through time. While the annual GEP variation is large, inventory is the cumulative sum of growth over many years and the annual inventory impacts are small. Figure 6.2 shows the projected change in pine growing stock when static 2009 USDA Forest Service FIA growth rates are compared to climate adjusted growth from WaSSI GEP. For these projections, timberland area and demand were held constant. Note that constant demand means that if prices stay constant, harvest does not change, but changes in price will lead to harvest adjustments. Across the Southeast, harvest removals increased in areas where inventory was rising due to lower prices and vice versa. In this way, markets tend to dampen regional variation over the long run. For the Southeast as a whole, climate-conditioned growth increases pine growing stock by about 15% relative to the constant growth rate projection. Regional growth trends do affect inventories as expected, but over time, inventories tend to show more convergence toward a regional average as removals adjust to compensate for increases or decreases in forest growth.

These results demonstrate our ability to assess ecological and market impacts at the regional level. Our next step is to incorporate PINEMAP climate projections and 3-PG growth simulations. The modeling analysis approach described here will enable the PINEMAP pine plantation field studies to be placed into the larger regional land use and market environment in which plantation forestry operates.

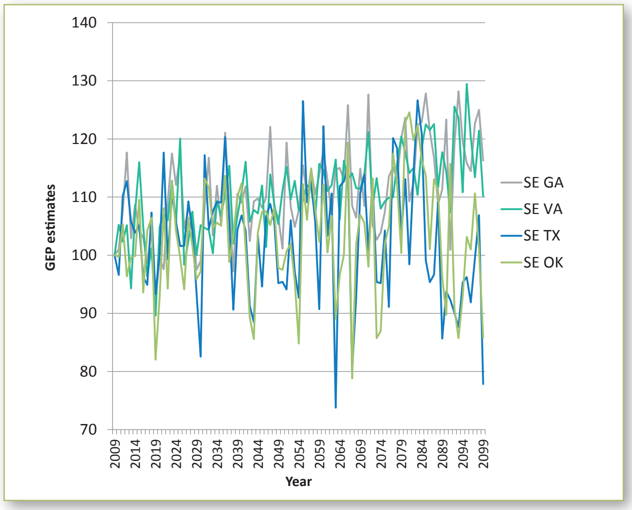

Figure 6.1. Predicted future forest productivity estimates from the Water Supply Stress Index (WaSSI) Model, expressed as gross ecosystem production (GEP) (relative to 2009 levels, which are set at 100%) for four substate regions: Southeast Georgia (SE GA), Southeast Virginia (SE VA), Southeast Texas (SE TX), and Southeast Oklahoma (SE OK). Over the 100-year simulation period, predicted productivity increased by 16% for Southeast Georgia, 17% for Southeast Virginia, and 4% for Southeast Oklahoma and declined by 5% for Southeast Texas.

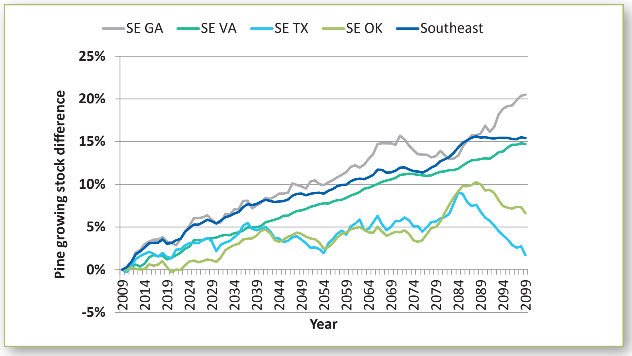

Figure 6.2. Projected change in pine growing stock when static 2009 USDA Forest Service Forest Inventory and Analysis (FIA) growth rates are compared to climate adjusted growth from Water Supply Stress Index (WaSSI) Model gross ecosystem production (GEP) projections for four substate regions: Southeast Georgia (SE GA), Southeast Oklahoma (SE OK), Southeast Texas (SE TX), and Southeast Virginia (SE VA) and the Southeast as a whole.

7. Using the Tier III Experiments to Investigate the Effects of Drought and Fertilization on Forest Water Use and Stomatal Conductance

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The effects of fertilization and drought on the leaf area of forest canopies and the amount of water used by those canopies are important factors in determining the productivity of forests. Such information is critical in forming management recommendations that increase forest resilience to climate variability and disturbance.

The leaf area and transpiration of forest canopies are primary factors determining stand growth in PINEMAP modeling efforts. Thus, this research forms an important interdisciplinary link between data collected in the field and computer models used to forecast future scenarios.

When trees open their stomata (microscopic leaf pores) to allow carbon dioxide (CO_2) into the leaf for photosynthesis, water is lost through the stomata (transpiration, E_C) as a consequence. The degree of stomatal opening, also called stomatal conductance (G_S), is actively regulated by the tree throughout the day in response to both photosynthetic demand for CO_2 and the stress induced by water loss. At the stand level, the total amount of photosynthesis and transpiration is heavily influenced by the amount of leaves in the tree canopy, quantified as Leaf Area Index (LAI), the area of leaves per unit ground area. Because the stomata regulate both water loss and carbon gain, our understanding of forest transpiration, leaf area index, and stomatal conductance under different scenarios is linked to our understanding of forest growth, productivity, and carbon uptake potential. In the previous annual report, we outlined how researchers are using a network of hundreds of sensors that measure water movement in the trunks of trees, or *sap flux density,* to quantify stand transpiration at the Tier III throughfall reduction x fertilization experiments (see Chapter 1, page 6) where we are investigating the effects of drought and fertilization on loblolly pine stands. In that report, we described the sampling of sap flux density and important environmental variables, including centralized data collection and automated programs for quality control and data processing, and we presented early results from the Tier III experiment in Buckingham County, Virginia. For the 2013 growing season (the first full year after the imposition of treatments in the first half of 2012), we present results from this site; a site in Taliaferro County, Georgia; and a site in Taylor County, Florida.

Methods

At each site, we measured sap flux density in trees in four different treatments: control (C), ~30% throughfall reduction (R), fertilization (F), and the combination of throughfall reduction and fertilization (FR). We use a hierarchical Bayesian state-space approach (Ward et al. 2013) to infer mean stomatal conductance from sap flux data at half-hour increments for each treatment at each site. Use of a common analytical platform facilitates integration of analyses across sites and ensures the comparability of results.

Tier III Treatment	Measurements
C: Control **R:** ~30% throughfall (rainfall) reduction **F:** Fertilization **FR:** ~30% throughfall (rainfall) reduction plus fertilization	**LAI:** Leaf area index, area of leaves per unit ground area **G_S:** Stomatal conductance or degree of stomatal opening per unit leaf area **E_C:** Transpiration or amount of water loss per unit ground area

Results and Discussion

Treatment effects on stand leaf area index would be expected to translate to proportional changes in transpiration per unit ground area (E_C) unless changes in the regulation of stomatal conductance per unit leaf area (G_S) are observed. In general, we may expect the throughfall reduction treatment to have low LAI, due to decreased water availability, and the fertilization treatment to have high LAI, due to increased nutrient availability. We did not see a consistent pattern of LAI across sites during the spring of 2013, when LAI is at its annual minimum (Figure 7.1). By the beginning of autumn 2013,

PINEMAP field researcher Joshua Cucinella measures leaf area index (LAI) at the PINEMAP Tier III throughfall reduction x fertilization site in Taylor County, Florida. Photo by Jessica Ireland.

Increases in transpiration may be less than proportional to increases in LAI due to fertilization in a future climate with reduced rainfall because stomata will close in response to increased water stress.

when LAI is at its annual maximum, we began to see the expected pattern of LAI between treatments at the Georgia and Florida sites but not at the Virginia site. Loblolly pine needles have an average longevity of 18 to 24 months, so stand LAI may take multiple years to respond to treatments (McCarthy et al. 2007) and overcome any initial differences between plots. Results will be of particular interest if expected patterns in LAI strengthen as growth responds to treatments at each site.

Following the pattern of LAI, we saw that E_C is higher in the fertilization treatment relative to the control for most of the growing season at the Georgia and Florida sites (Figure 7.2, left panels), where LAI exhibited an increase due to this treatment. At the Georgia site, we saw a reduction in E_C in the throughfall reduction treatment, where both minimum and maximum LAI were lower; at the Florida site, the throughfall reduction treatment had higher E_C and LAI in the early growing season but not the later growing season. However, when we examined G_S, we saw that not all differences in water use were explained by LAI alone. Of particular note was that the combined throughfall reduction and fertilization treatment had lower G_S than the control in most of the growing season at all three sites (Figure 7.2, right panels). This suggests that the combined effects of throughfall reduction, which reduces soil water availability, and fertilization, which tends to shift carbon allocation away from roots to aboveground components such as leaves, may produce more water stress and decreased G_S in trees than either treatment in isolation.

This suggests that increases in transpiration may be less than proportional to increases in LAI due to fertilization in a future climate with reduced rainfall because stomata will close in response to increased water stress. However, increased atmospheric demand for water vapor is likely to accompany reduced rainfall and could increase transpiration despite decreases in G_S. Such results highlight the importance of integrating field research with process-based models, allowing for better interpretation of empirical observations in the context of future climate and management scenarios.

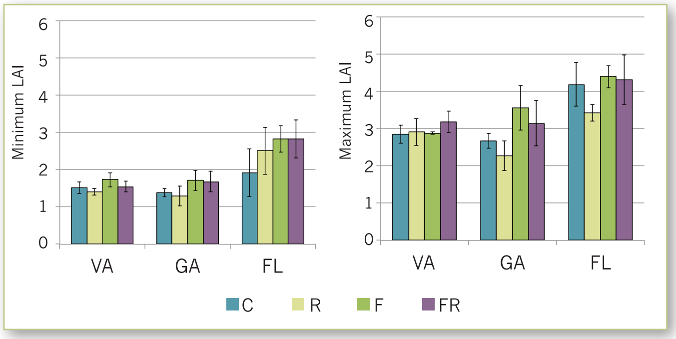

Figure 7.1. Mean leaf area index (LAI, m^2 leaf m^{-2} ground) for control (C), throughfall reduction (R), fertilization (F), and combined (FR) treatments for the Tier III sites in Virginia, Georgia, and Florida. Minimum LAI (left) represents measurements taken March through May 2013 and maximum LAI (right) represents measurements taken August through October 2013. Bars represent standard deviation (n = 4 per site).

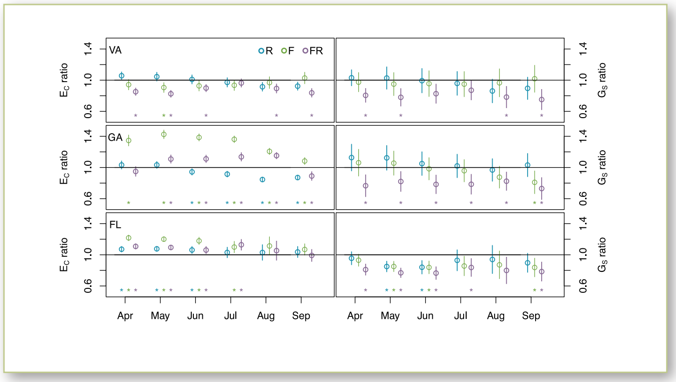

Figure 7.2. Monthly mean estimates of canopy transpiration (E_C) and daytime stomatal conductance (G_S) for throughfall reduction (R), fertilization (F), and combined (FR) treatments expressed as a ratio of the control treatment at Tier III sites in Virginia, Georgia, and Florida. Ratios falling on the 1.0 line would have the same value as the control treatment. Error bars represent 95% confidence using a normal parametric bootstrap of monthly mean values.

8. Partitioning Soil Respiration to Quantify Carbon Sequestration: A Regional Synthesis of Fertilization and Throughfall Reduction

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Jason Vogel[1,8] • Geoffrey Lokuta[5,9] • Eric Jokela[4,9]

[1]Assistant Professor • [2]Alumni Distinguished Professor • [3]M.S. Student • [4]Professor • [5]Research Associate
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[8]Department of Ecosystem Science and Management, Texas A&M University • [9]School of Forest Resources and Conservation, University of Florida

The amount of carbon metabolized by soil organisms (heterotrophic respiration) is a key component of the forest carbon cycle and links total ecosystem productivity to net carbon sequestration. By quantifying how heterotrophic respiration responds to silviculture and environmental factors, this research will improve our understanding of carbon sequestration impacts from silvicultural and genetic enhancement of productivity, efficiency of fertilizer use, and resilience to climate variability and disturbance.

Forests are strong terrestrial carbon sinks, but our knowledge of the impact of management activities on carbon (C) sequestered by planted pine systems is limited by our lack of information on below ground carbon dynamics. Forest trees allocate photosynthetically fixed atmospheric carbon dioxide (CO_2) both aboveground (e.g., stems and leaves) and belowground (e.g., roots and soil), where at least some portion of that C is respired (metabolized by plant cells and soil organisms) and passed back into the atmosphere as CO_2. The challenge is to quantify the balance between C fixation and respiration at stand and ecosystem scales. Models (e.g., Physiological Principles in Predicting Growth [3-PG], Landsberg and Waring 1997) are commonly used to estimate C fixation and respiration for the trees themselves, but require further refinement in order to account for C that passes through or resides in the soil.

This refinement requires the separation of total soil respiration (R_S) into components of heterotrophic, microbial respiration (R_H) and autotrophic, root respiration (R_A). With these numbers in hand, net ecosystem production (NEP), or the measure of C accumulated by the ecosystem, can be derived by subtracting R_H from model estimates of net primary production (NPP), a measure of ecosystem biomass production. Based on current PINEMAP efforts to model regional NPP across the range of loblolly pine and previous work partitioning soil respiration at a single site (see PINEMAP Year 2 Report), we present a synthesis of efforts to quantify the R_H proportion of soil respiration in response to fertilization and throughfall reduction at three contrasting sites at the edges of the loblolly pine range.

Over the past two years, researchers at the Tier III throughfall reduction x fertilization sites in Oklahoma, Florida, and Virginia have installed a series of root-

NPP: Net primary production, ecosystem biomass production
NEP: Net ecosystem production, net increment of carbon; carbon accumulated by the ecosystem
R_H: Heterotrophic, microbial respiration
R_A: Autotrophic, root respiration
R_S: Total soil respiration (R_H + R_A)

Figure 8.1. Right: Root-severing core installed at the Virginia Tier III site. Left: Root-severing core being excavated. Photos by Brett Heim.

PINEMAP field researcher Geoffrey Lokuta uses a LI-COR LI-8100A instrument to measure soil respiration at the PINEMAP Tier III throughfall reduction x fertilization site in Taylor County, Florida. Photo by Jessica Ireland.

Our field measurements suggest that the R_H fraction of respiration is much higher than originally thought, and that more of the photosynthetically fixed C that is allocated belowground passes through the soil and back to the atmosphere rather than being sequestered in the system.

severing cores intended to eliminate root respiration (i.e., R_A) and allow direct estimation of the microbial (i.e., R_H) contribution to soil respiration (Figure 8.1). Despite the diversity of soil types, stand ages, seasons, and treatments (fertilization and throughfall reduction), the proportion of soil respiration from R_H was remarkably consistent (Figure 8.2). Statistical analysis of the possible treatment combinations confirmed this consistency. We evaluated soil respiration from R_H for all season-by-site combinations and across seasons and sites. When evaluating each season-by-site combination independently, there were very few significant ($p < 0.05$) interactions (July 2013, Oklahoma) or main effects of fertilization or throughfall reduction. Further, when analyzed collectively, there were no significant differences in R_H contributions to soil respiration across sites or seasons.

Perhaps the most surprising result was the estimated R_H proportion itself. Given the general lack of observed differences across sites, seasons, and treatments, a single regional estimate of 0.840 ± 0.026 emerges as the R_H proportion of soil respiration. The robustness of this estimate will greatly aid the modeling of NEP across the range of managed loblolly pine, because the models will not need to account for site, season, or treatment effects. Without the need to account for site- or stand-specific characteristics to estimate R_H, modeling efforts can focus on improving NPP estimates alone.

An implication of these field results is that soil C sequestration in managed southern pine forests may be smaller than some previous estimates. Most efforts to use NPP to model NEP assume that soil respiration is evenly partitioned between R_H and R_A. Our field measurements suggest that the R_H fraction of respiration is much higher than originally thought, and that more of the photosynthetically fixed C that is allocated belowground passes through the soil and back to the atmosphere rather than being sequestered in the system. Incorporation of these results into models like 3-PG will allow PINEMAP to more accurately quantify the C sequestration potential of planted pine in the region.

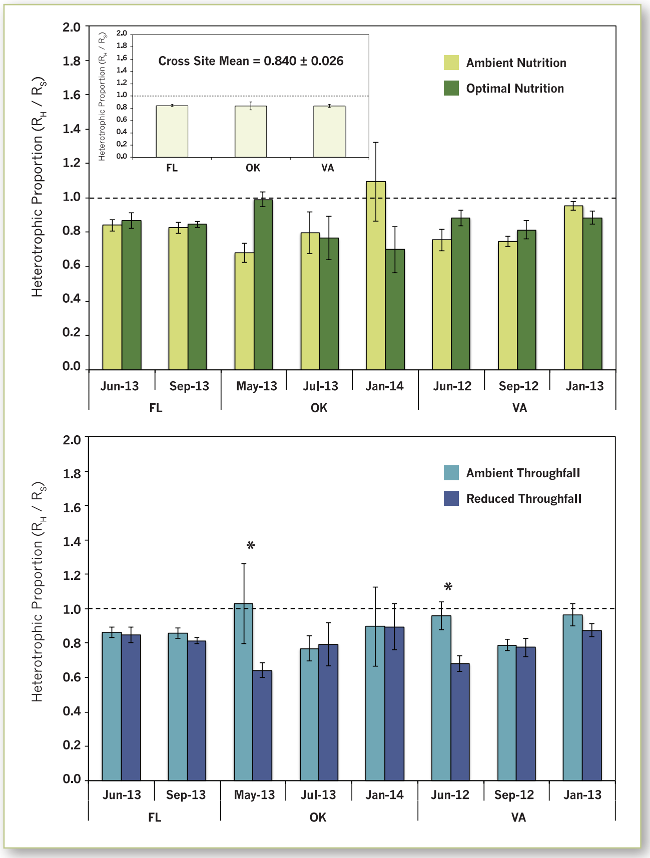

Figure 8.2. Proportion of total soil respiration (R_S) from heterotrophic, microbial respiration (R_H) at the PINEMAP Tier III sites in Florida (FL), Oklahoma (OK), and Virginia (VA) at multiple points in time. Upper panel shows main effect of fertilization; lower panel shows main effect of throughfall reduction. Inset provides site and regional means. Asterisks represent significant main effect differences ($p < 0.05$).

9. Which Trees Should I Plant?

Tom Byram[1,4] • Steve McKeand[2,5] • Ross Whetten[3,5] • Gary Peter[2,6]

[1]Assistant Professor • [2]Professor • [3]Associate Professor • [4]Department of Ecosystem Science and Management, Texas A&M University, Texas A&M Forest Service
[5]Department of Forestry and Environmental Resources, North Carolina State University • [6]School of Forest Resources and Conservation, University of Florida

Planting seedlings with proven potential for fast growth and disease resistance increases productivity and carbon sequestration; however, balancing growth potential with adaptability to future climate is not as well understood. Here, forest geneticists are collaborating with climate scientists to identify key climate variables most important for deployment of pine germplasm. Together they are creating a tool to guide planting decisions and to provide resources for an engaged and literate public.

One of the most important management decisions a landowner makes over the lifespan of a pine plantation is the choice of seedlings to plant, including species, seed source, and level of genetic improvement. This decision is made once, at the beginning of a rotation, and very little can be done to mitigate a poor selection. Most landowners understand that the decision is a tradeoff between seedling costs and financial returns. Generally less well understood is that seedling choices balance factors that favor productive potential with those that favor adaptability and survival. One of the aims of PINEMAP is to provide landowners with new tools to more explicitly explore this second set of tradeoffs.

To this end, the three southern tree improvement cooperatives have evaluated common garden experiments with families (trees sharing one or both parents in common) from multiple seed sources established in plantings spanning a range of environmental conditions (Figures 9.1 and 9.2). Researchers are using relative performance as an indicator of local adaptation, and from this information, they are predicting the optimal distance a loblolly pine seed source can be planted away from the location from which it was derived (transfer distance). Historical weather patterns at the test sites can also be used as a basis to extrapolate performance predictions to future climates. Using a similar approach, Schmidtling (2001) recommended that the optimal transfer from warmer to colder climates was a distance of 150 to 200 miles, a distance equivalent to a 5° F reduction in average minimum winter temperature. Trees have also been moved long distances east to west, but with caution required where trees are moved to areas with limited average summer rainfall. Researchers from the three southern tree improvement cooperatives have confirmed Schmidtling's recommendations for seed sources with two caveats and one important caution.

The first caveat is that as average minimum winter temperature increases, the transfer distance of 150 to 200 miles recommended by Schmidtling may also increase. The proposed PINEMAP Decision Support System seed deployment tool will enable landowners to view historical weather conditions and seed source zones for planting sites as well as predicted weather conditions and shifts in suitable seed source zones under different future climate scenarios. The second caveat is that transfer distances for loblolly pine derived from common garden experiments apply broadly to seed sources but are much more difficult to generalize to specific families (trees that share one or both parents in common) because of the species' tremendous tree-to-tree genetic variation. Growing season rainfall or aridity is an important factor in all of the recently developed models. Historically, water availability has limited the distribution and productivity of loblolly pine at the westernmost edge of its range. Water availability may become more important across a broader area of the loblolly pine range if rainfall decreases due to climate change, or if water demand increases because of longer growing seasons. Fortunately, other studies in the PINEMAP project are showing that trees

Table 9.1. Average number of loblolly pine seedlings grown across the South over the last three years and average number of families available to the public by vendor and region.

	Bulked seedlots	Open pollinated	Full-sibs	Clones	Total
Seedlings (millions)	39.4	619.4	58.8	16.9	734.5
Families by vendor per deployment zone		15	7	not reported	

Photo by Steve McKeand.

The promise of PINEMAP is that a better understanding of tree growth and its impact on stand dynamics will identify specific physiological traits essential for adaptability and growth, and specific genetic characteristics associated with those traits.

are flexible in response to water availability and are well placed to have "first dibs" on available water. In addition, studies are showing that silviculture can play an important role in impacting site quality.

So, what seed source choices are currently available to the landowner? A survey reported by McKeand et al. (2003) examining southern pine deployment strategies was repeated as part of PINEMAP's benchmarking effort. Two trends are evident (Table 9.1). First, planting is overwhelmingly done in family blocks today, either open-pollinated families (where all trees in a block share one parent in common) or full-sib families produced through controlled pollination (where all trees in a block share both parents in common). Second, the number of loblolly families available in any given region is limited and highly selected based on predicted performance estimated from local field trials regardless of the original seed source. Given the current state of our knowledge about the genetic basis for adaptability, this deployment strategy is not surprising—field testing is the gold standard.

The common garden analysis described previously complements the PINEMAP genotyping project, which quantifies how gene markers change across the region as an alternative method to find signs of selection for local adaptation. The promise of PINEMAP is that a better understanding of tree growth and its impact on stand dynamics will identify specific physiological traits essential for adaptability and growth, and specific genetic characteristics associated with those traits. This information, when combined with the gene markers from the genotyping effort and knowledge of the underlying genes from the companion USDA National Institute of Food and Agriculture funded pine genome project, PineRefSeq, will enable more precise and efficient selection, breeding, and deployment in the future. With this knowledge, our response to changing climates can be both more rapid and more effective.

Figure 9.1. PINEMAP researchers Fikret Isik (left) and Ross Whetten examining an 18-year-old progeny test of plantation selections used in this study. The test is located in Oliver, Georgia, and is owned and maintained by Plum Creek Timber Company, Inc. Photo by Steve McKeand.

Figure 9.2. Common garden experiment locations analyzed to refine transfer methods. (1) North Carolina State University Cooperative Tree Improvement Program plantings, (2) Cooperative Forest Genetics Research Program plantings, and (3) Western Gulf Forest Tree Improvement Program plantings.

10. Genetic Enhancement of Productivity and Fertilizer Use Efficiency

***Ross Whetten*[1,3] • *Gary Peter*[2,4]**

[1]Associate Professor • [2]Professor • [3]Department of Forestry and Environmental Resources, North Carolina State University
[4]School of Forest Resources and Conservation, University of Florida

As researchers discover the genetic basis for adaptation of loblolly pine to the wide environmental variation across its native range and incorporate this knowledge into breeding programs, their ability to enhance silviculture efficiency will improve. For instance, such information will lead to ways to enhance productivity, use fertilizer more efficiently, and increase resilience to climate variability and disturbance, all of which can lead to increases in carbon sequestration and a more robust forest-based economy.

Some of PINEMAP's central goals are to better understand genetic adaptation to climate and to improve productivity and fertilizer use efficiency. These goals will be achieved in part through characterizing genetic variation in pine breeding populations to help forest landowners establish productive plantations of well-adapted trees that are more resilient to changes in growing conditions predicted to occur over the coming decades. Some decisions, such as where to plant current commercial germplasm, may affect plantations established within the next few years. In the meantime, breeding programs are generating new germplasm selected for greater resilience to provide appropriate genetic stock as climate conditions change. Assisted migration, the planting of trees derived from nonlocal seed sources, is a strategy that has been used successfully for many years with loblolly and slash pines in the southeastern United States (Lambeth et al. 2005). The results of PINEMAP genetic research will offer land managers additional tools to mitigate risks and capitalize on opportunities from climate change by selecting the most productive and resilient planting stock that will enable tree breeders to include specimens with resilience to variations in temperature and water availability in breeding programs.

Pine breeders have long studied adaptability by analyzing how seed sources or genetic types perform when they are planted in different locations, but this method has had limited power to predict responses in environments outside areas in which the experiments were performed. However, the new ability to quantify genetic variation within breeding populations and relate this to growth and adaptation under different environmental conditions may enable better predictions of responses to future climate change.

The natural range of loblolly pine spans about 350,000 square miles, a broad swath reaching from eastern Maryland to Florida to eastern Texas and southeastern Oklahoma. Loblolly pine grows well across the wide variety of soils and climate in this diverse region and displays a wide range of environmental traits that indicate the species is quite plastic (Figure 10.1). An early indication that

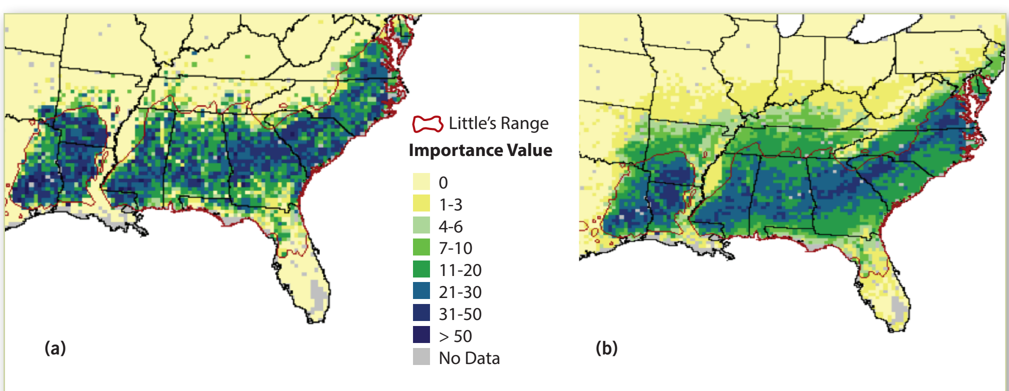

Figure 10.1. (a) The current distribution of loblolly pine based on USDA Forest Service Forest Inventory and Analysis data. The red outline is the range of loblolly pine described by Little (1971). The "Importance Value" is calculated for 20 km x 20 km inventory cells, and is essentially a percentage of loblolly pine relative to all tree species within the cell, using a combination of basal area and number of stems. (b) The predicted expansion of suitable habitat for loblolly pine by 2100 based on an average of three climate models under a "low-emissions" atmospheric CO_2 scenario (Source: http://www.fs.fed.us/nrs/atlas/tree/131?spp=131).

Loblolly pine seedlings at a nursery in Oliver, Georgia owned and maintained by Plum Creek Timber Company, Inc. Photo by Steve McKeand.

The results of PINEMAP genetic research will offer land managers additional tools to mitigate risks and capitalize on opportunities from climate change by selecting the most productive and resilient planting stock that will enable tree breeders to include specimens with resilience to variations in temperature and water availability.

this plasticity is due, at least in part, to genetic differences is the demonstration that the frequency of some genetic variants is associated with differences in environmental conditions, suggesting that natural selection has enriched genes or alleles (parts of genes) that confer adaptability to specific conditions (Eckert et al. 2010).

One goal of the PINEMAP genetic research effort is to extend this survey to most genes in pine in order to discover alleles that are predictive of adaption to specific environmental conditions, such as disease resistance or variation in availability of water or soil nutrients. A second goal is to characterize the presence of adaptive alleles in breeding populations and better describe the genetic variability within and among families (trees sharing one or both parents) to better understand adaptation to changes in climate, soils, and nutrient availability. Family level knowledge about genetic variation is especially important as most plantations are established with relatively few fast growing families. Characterization of the genotype of specific families should enhance the ability to predict responses to future changes in climate. Overall, such knowledge can help guide current planting decisions in the near term and breeding programs in the longer term to maximize the stability and resilience of future pine plantations over coming decades.

To achieve these goals, PINEMAP investigators are investigating and mapping genetic variation in several experimental plantings of loblolly pine with targeted and nontargeted genotype sequences. One approach targets genetic variation in the protein-coding regions of identified genes. The second, nontargeted, approach identifies genetic variation in any region of the genome. A high-quality draft assembly of an individual loblolly pine genome sequence, generated by the companion USDA National Institute of Food and Agriculture pine genome project, PineRefSeq, will be invaluable to PINEMAP investigators in efforts to document and organize the newly discovered genetic variation in pine breeding populations. The genetic variation discovered in these natural and breeding populations can be used to develop information that land owners and managers can apply in making practical reforestation decisions, a key outcome of the PINEMAP project. Knowledge of such genetic variation, for example, may lead to solutions for adaptation to climate, increased growth potential, resistance to insects and fungus, and efficient fertilizer use.

The long-term benefit of including adaptability as a criterion in breeding programs is that every plantation established receives the benefit of that genetic improvement, because virtually all pine plantations established in the southeastern United States use planting stock derived from the pine breeding programs involved in PINEMAP genetics research (McKeand et al. 2003). Improved management practices will be important tools for landowners and have the potential to mitigate short-term effects of changing conditions on existing plantations. The combination of improved planting stock and better management practices will be essential to maintaining and increasing the productivity of planted pines in the southeastern U.S. under new climate conditions.

11. PINEMAP Decision Support System: Connecting PINEMAP Research to Stakeholder Decisions

Heather Dinon Aldridge[1,4] • Corey Davis[2,4] • Ryan Boyles[3,4]

[1]Applied Climatologist • [2]Environmental Meteorologist • [3]Director and State Climatologist • [4]State Climate Office of North Carolina

The PINEMAP Decision Support System (DSS) applies to almost every outcome theme, particularly engaging our target audience to make informed, practical decisions related to climate, forest ecosystems, and forest management. The development of the DSS has relied on input from all PINEMAP research teams, and therefore, it is enhancing capacity for regional, interdisciplinary collaboration. As we present the DSS for evaluation at workshops and trainings, connections will be enhanced among forestry professionals, climate researchers, and education/outreach professionals. Future DSS tools will help in efforts to increase carbon sequestration from silvicultural and genetic enhancement of productivity and efficiency of fertilizer use, improve forest resilience to climate variability and disturbance, and contribute to a more robust and resilient forest-based economy in the southeastern United States.

The PINEMAP Decision Support System (DSS) is a project-wide integration vehicle designed to provide information on climate-related risks and opportunities for southern pine management, as well as information and tools for mitigating risk and capitalizing on opportunities. The DSS will include a collection of web-based tools and educational materials to assist foresters with decision making related to land management practices to reduce risk to factors such as pests, disease, and climate change impacts. These web-based tools will integrate science and data from PINEMAP research to produce results that can help professionals and clients make informed land management decisions.

While most forestry decision support systems are focused on decisions at the stand scale, the PINEMAP DSS will primarily focus on larger, regional scales. The rationale for this large-scale emphasis is that most of the PINEMAP research questions have a regional focus, e.g., "How will the climate of the Southeast United States change in the future, and how will these changes affect pine productivity?"; "Where will risks associated with changing temperature be most pronounced?"; and so on. There are many other decision support systems that focus on stand-scale problems, such as fertilization and growth and yield modeling; some of them are provided by the regional forestry research cooperatives associated with PINEMAP. Rather than replicate these efforts, the PINEMAP DSS will deliver information in areas where PINEMAP can provide a unique perspective, including climate, management, and soils impacts on forest management risks and opportunities across the entire range of loblolly pine.

The following is an example of how a user might interact with the regional-scale PINEMAP DSS.

First, a user selects a particular decision point and associated risk, e.g., "Management" and "Pests." Then, a user selects a tool of interest, e.g. "Southern Pine Beetle Outbreak Risk," and a map pops up showing predictions of future risk of southern pine beetle outbreaks across the southeastern U.S., as shown in Figure 11.1. The user then clicks on a specific area of interest on the map and is presented with details of the risk category, along with tools or resources to aid in reducing that risk. These resources could include items such as a fact sheet on helpful management practices to prevent southern pine beetle outbreaks in the future or a model to assess pest and disease impacts on loblolly pine stands. In this way, the PINEMAP DSS will help foresters understand how climate-related factors are likely to affect loblolly pine management, how these factors vary across the region, and what tools or management approaches might be helpful for moderating these factors.

Significant progress has also been made toward the development of a web-based framework to host the DSS on the PINEMAP website. Through collaborations with the PINEMAP website administrator and PINEMAP data managers, the back-end framework has been built and populated with new and existing decision support tools.

During the next two years of the PINEMAP project, the DSS will continue to be developed and improved using an iterative process of interaction between stakeholders and scientists. New tools will be implemented over the next year, such as the seed deployment tool (see Chapter 9, page 22). The DSS will also undergo evaluation by key user groups in the PINEMAP region. Feedback from this evaluation will inform future direction of the PINEMAP DSS.

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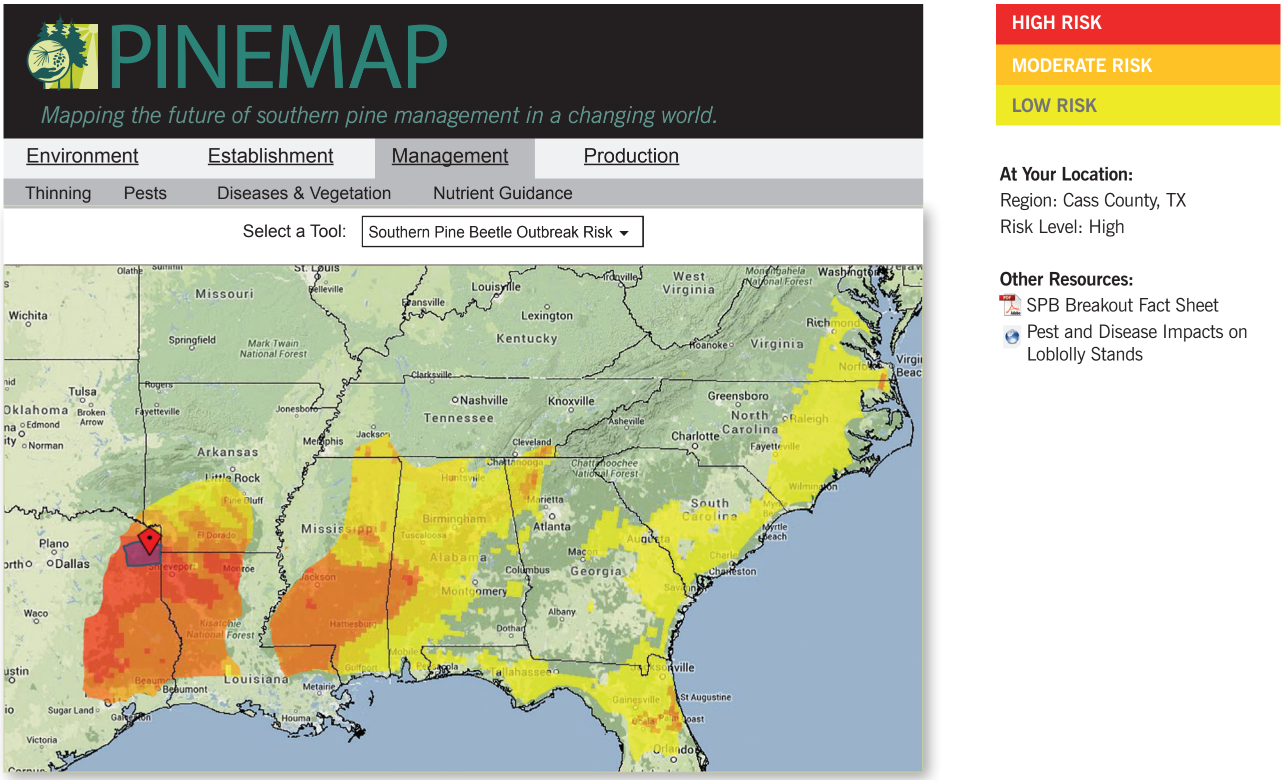

Figure 11.1. Mock-up of a map-based, regional Decision Support System (DSS) tool on the risk of future southern pine beetle outbreaks across the southeastern United States.

12. A Framework for Identifying Carbon Hotspots and Forest Management Drivers

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[1]Associate Professor • [2]Assistant Professor • [3]School of Forest Resources and Conservation, University of Florida • [4]College of Natural Resources, University of Wisconsin-Stevens Point

The capacity to make informed decisions related to climate, forests, and forest management, and how these relationships can be used to increase carbon sequestration, are key outcome themes of PINEMAP. Findings from this research provide us with a better understanding of how to locate and map carbon hotspots (high aboveground carbon stocks) and also inform what, and how, forest management activities and climate-related factors such as fires and hurricanes affect forest carbon stocks. This information can be used to inform policies that support sustainable management of planted and natural pine forests under future climate scenarios.

We used Florida as a case study to locate forests with high aboveground carbon stocks (hotspots), and then, using statistical relationships, we identified the existing forest management and ecological factors (drivers) potentially influencing these carbon hotspots. Our framework, based on publicly available forest inventory and geospatial data, can provide insights for regional decision makers and researchers about key forest structure characteristics and management practices that are optimal for carbon storage.

To develop this framework, we collaborated with the USDA Forest Service Forest Inventory and Analysis (FIA) program and used their data and spatial analyses to develop a repeatable method for mapping carbon hotspots (i.e., areas of significantly high aboveground carbon stocks) and coldspots (i.e., areas of low aboveground carbon stocks) in different forest types in Florida. We also analyzed key potential forest management drivers (e.g., forest types, fire, hurricanes, tenure, and silvicultural activities) using statistical modeling to identify which of these drivers were associated with these hotspots.

Our results show that most carbon hotspots were located in the highly forested northern third of Florida, and we found no identifiable hotspots in the more urbanized and agricultural landscapes of south Florida (Timilsina et al. 2013) (Figure 12.1). Many of the carbon hotspots in north Florida were located in urban-interface areas around Jacksonville, Tallahassee, and Gainesville. Forest silvicultural treatments—such as site preparation, thinning, and logging, as well as ownership (private versus public) and disturbance types (fire, grazing, and hurricanes)—were not significant predictors of carbon hotspots. Time since hurricane disturbance was also not a significant predictor in our analyses (Figure 12.2). However, forest

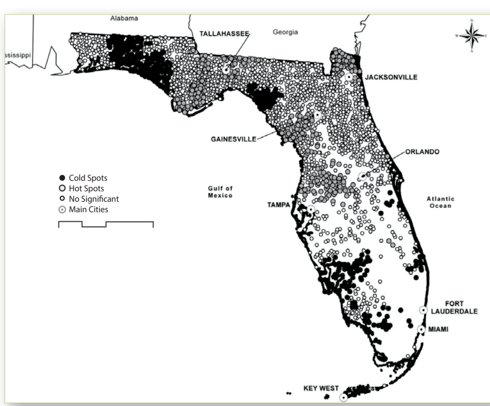

Figure 12.1. Map showing aboveground forest carbon hotspots (grey circles) and coldspots (black circles) in Florida based on USDA Forest Service Forest Inventory and Analysis data.

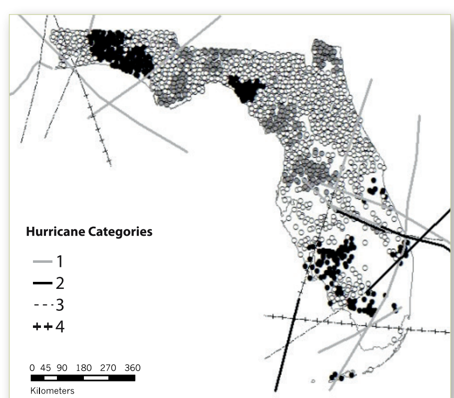

Figure 12.2. Forest carbon hotspots (grey circles) and coldspots (black circles) in Florida with respect to hurricane tracks from 1998 through 2008.

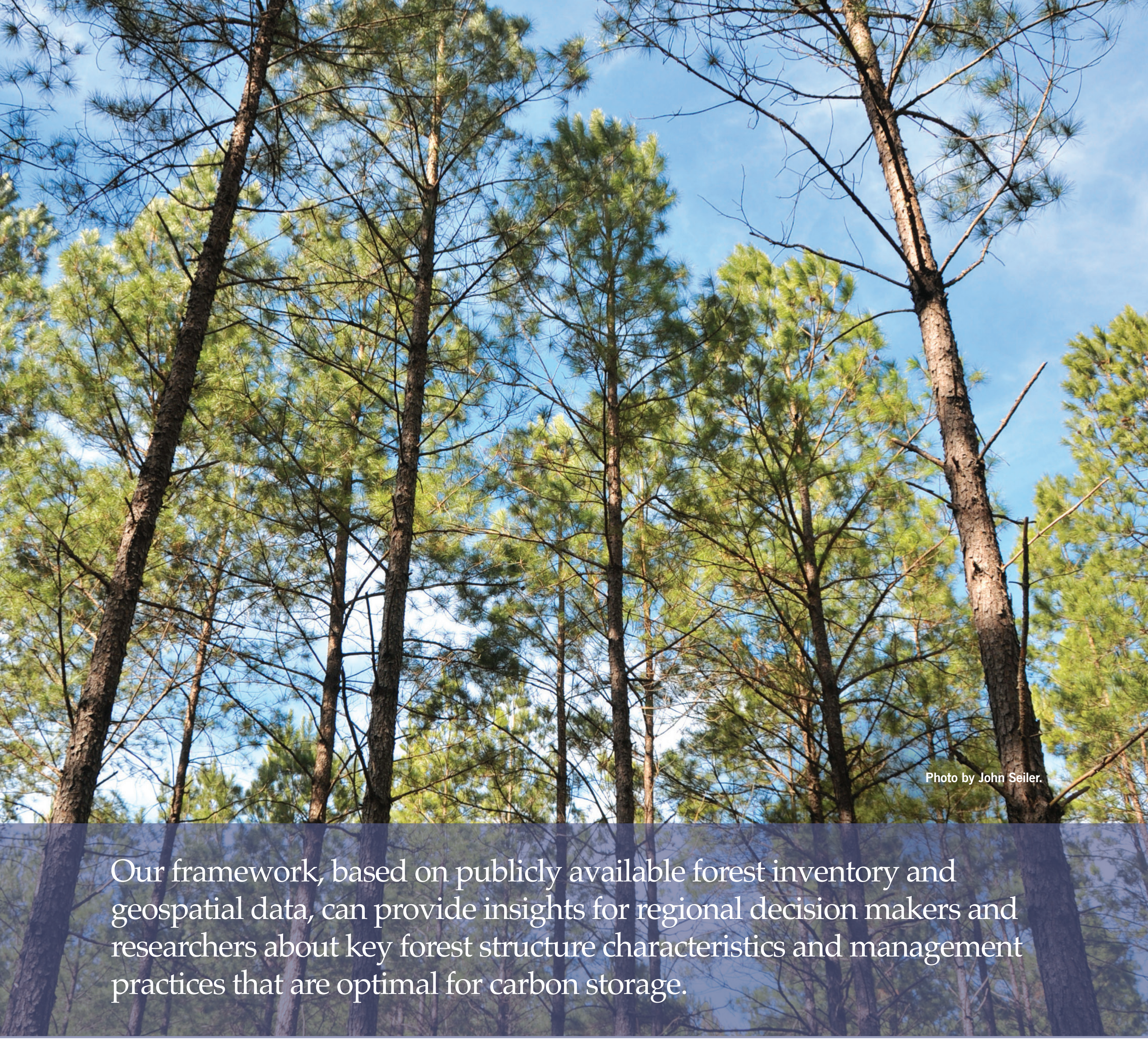

Photo by John Seiler.

Our framework, based on publicly available forest inventory and geospatial data, can provide insights for regional decision makers and researchers about key forest structure characteristics and management practices that are optimal for carbon storage.

type, site quality, and stand age were significant predictors. Mixed upland hardwood, oak hickory, and slash pine forests had a greater probability of being carbon hotspots than pine-hardwood and longleaf pine forests. Additionally, plots with a higher FIA-defined site quality class and older stand ages were associated with a higher probability of a forest being classified as a carbon hotspot.

This study provides a framework for expansion to other states and regions in the United States. In addition, it identifies some key forest structure and management factors related to subtropical forests with high carbon stocks. Hence, managers and policy makers can focus on these factors if increased carbon stores are an objective. Furthermore, PINEMAP and other researchers can incorporate these identified factors into climate effects modeling scenarios.

Carbon hotpots located adjacent to metropolitan areas in north Florida could be used to identify areas of interest for the conservation of working forests because of the potential risk of forest loss due to urbanization. Staff with the USDA Forest Service FIA program also suggested that this framework could be used to identify and map areas that are optimal for supplying biomass to bioenergy plants. Results from this study are currently being used to analyze the tradeoffs associated with managing specific forest types (i.e., longleaf, loblolly, and slash pine plantations) for carbon storage, as well as ecosystem services such as biodiversity, recreation, and water yield.

13. Economics of Climate Change in Even-Aged Forest Management

Andres Susaeta[1,4] • Douglas Carter[2,4] • Damian Adams[3,4]

[1]Postdoctoral Research Associate • [2]Professor • [3]Assistant Professor • [4]School of Forest Resources and Conservation, University of Florida

Results from this economic analysis will help policy makers formulate instruments and incentives to encourage the sustainable management of planted pines and foster the forest based-economy in the Southeast United States under changing climatic conditions.

Persistent changes in future temperatures, atmospheric carbon dioxide (CO_2) concentration, and precipitation patterns are likely to affect forest productivity and, thus, the supply of timber (Huang et al. 2011). In the southeastern United States, studies have postulated an increase in pine forest productivity due to elevated atmospheric CO_2 and a decrease in productivity due to elevated temperatures (Teskey 1997, Wertin et al. 2010). A substantial reduction in precipitation, which is suggested by some downscaled global climate models for parts of the southeastern U.S., would likely negatively impact forest productivity. In addition to these primary effects of climate change on pine tree growth, secondary effects, including increased severity of disturbances such as wildfires, pest outbreaks, and hurricanes, are also expected to negatively affect forest productivity and important forest-related ecosystem services (Chmura et al. 2011).

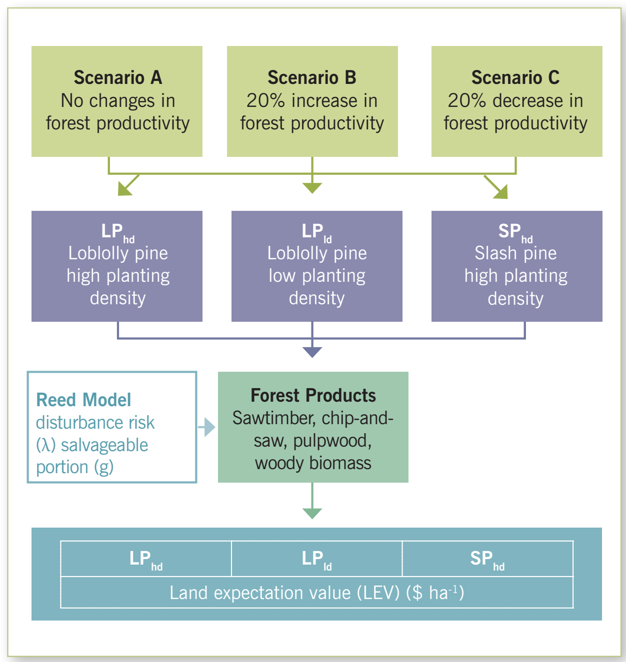

Figure 13.1. Overall framework of the economic study.

In this study, we simulated three forest productivity scenarios and two levels of disturbance risk due to climate change and their implications for the economics of southern pine stands (Figure 13.1). We also simulated the use of silvicultural strategies to reduce the effects of disturbances to gauge the economic implications on the profitability of these alternative forest management practices. Risk (λ) is defined as the arrival rate of catastrophic disturbances such as hurricanes, wildfires, and pests. The probability of risk was modeled for disturbance events every 100 years and every 33 years. We also considered the salvageable portion (g) of a stand that can be harvested for use after a catastrophic disturbance.

As expected, increases in forest productivity result in higher land values and decreases in forest productivity result in lower land values (the value of the land assuming forestry use in perpetuity) (Table 13.1). For example, a 20% increase in forest productivity for loblolly pine high density (Scenario B, g=0.3 and λ=0.01) increased land values by 117%. In the case of a 20%


Photo by John Seiler.

This analysis suggests that careful species selection and management (e.g., silvicultural efforts, such as thinning, aimed at increasing the amount of undamaged timber that can be recovered after a natural disturbance) are important factors influencing the economic resilience of southern pine stands to climate-related disturbance.

decrease in pine productivity, continuing to invest in plantations may result in economic losses (negative land expectation values) for landowners. Increased risk of disturbance reduced the land values regardless of changes in forest productivity.

To reduce potential losses from an increase in disturbance frequency due to changing climatic conditions, landowners can plant better adapted species and change tree density. For example, slash pine is less susceptible than loblolly pine to breakage, uprooting by hurricanes, and deterioration by insects and diseases (Stanturf et al. 2007). Lower planting density reduces the accumulation of forest fuels that influence wildfires and tree mortality and reduces susceptibility to pest outbreaks.

Differences in species selection and planting density were simulated with discounted cash flow modeling of loblolly at high and low planting densities and slash pine at high planting density. At a 20% increase in growth, planting fewer loblolly pines per hectare generates better land values than higher planting density. Overall, slash pine has slightly lower economic returns compared to loblolly except when high salvageable portions are considered, in which case landowners will be better off planting slash pine instead of loblolly pine at high density.

This analysis suggests that careful species selection and management (e.g., silvicultural efforts, such as thinning, aimed at increasing the amount of undamaged timber that can be recovered after a natural disturbance) are important factors influencing the economic resilience of southern pine stands to climate-related disturbance.

Forest species	Salvageable portion	Risk	Scenario A No change	Scenario B +20%	Scenario C -20%
	g	λ	Land expectation value ($ ha^{-1})		
LP_{hd}	0.3	0.01	573	1246	-66
		0.03	-804	-233	-1345
LP_{ld}	0.3	0.01	662	1319	38
		0.03	-647	-93	-1169
SP_{hd}	0.3	0.01	427	1185	-260
		0.03	-931	-297	-1500
	0.5	0.01	481	1251	-216
		0.03	-796	-132	-1393

Table 13.1. Land expectation values for forest species, salvageable portion, and disturbance risks under different productivity scenarios (site index = 20 m). The scenario designations are described in Figure 13.1.

14. Non-Industrial Private Forest Landowners' Willingness to Sequester Forest Carbon in the Southern United States

***Donald Grebner*[1,3] • *Puskar Khanal*[2,3]**

[1] Professor • [2]Ph.D. Student • [3]Department of Forestry, College of Forest Resources, Mississippi State University

Forest landowner willingness to sequester forest carbon is useful in making better forest management decisions and in assisting policy makers to design and implement more effective policies to mitigate climate change.

Forested lands in the southern United States sequester substantial amounts of carbon and play an important role in climate change mitigation. Management is considered to be the most cost effective strategy to sequester about 400 million tons of CO_2 equivalent (CO_{2e}) per year in the southern U.S. (Galik et al. 2013). Some major strategies prescribed to increase carbon storage of forest stands include altering rotation length, reducing disturbance and harvest removal, and increasing productivity. Non-industrial private forest (NIPF) landowners are the largest timberland ownership category in the southern U.S., owning 66% of the total private timberland acreage. The willingness of NIPF landowners to implement forest carbon strategies in this region needs to be understood in order to capitalize on the carbon sequestration potential of managed forests.

The goal of this study is to assess southern NIPF landowner attitudes toward climate change, their understanding of carbon sequestration, and the factors affecting their willingness to implement forest carbon sequestration practices for climate change mitigation. The survey asked several questions related to climate change beliefs and willingness to accept revenues in exchange for delaying harvest (e.g., "Would you be willing to defer final harvest of your timber stand for more forest carbon sequestration if such action were to contribute to climate change mitigation as well as generate additional revenue for you?"). A regional mail survey was sent out in fall 2013 to 5,110 randomly-selected NIPF landowners with more than 20 acres of forested land in the 11 southern states (excluding Tennessee). A total of 734 responses were received, for an adjusted response rate of 15.02 percent, which provided sufficient data for our analyses. This response rate is similar to another large scale study by Thompson and Hansen (2012). We used the same vendor to compile our forest landowner mailing list. To test for nonresponse bias, we randomly selected nonrespondents and obtained answers to key survey questions that described their forest land (size of largest forested parcel), management behavior (availability of written management plan), and climate change attitude (human activities are contributing to climate change). Our t-test between respondents and nonrespondents showed no statistical difference in terms of the three questions asked.

Of the survey respondents, 38% agreed or strongly agreed that climate change is scientifically proven, and 25% disagreed or strongly disagreed (Figure 14.1). Similarly, regarding forest carbon sequestration, 55% of the respondents indicated they had a poor or very poor understanding of forest carbon sequestration, while 20% indicated they had a good or very good understanding (Figure 14.2). These findings imply that NIPF landowners in the southern U.S. vary widely in their climate change attitudes and understanding of carbon sequestration. Furthermore, the measure of NIPF landowner willingness to adopt forest carbon sequestration practices revealed that 50% of respondents are willing to practice carbon sequestration if it produced additional revenue. It is promising for forest carbon sequestration that about half of the landowners were willing to sequester carbon with offset revenue, although the actual number could vary depending on specific

Photo by John Seiler.

> The goal of this study is to assess southern NIPF landowner attitudes toward climate change, their understanding of carbon sequestration, and the factors affecting their willingness to implement forest carbon sequestration practices for climate change mitigation.

enrollment requirements. A statistical binary probit model was fitted to identify factors affecting landowners' willingness to manage forests for carbon sequestration. We found that the number of parcels owned, attitudes toward climate change and carbon sequestration, understanding of carbon sequestration, household income, and bequest motive were positively related with NIPF landowners' willingness to defer final harvest for carbon sequestration. In contrast, other land use contracts, concern regarding carbon offset revenue, and beliefs that climate change is a tactic used to scare people were negatively associated with their willingness to sequester carbon.

Respondents' willingness to sequester carbon increased with the number of parcels owned and household income. This implies that relatively wealthy landowners owning multiple parcels would be more willing to sequester carbon. Those planning to bequest their land to heirs were willing to defer final harvest for carbon sequestration. Similarly, forest landowners who believe that human activities contribute to climate change and that carbon sequestration is an effective mitigation tool were willing to manage for carbon sequestration. However, factors such as carbon offset revenue, other land use contracts, and beliefs that climate change is a tactic used to scare people decreased their willingness to manage forests for carbon sequestration. Therefore, it is important to consider factors affecting willingness to sequester carbon for this important ownership group in order to design and implement more effective policies to mitigate climate change in the southern U.S.

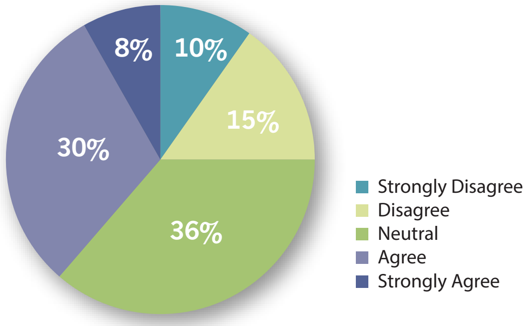

Figure 14.1. Responding non-industrial private forest (NIPF) landowners' level of agreement with the statement "climate change is scientifically proven."

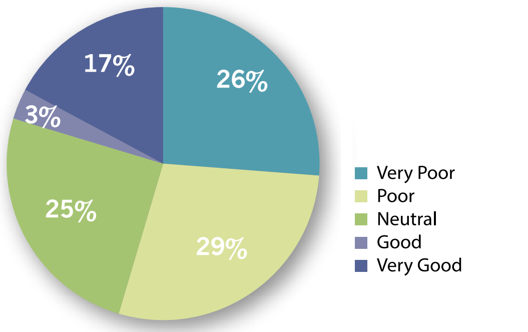

Figure 14.2. Responding NIPF landowners' understanding of forest carbon sequestration.

15. Assessing Corporate Forest Landowner Needs

Jessica Ireland[1,6] • Timothy Martin[2,6] • Gary Peter[3,6] • Wendy-Lin Bartels[4,7] • Richard Plate[5,7]

[1]PINEMAP Project Coordinator • [2]Professor; PINEMAP Project Director • [3]Professor • [4]Assistant Research Scientist • [5]Postdoctoral Research Associate
[6]School of Forest Resources and Conservation, University of Florida • [7]Florida Climate Institute, University of Florida

Assessing corporate forest landowner research needs and preferred research delivery mechanisms will enable us to identify opportunities for additional analyses and develop an outreach plan to aid corporate landowners in making informed, practical decisions related to climate, forest ecosystems, and forest management. This will also help us to enhance connections between corporate forest landowners and forestry and climate researchers so that science can be translated to key PINEMAP outcomes: increased carbon sequestration, increased efficiency of nitrogen and other fertilizer inputs, and increased forest sustainability and resilience in the face of a changing climate.

The overall goal of the PINEMAP project is to create, synthesize, and disseminate the knowledge that enables southern-pine landowners to manage forests to increase carbon sequestration, increase efficiency of nitrogen fertilizer use, adapt forest management approaches, and plant improved tree varieties to increase forest resilience and sustainability under variable climates. Corporate entities own and manage more than 20 million acres of planted pine forests in the southeastern United States (about 55% of the total privately owned planted southern pine forestland). For this reason, effective dissemination of PINEMAP research results to corporate forest landowners is essential to our mission and necessary to achieve our objectives.

In the winter of 2013-2014, we surveyed corporate landowners about their research needs and preferred research delivery mechanisms. The objectives of the survey were to (1) determine which PINEMAP research would be of most use to industry scientists and managers, (2) gain an understanding of industry needs and how information should be tailored for specific audiences, and (3) determine the most effective mechanisms for information delivery to meet stakeholder needs.

The survey was sent to individuals who work with companies that own or manage pine plantations in the southeastern U.S. and who are members of one or more of the eight major southeastern University-Corporate-Governmental Forestry Research Cooperatives. Of the 129 individuals surveyed, 12 opted out due to a decision within their organizations to submit only one set of responses per organization or because they did not work directly for a company that owns or manages pine plantations. This resulted in 117 total possible respondents. Sixty surveys were partially or fully completed for a 51% response rate. The survey contained five sections: research needs, research barriers/limitations, research delivery mechanisms, long-term planning, and organization information. The survey contained rating scales and open-ended questions. The questions in the research needs section were adapted, with permission of the authors, from previous survey research on assessment of climate change vulnerabilities and adaptation options conducted in the Yukon and Northwest territories (Ogden and Innes 2009).

Survey respondents were grouped into categories by organization type and acreage owned or managed (Table 15.1). Responses of "important" and "very important" were combined for each question and percentages of responses in each category were reported. Responses were sorted by type of organization and acreage owned or managed to determine if there was a significant statistical difference

Organization Type	n	%
Consulting	10	18%
Real Estate Investment Trust (REIT)	17	30%
Timber Investment Management Organization (TIMO)	7	12%
Vendor	4	7%
Forest Products Manufacturing	8	14%
Public Land Management	8	14%
Large Private Landowner	3	5%
Acreage owned or managed	**n**	**%**
0-100,000 acres	20	36%
100,001-1,000,000 acres	15	27%
> 1,000,000 acres	20	36%

Table 15.1. Summary of survey respondents by employer organization type and acreage owned or managed by employer.

University of Florida students and researchers and members of the Forest Biology Research Cooperative participate in a field tour at the PINEMAP Tier III site in Taylor County, Florida. Photo by Angelica Garcia.

Corporate entities own and manage more than 20 million acres of planted pine forests in the southeastern U.S. (about 55% of the total privately owned planted southern pine forestland). For this reason, effective dissemination of PINEMAP research results to corporate forest landowners is essential to our mission and necessary to achieve our objectives.

among categories. This allowed us to determine if there were different research priorities and/or preferred research delivery mechanisms for different types of respondents, which will help us to best tailor corporate outreach efforts. Finally, responses to open-ended questions were coded and grouped into categories.

Some key research needs that were rated as important or very important by all respondents are summarized in Table 15.2. Fifty-five percent of respondents indicated they were familiar or very familiar with PINEMAP research, which indicates that PINEMAP has been doing a fairly good job of research dissemination to corporate landowners, but also that there is room for improvement. For mechanisms of research delivery, 45% responded that the current forest research cooperative technology transfer model (i.e., industry cooperators attending meetings, reviewing reports, and disseminating research within their organization) was effective or very effective, and 41% responded that it was only moderately effective. This indicates that the current model could be supplemented with additional technology transfer mechanisms to improve overall effectiveness of corporate landowner outreach. Fifty percent or more of respondents indicated that they were interested or very interested in the following types of technology transfer media: website containing research information, printed reports, reports in video or PowerPoint® format, in-person workshops or short courses, and webinars. Seventy-seven percent of respondents indicated they were interested or very interested in receiving specific guidelines for management based on PINEMAP research results.

Packaging and disseminating research results to corporate landowners is central to the PINEMAP mission and essential to achieve our objectives. This survey and subsequent discussions with corporate forest landowners enable us to better understand research needs related to the impact of climate on forestry now and in the future as well as preferred information delivery mechanisms and perceived barriers/limitations to organizational ability to incorporate climate projections into forest management planning. The results are helping us identify opportunities for additional research analyses and to develop outreach plans to extend PINEMAP research to forest industry cooperators.

Please rate the importance to your organization of research on the following potential impacts of climate variability and climate change.	
Type of research	Important or very important
Changes in forest growth and productivity	92%
Changes in timber supply	79%
Changes in land values and land use options	70%
Changes in forest management risk associated with the intensity, severity, or magnitude of forest insect or disease outbreaks	64%
Please rate the importance to your organization of research on the following silvicultural activities.	
Type of research	Important or very important
Planting genotypes that are tolerant of drought, insects, and/or disease	75%
Breeding for enhanced yield	72%
Silvicultural techniques to promote forest productivity and increase stand vigor (i.e., partial cutting or thinning) to lower the susceptibility to insect attack or disease outbreaks	72%
Species and/or genotype selection	68%
Fertilization to enhance forest growth	68%
Breeding for pest resistance and for a wider tolerance to a range of climate stresses and extremes	j2 %
Managing forest insects and diseases	65%
Long-term seedlot trials to test improved genotypes across more diverse array of climatic environments than previous tests	53%
Control of undesirable plant species that will become more competitive in a changed climate	52%
Movement of seed stocks from one area to another	50%

Table 15.2. Research areas that were rated as important or very important by 50% or more of respondents.

16. Climate Change Perceptions of Southern Foresters

Leslie Boby[1,4] • William Hubbard[2,4] • Hilary Morris[3,5]

[1]Extension Associate • [2]Regional Forester • [3]M.S. Student • [4]Southern Regional Extension Forestry • [5]Department of Forestry and Environmental Resources, North Carolina State University

The PINEMAP Extension team's primary effort in sharing new developments from the PINEMAP project and increasing forest resilience is directed toward southern foresters who work for industry and private landowners. A survey was conducted to learn more about foresters' views on climate change and interest level in various forestry issues. Survey results are informing our approach to working with foresters and other forestry stakeholders as we develop continuing education programs and outreach materials with the goal of building an engaged and literate public with the capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management. These education programs will also enhance capacity for regional, interdisciplinary collaboration among climate and forest scientists and Extension professionals, as well as enhance connections between forest landowners and researchers and outreach professionals.

Professional foresters in the southeastern United States are an important stakeholder group for PINEMAP. This group, comprised of professionally trained individuals from private industry, consulting firms, public agencies, universities, and nonprofits, will need to provide several critical services if PINEMAP is to accomplish its goals and objectives. Many professional foresters are in the business of serving private family forest owners. They provide oversight in the development of management plans, recommend and oversee implementation of preferred silvicultural practices, and initiate several other practices on behalf of the landowner. Currently, little information exists regarding southern foresters' views on climate change, their receptivity to new information regarding climate change concepts, and their willingness to implement forest management strategies to mitigate impacts of climate variability.

A survey was conducted to gain a better understanding of professional foresters' experiences, perceptions, beliefs, and attitudes with regard to climate change. The survey was also used to gain an understanding of the level of knowledge and interest in continuing education topics and formats regarding climate science and climate change.

Twenty-four questions relating to foresters' personal observations, perceptions, beliefs, and continuing education needs were developed in areas relating to changing climatic conditions, weather, and resilient forest management strategies. Eight questions collected demographic information. Most of the questions used rating scales with open-ended options to provide additional information.

A comprehensive database of professionally trained foresters was developed through Internet searches and personal contacts with state forestry agencies, Cooperative Extension, private companies, and nongovernmental forestry organizations. This working database consisted of nearly 6,700 foresters in the 13 states that make up the USDA Forest Service's Southern Region (including all 9 states within the PINEMAP region). The survey was implemented with guidelines from the Tailored Design Method (Dillman et al. 2009) to increase the response rate. Nonresponse bias was tested using late respondents as proxies for nonrespondents and no bias was detected for any of the response variables tested.

More than 1,700 foresters completed the survey, yielding a 27% response rate and a sampling margin of error of 2% at the 95% level of confidence, which is typical for web-based surveys that do not provide completion incentives (Dillman et al. 2009). The following key findings emerged from the survey:

- Nearly all of responding foresters were male (95%) and have bachelor's degrees (97%). Respondents were approximately equally represented among different age classes, which was important because previous studies (Labriole and Luzadis 2011) have found age to influence levels of acceptance of climate change.
- Of the responding foresters, 61% agreed that the climate is changing but differed in their views of the cause, with only 14% agreeing that it is primarily anthropogenic in origin. Of the 39% who did not believe that the climate is changing, 6% thought that sufficient evidence exists to show that climate change is not occurring (Figure 16.1).

While many foresters had different views and perceptions on climate change, the majority were interested in educational programs that would help them increase forest resilience.

- Of the responding foresters, 75% felt "somewhat" to "very knowledgeable" about climate and climate change, and 63% were "somewhat" to "very interested" in learning more. Only 25% of respondents responded that their clients had asked about climate change.
- Climate change views among responding foresters differed by state, with Texas and Oklahoma foresters having the highest rates of acceptance that climate change is occurring and Mississippi and Alabama having lowest rates of acceptance. This could be partially due to the extreme drought and dry weather experienced by states such as Texas and Oklahoma during the survey period.
- Of the responding foresters, 45% thought that changes in forest management strategies are needed to respond to and mitigate climate uncertainty, and more than 70% were interested in learning about forest resilience strategies.
- Responding foresters expressed varying levels of interest in learning more about specific topics such as planting guidelines and silvicultural recommendations (Figure 16.2).

Potential Application of Findings

Results from this survey have informed our approach to working with foresters and other forestry stakeholders as we develop continuing education programs and outreach materials. For example, we found that while many foresters had different views and perceptions on climate change, the majority were interested in educational programs that would help them increase forest resilience, which is consistent with a similar survey of Midwestern foresters (Carlton et al. 2014). Because our overall task is to disseminate the latest developments from PINEMAP research and to increase forest resilience, the results of this survey suggest that PINEMAP objectives are congruent with foresters' goals of maximizing production and minimizing risk. Further, findings suggest that aligning our educational programs toward reducing risk, increasing resilience, maximizing productivity, and helping landowners achieve specific management objectives may be most effective for achieving PINEMAP objectives.

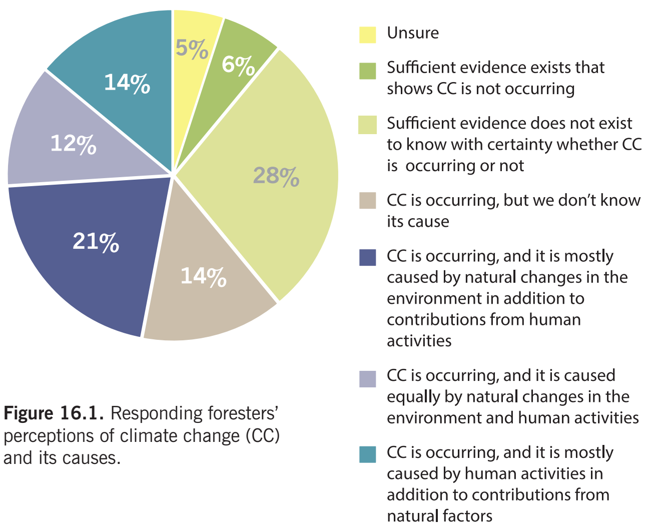

Figure 16.1. Responding foresters' perceptions of climate change (CC) and its causes.

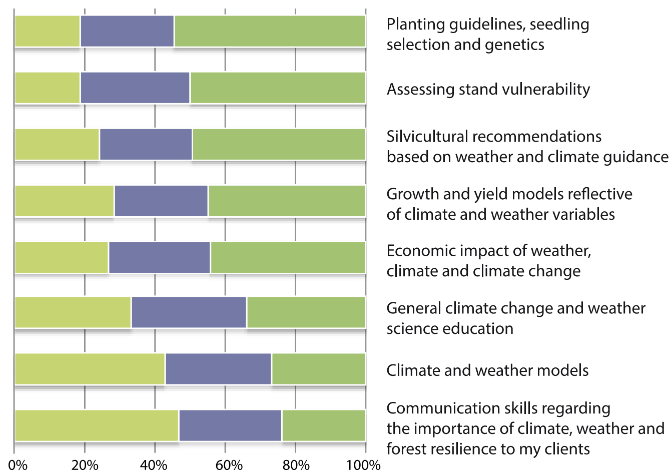

Figure 16.2. Responding foresters' level of interest in forestry and climate science topics, organized by topics of greatest interest to least interest.

17. Communicating Climate Change with Forest Landowners through Video

Shelby Krantz[1,3] • Martha C. Monroe[2,3]

[1]M.S. Student • [2]Professor and Extension Specialist • [3]School of Forest Resources and Conservation, University of Florida

This research project explores effective communication strategies for educating non-industrial private forest landowners about climate change so they can make informed, practical decisions about forest management. We forged a connection between PINEMAP biological research and forest landowners in the Southeast United States in a new and interesting way: video. Furthermore, forest landowners who manage their properties to increase resilience should be able to sequester more carbon, maintain their forest, and retain their livelihoods.

Forest landowners in the Southeast United States need to be aware of current and potential impacts of climate change so their forests can be resilient, thereby protecting their livelihoods and important ecosystem services (functions such as wildlife habitat, carbon storage, water and air purification, and recreation). Climate science and climate change communication, however, is a difficult task. Because changes in carbon dioxide and other greenhouse gases are invisible and undetectable, it is easy for the public, and the southeastern landowner, to ignore climate change information. Despite confusion or disinterest in climate change, the economic, ecological, and cultural importance of southeastern forests suggests it is important to better understand how to communicate climate change impacts and potential solutions with forest landowners. A number of factors suggest that video could be an effective communication tool (Vojtek & Vojtek 2000). Video can also be a flexible research tool, because it can be easily adapted to feature different subjects and speakers.

Social science has many well-known models that help us explore effective ways of communicating. Within this study, we looked at how framing of messages in a video can affect landowners' attitudes toward and intention to adopt climate change adaptation and mitigation management strategies. Forest management strategies can be thought of as an innovation; Rogers (1983) suggests that the degree of perceived similarity, or homophily, can accelerate an innovation's diffusion. Based on previous research, we define trust as a function of homophily. Thus, we expect that forest landowners who feel homophilous with the forest landowners featured in the videos will trust those landowners to speak about forest management strategies; both homophily and trust should increase motivation to adopt behaviors.

We created four videos to study the importance of homophily and messaging (Figure 17.1). Each video featured interviews with both a forest landowner and a university researcher. The interviews with forest landowners focused on either economic (timber) objectives or stewardship (preservation or conservation) objectives. The interviews with the researcher focused either on climate change or forest health. We combined these variations of the interviews to make four videos: (1) Steward-Climate, (2) Steward-Health, (3) Timber-Climate, and (4) Timber-Health. This study tested which frame (video message) was most appealing to forest landowners and motivated their commitments to change. We sent videos electronically to landowners and used pre- and post-surveys to gather their impressions. The study generated

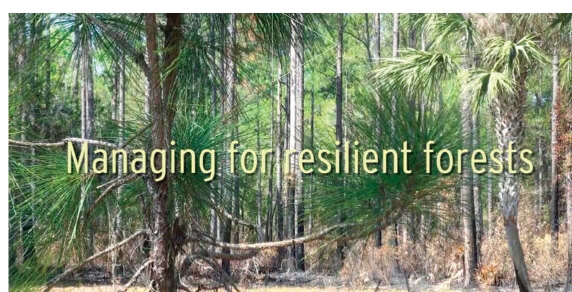

Figure 17.1. Screenshot of one of the videos created for this research.

Video is a practical communication tool because it can portray multiple values and land objectives in order to engage a diversity of landowners in the conversation about adapting to and mitigating for climate change.

199 completed responses (completed responses included both the pre- and post-surveys). Respondents had a mean age of 61 years, and were mostly white (89.9%) and male (77.8%).

Results from the study include the following observations. All four videos were able to motivate intention to act, but they were not equally effective at increasing feelings of efficacy (the strength of one's belief in one's ability to complete tasks or reach goals) with regard to these behaviors. The data show that only three of the four videos increased efficacy from the pre- to post-survey ($p < .001$, $p < .001$, $p = .002$); those that featured stewardship values were more effective in overcoming climate change communication barriers and increasing efficacy. Perceived similarity (homophily) between the viewer and the speaker in the video was important for the viewer to trust the speaker, and when values portrayed in the video aligned with viewers' values, they were more likely to like the videos, trust the speakers, and indicate an intention to act. Homophily was clearly important, but diversity within the population suggests that one speaker will not resonate with all viewers. Videos about forest management and climate change portraying multiple values, attitudes, and objectives may help increase feelings of efficacy and homophily by resonating with a wider audience, and therefore increase intention to act (Figure 17.2). This study also shows that researchers and Extension agents can be trusted sources of information (mean= 3.33 on a scale of 1-4, where 1 = strongly disagree and 4 = strongly agree that information from the researcher was trustworthy) and can be integral in connecting forest landowners with PINEMAP research. Respondents also expressed interest in learning more through video (mean = 4.05 on a scale of 1-5, where 1= not at all interested and 5 = extremely interested).

Video is a practical communication tool because it can portray multiple values and land objectives in order to engage a diversity of landowners in the conversation about adapting to and mitigating for climate change. In order to engage non-industrial private forest landowners in the Southeast, it is important to communicate in a way that promotes homophily and feelings of efficacy. This study also shows that video is a practical way to increase motivation to act.

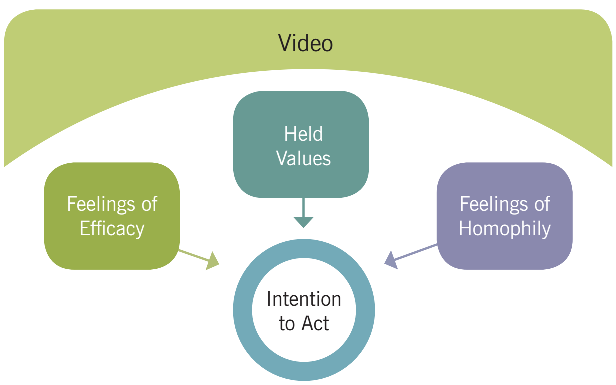

Figure 17.2. Videos that reinforce held values, demonstrate information in a way that increases feelings of efficacy, and generate feelings of homophily with the speakers will increase a viewers' intention to adopt or adjust forest management practices to increase forest resilience.

18. A Year in Review: PINEMAP's Landowner Outreach Activities

Eric Taylor[1,9] • Sean Burns[2,10] • William Hubbard[3,11] • Mark Megalos[4,12] • Leslie Boby[5,11]
Heather Dinon Aldridge[6,13] • Joshua Idassi[7,14] • Gwendolyn Boyd[8,15]

[1]Associate Professor and Extension Forestry Specialist • [2]Extension Assistant • [3]Regional Forester • [4]Extension Forestry Specialist • [5]Extension Associate
[6]Applied Climatologist • [7]Natural Resources Specialist • [8]Associate Professor; Forestry Director • [9]Texas A&M Forest Service • [10]Texas A&M AgriLife Extension Service
[11]Southern Regional Extension Forestry • [12]Department of Forestry and Environmental Resources, North Carolina State University • [13]State Climate Office of North Carolina
[14]School of Agriculture and Environmental Sciences, North Carolina A&T State University • [15]Department of Agriculture, Alcorn State University

Using a variety of methods and information delivery technologies, PINEMAP is gathering the latest research-based knowledge and disseminating it to silviculturists, natural resource managers, and landowners. Through these efforts, PINEMAP will enhance capacity for regional, interdisciplinary collaboration among climate and forest scientists and Extension and education professionals and enhance connections between corporate and noncorporate forest landowners and forestry and climate researchers and education and outreach professionals. These connections will foster an engaged and literate public with the capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management.

PINEMAP is dedicated to linking research findings to outreach and education opportunities. The success of the project will ultimately be measured by the impact PINEMAP tools and research have "on the ground" toward improving the health and resilience of southeastern pine forests, as well as educating landowners and foresters about the impact of climate change, increasing carbon sequestration, and advancing the skill set of natural resource professionals. PINEMAP is delivering cutting-edge knowledge pertaining to forest health and resilience, sustainability, and productivity through Extension programming. To achieve these goals, PINEMAP's Extension team is using state-of-the-art information delivery systems to engage a greater number of forest resource practitioners and landowners and to impact a more diverse range of individuals and groups than might have been reached with more traditional Extension programs. In the last year, PINEMAP has implemented a variety of events. This article summarizes some notable examples of our efforts.

Western Gulf Silvicultural Technology Exchange

The Western Gulf Silvicultural Technology Exchange is a biennial workshop focused on disseminating new knowledge, tools, and strategies about pine plantation silviculture to industrial and large-scale silviculturists working primarily in the Western Gulf region of the United States. This event is an important opportunity for Western Gulf region foresters and forest landowners to learn about the unique climate conditions of the region and the effects of climate and climate variability on southern forests. PINEMAP is sensitive to the greater urgency of adaptive silvicultural strategies in the Western Gulf region and has established a multi-institutional committee, consisting of not only PINEMAP members, but also, non-PINEMAP funded universities and agencies in the Western Gulf, including the Louisiana State University AgCenter, Stephen F. Austin College of Forestry, and Louisiana Tech School of Forestry. To date, PINEMAP information disseminated through the Western Gulf Silvicultural Technology Exchange has reached 72 silviculturists, representing 9 million acres, 5 million of those in pine.

Professional Development Webinar Series

The Professional Development Webinar Series is an ongoing, monthly series of webinars started up in November 2012 using the Forestry Webinars portal (www.forestrywebinars.net). This effort primarily targets large-scale forest managers and natural resource professionals such as forestry consultants and state forestry agency personnel. The series packages and delivers new knowledge and tools developed by PINEMAP in such a way that the audience can confidently incorporate these into their daily business and, as a result, improve the resilience, productivity, carbon sequestration, and nutrient management of their forest lands. Combined survey results show that participants feel satisfied with the amount of information covered in the webinars (Figure 18.1). To date, there have been two parts in the series: the first session of three webinars focused on soils and soil management and the second part was a single session focused on climate change in the Southeast that also covered myths and misconceptions surrounding the topic. So far, there have been a total of 315 viewers.

Participants at the PINEMAP Climate Change Workshop series for 1890 Land Grant universities event, January 21–23, 2014, tour a pine plantation agroforestry system near Wilmington, North Carolina. Photo by Leslie Boby.

To date, PINEMAP information disseminated through the Western Gulf Silvicultural Technology Exchange has reached 72 silviculturists, representing 9 million acres, 5 million of those in pine.

Adaptive Silvicultural Training: State Forestry Agency Training

PINEMAP is driving efforts in adaptive silvicultural training for state agency foresters. The key goal is to inform foresters of the latest research and tools so they can transfer information to their clients (primarily small-scale family forest landowners) and positively impact forest health, resilience, and productivity. To date, the program has been tested with the Texas A&M Forest Service. Sixteen foresters participated in the initial training program and have already incorporated the new strategies into their forest management plans and used new decision-support tools to guide landowners. Plans are in place to conduct four trainings of this type across the region in 2014.

PINEMAP Climate Change Workshop Series for 1890 Land Grant Universities

The PINEMAP Climate Change Workshop Series for 1890 Land Grant universities is a strategic effort to train educators from various agencies in forestry and natural resource-based climate change mitigation and adaptation solutions. The first event was held at the Alabama A&M University Agricultural Research Center in Huntsville, Alabama in May 2013. Thirty registered participants attended this workshop. An additional event was held in Wilmington, North Carolina in January 2014. About twenty-five participants attended this workshop, including members of the North Carolina Cooperative Extension Service, as well as forestry outreach agents from the Southern Federation of Forest Cooperatives (Figure 18.2). Targeted toward the 1890 Land Grant University faculty, as well as specialists in research, Extension, and education, the event featured discussion panels that examined a variety of forestry strategies to educate the general public on various aspects of climate change and forest responses to changing conditions.

Whether hosting professional development webinars or conducting traditional face-to-face workshops via county Extension agents, the PINEMAP Extension team focuses on delivering the most relevant and timely information to our audience, while collaborating with PINEMAP researchers and specialists to glean up-to-the-minute research findings, information, and tools generated by the project. We are using evaluation results to improve and expand our programming over the next two years.

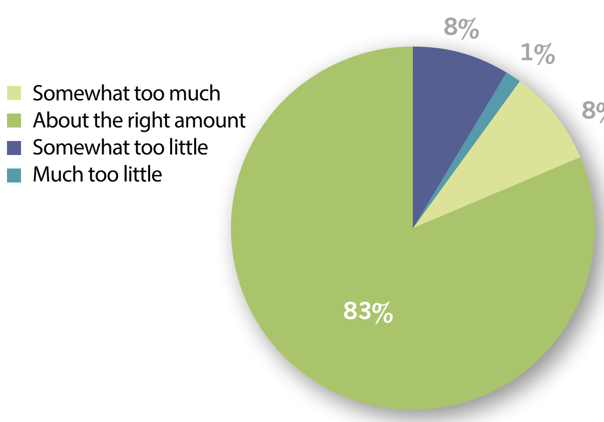

Figure 18.1. Combined survey results from the PINEMAP Professional Development Webinar Series, showing an overall satisfactory opinion regarding the amount of information covered during the webinars.

Figure 18.2. Participants at the PINEMAP Climate Change Workshop series for 1890 Land Grant universities event, January 21–23, 2014 in Wilmington, North Carolina.

19. The PINEMAP Undergraduate Fellowship Program: Integration Across Boundaries

John B. Kidd[1,3] • John R. Seiler[2,3]

[1]*Coordinator, PINEMAP Undergraduate Fellowship Program* • [2]*Alumni Distinguished Professor* • [3]*Department of Forest Resources and Environmental Conservation, Virginia Tech*

The PINEMAP Undergraduate Fellowship Program engages the public through fellow presentations to local, public secondary school teachers and students as they learn about forest resource science and climate issues. The program also builds capacity for greater integration across geographical and disciplinary boundaries as undergraduate fellows work with graduate students, staff, and principal investigators who may share similar and/or diverse interests within climate and forest science.

Outreach programs are critical to making research available and relevant to society. The PINEMAP Undergraduate Fellowship Program is a highly integrative education and outreach component of the PINEMAP project that brings together principal investigators, graduate students, and undergraduate students (Figure 19.1). This vertical integration offers the potential for each participant to be exposed to a variety of research interests, skillsets, and learning experiences. Undergraduates from across the southeastern United States are hired as wage employees of Virginia Tech, earning up to $7,000. These undergraduate fellows are paired with graduate student researchers at PINEMAP's collaborating universities. The program includes an intensive, distributed (i.e., students go to different sites) summer research internship followed by a distance-delivered education course undergraduate fellows take to learn science communication skills and develop and teach lessons on natural resources and climate change issues directed toward public secondary school students.

The structure of the program allows it to bridge some of the gaps between disciplinary research groups and geographic regions. In the program's first year, most applicants came from PINEMAP institutions and departments, but the second year of the program saw greater diversity among the undergraduate fellows' home universities (e.g., Kansas State University, Virginia State University, and University of West Florida) and degree programs (e.g., geography and microbiology). The fellows in the second year were also distributed across a larger diversity of disciplines and collaborating institutions than the pilot year (Figure 19.2). This fellowship provides undergraduate students the opportunity to experience working in a setting outside of their home universities and, frequently, outside of their majors. Fellows carry these new research interests and learned education and communication skills back to their home universities where, as part of the distance course, they develop interactive STEM (science, technology, engineering, and math) or social studies lessons directed toward secondary school students. In the first two years of the program, 17 undergraduate fellows reached more than 3,600 secondary school students (Table 19.1).

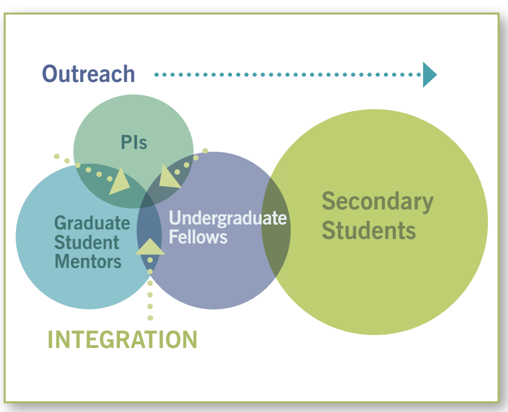

Figure 19.1. Basic conceptual model of the PINEMAP Undergraduate Fellowship Program's integration of principle investigators, graduate student and staff mentors, and undergraduate fellows, the last of which provide outreach about PINEMAP research to local public secondary school students.

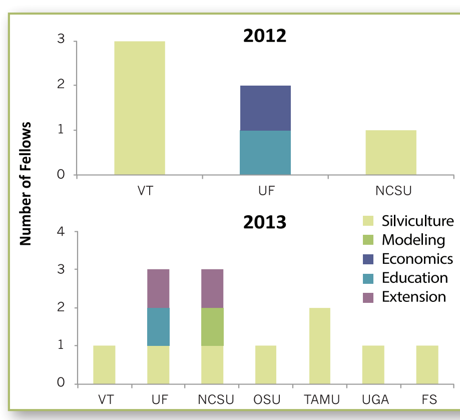

Figure 19.2. Distribution of 2012 and 2013 undergraduate fellows among PINEMAP's collaborating institutions and disciplines.

Graduate student mentor Elizabeth Wilson (left) and undergraduate fellow Madison Wigley (right) record pine needle fascicle lengths in a greenhouse experiment at Texas A&M University. Photo by Ayumi Hyodo.

"The mentor experience builds my ability to direct and motivate people… my communication skills…[my] ability to manage time and arrange tasks effectively…and [my] confidence and competence of being a good mentor"

—CHRISTINE LI, 2013 GRADUATE STUDENT MENTOR

Outreach metric	2012	2013	TOTAL
Fellowships completed	5	12	17
Presentations delivered	54	107	161
Schools visited	14	25	39
Teachers visited	29	40	69
Students reached	1,060	2,629	3,689

Table 19.1. Individuals reached through the PINEMAP Undergraduate Fellowship Program.

The fellowship program is committed to providing opportunities to a diverse set of undergraduates. PINEMAP has integrated historically black colleges and universities into the project by partnering with three 1890 land grant institutions. Five of 18 undergraduates came from Virginia State University, Alcorn State University, or North Carolina Agricultural and Technical State University. The opportunities and education this program offers are significant not only for minority students but for all undergraduate fellows. Fellows visit other universities for the summer to experience life as an undergraduate researcher in an alternative setting that provides new experiences and lasting memories. Leaving their home campuses for the summer, often to travel to other states, is a big step for many undergraduate students. Interactions with other students during program meetings and the fall distance course provide fellows with exposure to different ideas and research. The impact of this fellowship is evident from the statement of a graduate student mentor, Shelby Krantz, who reflected on her minority mentee, "She gushed about how much she had learned and wanted to change in her life now because of what she knew about climate change and forestry."

Similar to the interns (fellows), graduate student mentors have varied backgrounds and levels of experience with guiding students through work and research activities. Approximately half of the graduate student mentors had never before been in a position to work with an apprentice, and they recognized this as an opportunity to gain and practice skills in mentorship, organization, and communication. Graduate student mentor Christine Li noted, "The mentor experience builds my ability to direct and motivate people… my communication skills…[my] ability to manage time and arrange tasks effectively…and [my] confidence and competence of being a good mentor"

Another mentor, Adam Maggard, similarly reflected: "It was my first time mentoring a student and [I] gained a lot [from] the experience. As a Ph.D. student, communication and management are going to likely play significant roles in my future, and the experience gained from teaching, communicating, and leading throughout the process was priceless."

Additionally, during the summer, fellows begin planning public school lessons with help from their mentors. As mentors in this process, graduate students learn to consider how their research can be used to reach audiences not trained in their disciplines. Integrating graduate students in this fellowship program may allow them to improve their transition into mentoring undergraduates and others as they begin careers as postdocs, faculty, or research professionals.

As the program enters its third year, we are striving for additional representation from institutions outside of PINEMAP. We are offering funding for up to 18 undergraduate fellows, providing a greater number of opportunities for integrating PINEMAP's interdisciplinary research with educational experiences and a greater number of educational experiences for secondary public school students near all of the colleges and universities represented in this program.

20. Attitudes Toward Research: The Effects of an Undergraduate Research Experience

John B. Kidd[1,3] • John R. Seiler[2,3]

[1]Coordinator, PINEMAP Undergraduate Fellowship Program • [2]Alumni Distinguished Professor • [3]Department of Forest Resources and Environmental Conservation, Virginia Tech

The diversity of participants in the program, which can lead to greater interdisciplinary collaboration, makes this research relevant to the enhanced capacity outcome theme. It also relates to the engaged public outcome theme as undergraduates' attitudes toward research may influence their acceptance of and engagement with climate and forest related issues regardless of whether they continue as researchers.

The majority of existing research on undergraduate research experiences largely focuses on enhancing students' skills, improving student retention, and helping students to achieve career and educational goals. However, little research exists regarding undergraduates' attitudes toward research after participating in a research experience. The PINEMAP Undergraduate Fellowship Program is an innovative education component of the PINEMAP project that brings together principal investigators, graduate students, and undergraduate students (fellows). This program offers the potential for each undergraduate participant to be exposed to a variety of research interests, skillsets, and learning experiences (Figure 20.1). Undergraduate students in the program are paired with graduate student researchers at PINEMAP's collaborating universities for an intensive, 12-week summer research internship followed by a distance education course. During the summer research internship, undergraduate fellows were invited to participate in a survey on their attitudes toward research. Here we report on a preliminary analysis of two years of survey data on fellows' attitudes toward research before and after participation in the summer research internship.

Figure 20.1. Anthony Fields, a 2013 undergraduate fellow from Virginia State University, working with mentor Maxwell Wightman at University of Florida, installs sap flow probes at the PINEMAP Tier III research site in Taylor County, Florida. Photo by Tim Martin.

To quantify attitudes, we asked fellows participating in the summer research internship portion of the program to complete a pre- and post-experience survey. The surveys consisted of 24-Likert-type items (1 represented "strongly disagree" and 5 represented "strongly agree") that integrated 17 items from the "Attitudes Toward Research" (ATR) Scale (Walker 2010, Papanastasiou 2005) and 7 scientific-method oriented items. Students responded to additional single response items regarding their demographics and education/career goals. To date 17 of the 18 students in the program completed surveys, and 13 students completed both the pre- and post-experience surveys. Student respondents were categorized by their class standing and consisted of 5 freshmen, 3 sophomores, 8 juniors, and 1 senior. The sample was 47% female. Previous research experience was indicated by 6 interns (35%). Slightly over half were white (n = 10), with the remainder representing three racial and ethnic communities (blacks = 3, Hispanic = 1, multiracial = 1, and unreported = 2). Individual survey questions were grouped into four factors, three of which have been identified by Walker (2010): *research use, positive attributes of research,* and *negative attributes of research.* We included the methods items, independent from the ATR Scale, as the fourth proposed factor called research understanding. The *research use* factor included items such as (a) research is useful for my career and (b) knowledge I have acquired from this internship will be helpful to me in the future. The positive attributes of research factor included items such as (a) I am interested in research and (b) I enjoy research. Examples of the *negative attributes of research* included (a) research makes me anxious and (b) I make many mistakes in the research process. The *research understanding* factor contained statements such as (a) I understand the importance of experimental design and (b) I understand the role of statistics in research. Mean scores were calculated for each factor for both pre- and post-experience surveys.

Madison Wigley, a 2013 undergraduate fellow from Texas A&M University, working with mentor Elizabeth Wilson at the same university, showing remarkable enthusiasm for forest resources research. Photo by Elizabeth Wilson.

> "I love that [the internship] has introduced me to professional research…, but I especially like how it's taken everything (and more) that I've learned in the classroom and has allowed me to apply it to real life."
>
> —FIRST YEAR UNDERGRADUATE FELLOW

Wilcoxon signed-rank tests, a paired samples test for non-normal data with small sample sizes, identified no significant differences between pre- and post-experience scores for each factor (Table 20.1). However, while not a statistically significant finding, student attitudes became more positive with regard to research usefulness, attributes of research, and research understanding. It is important to note that during data analysis, negatively worded items were recoded so that higher numbered responses were associated with positive attitudes. For example, the item "research is difficult" was recoded as "research is easy." For positive attributes, most students' attitudes were either the same or became more favorable. From the students' individual perspectives, there were increases in positive attitudes within the following factors: *research use* (n = 8), *negative attributes of research* (n = 6), *positive attributes of research* (n = 4), and *research understanding* (n = 6). A number of students reported no change for some factors, and most of these cases were representative of students who scored highly on the pre-experience survey. Compared to men, women had fewer decreases and fewer or no changes in attitudes across all factors.

Based on this preliminary analysis, participation in the program's summer research experiences may foster changes in undergraduate attitudes toward research, although the finding is not statistically significant. The lack of a statistically significant finding could be due to a number of external factors such as students' previous research or work experiences. Also, it may be difficult to identify statistically significant changes in such a small sample. Additionally, some students may have overestimated their interest and attitudes prior to participation if they did not have a concrete understanding of what research involves. Seymour et al. (2004) found that shifts in attitudes to learning and working as a researcher accounted for 4% of student-identified benefits of undergraduate research experiences. Attitude increases in other studies account for up to 12% of student-identified benefits related to behaviors and attitudes needed for becoming a researcher (Hunter et al. 2007). As qualitative data from this study are further analyzed, better explanations will emerge of how attitudes compare before and after participating in the summer research internship. For example, a first year undergraduate fellow said, "I love that [the internship] has introduced me to professional research …, but I especially like how it's taken everything (and more) that I've learned in the classroom and has allowed me to apply it to real life."

The undergraduate fellowship program is beginning its third year, and we are recruiting up to 18 new undergraduate fellows. We will include their responses in a new, complete analysis of all survey data upon completion of the summer 2014 research internships.

	PRE-EXPERIENCE			POST-EXPERIENCE					
Pre-experience vs. post-experience	*Mean*	*Median*	*Standard deviation*	*Mean*	*Median*	*Standard deviation*	*Z*	*p*	*r*
Research use	4.14	4.18	0.47	4.24	4.09	0.52	-1.06	0.29	-0.2
Negative attributes of research	3.18	3.33	0.72	3.47	3.50	0.71	-1.41	0.16	-0.3
Positive attributes of research	4.05	4.00	0.69	3.97	4.00	0.57	-0.58	0.56	-0.1
Research understanding	4.41	4.57	0.33	4.42	4.43	0.34	-0.13	0.89	0.0

Table 20.1. Wilcoxon signed-rank test comparison of pre- and post-experience scores for Attitudes Toward Research factors.

21. PINEMAP's Teacher Module Integrates Research and Education

Martha C. Monroe[1,3] • *Annie Oxarart*[2,3]

[1]*Professor and Extension Specialist* • [2]*Coordinator, Environmental Education Programs* • [3]*School of Forest Resources and Conservation, University of Florida*

The development of a new teaching resource is directly tied to PINEMAP's education-focused outcome of developing an engaged and literate public with the capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management. By implementing the module activities in classrooms, teachers and students will learn about concepts that PINEMAP researchers are currently exploring. In addition, the module has provided an opportunity to connect PINEMAP collaborators and graduate students with educators and other stakeholders.

Educational resources for middle and high school science teachers are important PINEMAP deliverables. This resource, *Southeastern Forests and Climate Change,* has evolved into a module containing 14 activities that teachers can use in biology, environmental science, or agriculture courses to teach students about southeastern forests and climate adaptations. This module is a platform to support integration among PINEMAP researchers and stakeholders and is also a context for graduate student research.

Figure 21.1. PINEMAP graduate student Jianxing Zhang shared information about his research in a short video that is available as a teaching resource for educators.

Sharing Research with Science Educators

The overall goal of PINEMAP is to advance biological research on southern pine and to use those findings to improve forest management decisions. In the long term, introducing the public to the science that underpins this goal encourages understanding of management decisions aimed at making forests resilient and sustainable under variable climates. By building our teaching module to parallel the PINEMAP research agenda (see Table 21.1, page 47), we gained several key advantages: (1) researchers assisted in the development and review of the activities, ensuring accuracy in the material; (2) the process of research and research findings have been made available to educators and students as supplementary videos; and (3) faculty and graduate students have been engaged in teacher workshops to help educators understand and use the material.

The education team worked closely with the PINEMAP management team to brainstorm activity ideas that relate to the research agenda and involved researchers and graduate students in pilot tests and activity revisions. A set of creative, appropriate, and engaging activities evolved from this interaction between research scientists and the education team.

Meeting Stakeholder Needs

A partnership with Project Learning Tree® (PLT), a national environmental education program that has coordinators and facilitators in most states, established a recognizable home and distribution network for the new module. Using PLT's program development framework, we created the PINEMAP Education Advisory Committee that met bimonthly to review activity ideas, provide feedback and additional resources, and discuss potential concerns. Members of this committee have also been instrumental in offering presentations to introduce the materials and in considering how the southeastern-focused materials can be adapted for use in other regions of the country—significantly expanding PINEMAP efforts. We conducted a needs assessment after drafting the conceptual framework and asked teachers specific questions about activity format and usability. These results helped focus several activities on data analysis, systems thinking, and problem solving (Monroe et al. 2013). An evaluation of this draft document was conducted in fall 2013 (see Chapter 22, page 48), and this teacher feedback will be instrumental in making additional revisions to the materials.

Teacher feedback also guided the development of complementary module materials, such as slide presentations and short videos (Figure 21.1). These resources are available online to help teachers introduce basic concepts and current research activities. Student worksheets and slide presentations are available in an electronic format that educators can modify to best meet their needs. The module website also includes interactive activity descriptions, tests of knowledge, and a variety of web links for additional information (http://sfrc.ufl.edu/extension/ee/climate).

Teachers participating in a Climate Change Symposium in Gainesville, Florida learn how to measure a tree to calculate stored carbon. Photo by Jessica Ireland.

The opportunity to share PINEMAP's research findings with educators has engaged research faculty and graduate students in the process of developing education materials and interacting with teachers and students.

Research Findings Enhance Climate Education

Graduate students on the education team are using the module development process to answer a number of interesting research questions that will help create a more effective product. For example, when developing activities about the carbon cycle and carbon sequestration, we did not know if introducing the carbon cycle in the context of climate change would enhance or deter student interest. An experiment with high school students attending two summer science camps enabled us to determine that students who explored the carbon cycle and carbon sequestration in the context of climate change gained significantly more knowledge about these topics than students who explored them in isolation (Hall 2013). Additional work is underway to assess students' feelings of hopefulness regarding climate solutions and to explore teaching climate change within a systems thinking framework. While these findings will be incorporated into the PINEMAP module, they are also useful to the broader field of environmental education.

Summary

The opportunity to share PINEMAP's research findings with educators has engaged research faculty and graduate students in the process of developing education materials and interacting with teachers and students. Bringing the research process to the classroom makes science education tangible, local, and practical for both teachers and students. Giving PINEMAP graduate students opportunities to interact with teachers allows students to crystalize their research findings and reminds them that many audiences care about the applications of their work. Seeking partnerships with existing environmental education programs and practitioners has established a ready audience for distributing and using the new materials. Finally, engaging graduate students in social science research has improved the materials and led to new insights into climate education.

Research Concept	Teaching Objective	Activity
Changes in temperature and precipitation will influence forest habitats.	Climate affects forests.	A web-based exploration of the USDA Forest Service Climate Atlas enables students to learn about climate models and projected effects of tree habitat ranges (Activity 3).
Tree growth and yield responds to changes in soil fertilization and tree density.	Management strategies can increase forest resilience given climate variability.	After creating a systems model of a tree plantation, students use management and climate cards to draw additional relationships and predict outcomes from their model (Activity 5).
Trees can reduce levels of atmospheric carbon.	Trees sequester carbon as they grow.	Students measure carbon stored in a tree and extrapolate that to annual carbon sequestration in a forest, and then compare an estimate of their state's carbon emissions to their state's sequestration rate given current land use (Activity 8).
Tree breeding to select genetic traits that will enable trees to thrive in a changing climate.	Loblolly pine has a variety of traits enabling trees to survive in different climates.	Students graph data from test plots with six families to reveal two distinct populations (Activity 6).
Life cycle assessment can reveal opportunities to reduce atmospheric carbon.	Life cycle assessment provides important information about externalities and opportunities for consumer decisions. Consumers have the ability to select products based on contributions to atmospheric carbon.	Students "shop" for products and identify criteria that could be reflected in the product's price (Activity 9). Students use a life cycle assessment to determine the outdoor dining furniture with the lowest emission of greenhouse gases (Activity 10). Students debate parallel items and reflect on the criteria they could use to make purchasing decisions (Activity 11).
Wood substitution is an effective strategy to reduce atmospheric carbon.	Three forest carbon pools remove carbon or prevent it from going into the atmosphere.	A cooperative learning strategy helps students solve the puzzle of atmospheric carbon in the forest, long-lived wood products, and in the parallel products not used (concrete and steel) (Activity 12).

Table 21.1. Research concepts form the foundation of module activities.

22. Secondary Teachers Test PINEMAP Classroom Activities

Jie Li[1,3] • *Martha C. Monroe*[2,3]

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A recent formative evaluation of the PINEMAP secondary teacher module to meet education-related outcomes will help improve the activities and support materials. This module is designed to assist high school teachers engage and strengthen students' capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management.

The new resource for teachers, *Southeastern Forests and Climate Change* (see Chapter 21, page 46), has been developed through a partnership with the national environmental education program Project Learning Tree® (PLT). The module includes 14 activities that focus on climate change impacts on southeastern forest ecosystems; strategies for managing forests in an uncertain climate; life cycle assessment to explore how consumers can affect atmospheric carbon; and opportunities to practice data analysis, critical thinking, and systems thinking skills in the context of forests and climate change.

Objectives

To test the usefulness and effectiveness of this module, we conducted a formative evaluation during fall 2013. Formative evaluation is used to improve programs by pilot-testing materials with intended audiences and incorporating feedback and suggested revisions into the final program (Ernst et al. 2009). The formative evaluation plan was developed and revised with input from the PINEMAP Education Advisory Committee and designed to answer the following questions:

a. What are teachers' perceptions of the secondary teaching module?
b. How can the activities be improved?
c. What are teachers' perceptions of the online training resources and module website?

Procedure and Instruments

An invitation was sent through several email lists to recruit pilot testers. From 123 applicants, 64 teachers were accepted to represent regional and grade-level diversity. Of those, 28 teachers (46.4% high school and 53.6% middle school) agreed to use two activities and complete the online teacher evaluation form, and 36 high school teachers agreed to use four activities, complete the online teacher evaluation form, and involve their students in pre- and post-activity surveys. Teacher evaluation forms were developed, reviewed by ten experts, revised, and pilot tested with two teachers. Student pre- and post-tests were developed, reviewed by nine experts, revised, and pilot tested with 89 students who participated in the University of Florida's Center for Precollegiate Education and Training Student Science Training Program over the summer of 2013.

Results

As of January 24, 2014, 44 pilot testers had completed their evaluation forms, and about half (53%) of the teachers had used the activities in environmental science and advanced placement (AP) environmental science classes. About 15% used the activities for middle school integrated science classes and 14% used the activities in biology and AP biology classes. The remaining teachers (8%) used the activities in courses such as earth science, land resources, economics, and ecology (Figure 22.1). The pilot testers were from Florida (45%), Kentucky (16%), Virginia (14%), Arkansas (11%), North Carolina (9%), and Georgia (5%) (Figure 22.2). Although the activities were designed for high school students, we involved middle school teachers in the pilot test and asked them how the materials could be adapted for their students.

High school students diagram the carbon cycle as part of the PLT Secondary Module activity Carbon on the Move. Photo by Jessica Ireland.

> "I loved it (activity 2)! This activity taught me a lot about different perspectives and viewpoints from other people and opened my eyes to new horizons!" —HIGH SCHOOL STUDENT FROM FLORIDA

Pilot testers provided positive comments about the organization and detail of the materials and online supplemental resources. About 90% of high school teachers said the activity they pilot tested was ready for classroom use. On average, high school teachers agreed that their students were able to meet the activity's stated objectives (*Mean* = 4.27, *standard deviation [SD]* = 0.78 on a scale of 1 to 5, with 5 = strongly agree) and the activity procedure was appropriate for their students (*Mean* = 4.27, *SD* = 0.80). As expected, data from middle school teachers suggested that the activities were a little more challenging (*Mean* = 3.76, *SD* = 1.2) and the students were slightly less able to meet stated objectives (*Mean* = 3.91, *SD* = 0.90) as compared to high school students. Pilot testers indicated that the online training resources and module website effectively prepared them to use these activities (*Mean* = 4.58, *SD* = 0.58) and built their confidence to teach about climate science topics (*Mean* = 4.54, *SD* = 0.56). The results of the formative evaluation suggest that these activities are written in an appropriate tone and provide sufficient background information for teachers to effectively use them in their classrooms.

Recommendations

Teachers provided many excellent suggestions for improving the materials. After reviewing the teachers' feedback and recommendations on all the activities, the module development team is focusing on the following overall changes:

a. Include a section that offers an adaptation of each activity for middle school students or basic high school classes.
b. Provide multiple-choice questions to allow teachers to develop a student quiz and include writing prompts for assessments on each activity.
c. Add comments from teachers about their classroom experiences and suggestions for using the materials to both the printed document and website.

Many pilot testers indicated that they would like to implement the lessons with future classes and that were very pleased with the formative evaluation process. After the PINEMAP education team completes revisions and updates the website, we will begin plans for regional teacher workshops.

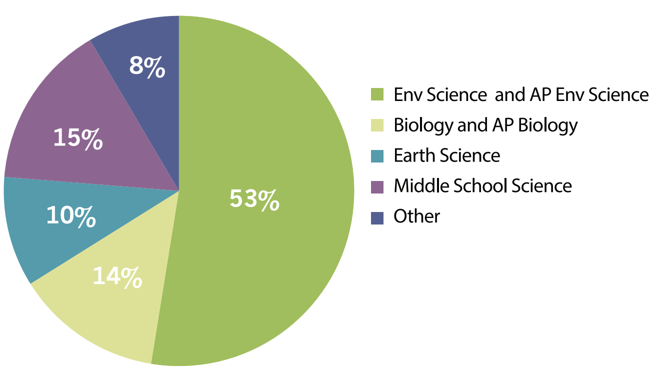

Figure 22.1. Course distribution of responding teachers.

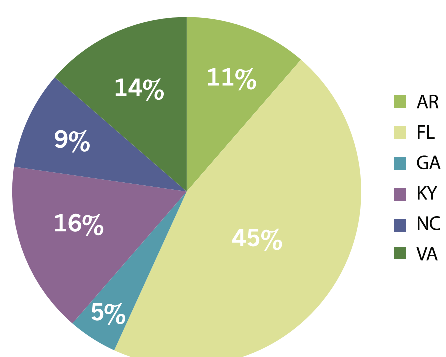

Figure 22.2. State distribution of responding teachers.

23. Exploring Team Science in PINEMAP

***Wendy-Lin Bartels*[1,4] • *Ricardo Mello*[2,5] • *Jessica Ireland*[3,6]**

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Rising investment in large-scale, cross-disciplinary scientific programs has fueled a new field of research that examines the nature and effectiveness of "team science" (Mâsse et al. 2008, Stokols et al. 2008, Thompson Klein 2011). Findings from the emergent *science of* "team science" provide guidance to funders and practitioners on effective collaborative practice (Bennett et al. 2010, Elfner et al. 2011). Within PINEMAP, research on team science is being conducted as part of the project's ongoing evaluation.

One of PINEMAP's overarching goals is to build enhanced capacity for regional, interdisciplinary collaboration among climate and forest scientists and their peers in Extension and education. Therefore, project participants are expected to integrate expertise across institutions, regions, and disciplines; among research, education, and outreach; and with the broader community of practitioners and managers beyond academia. Process evaluators are exploring the factors that facilitate and constrain such integration among project participants. This article describes current interactions among researchers and how the team evolved between 2011 and 2013.

One of PINEMAP's overarching goals is to build enhanced capacity for regional, interdisciplinary collaboration among climate and forest scientists and their peers in Extension and education. Therefore, project participants are expected to integrate expertise across institutions, regions, and disciplines; among research, education, and outreach; and with the broader community of practitioners and managers beyond academia. Process evaluators are exploring the factors that facilitate and constrain such integration among project participants.

Methods

Surveys and social network analysis (SNA) are being used to collect data. SNA can be used to characterize ties among researchers, the types of collaborations they represent, and changes in the network of relationships that develop over time. A computer software program (UCINET) is used to develop diagrams of the relationships among participants as well as divisions and subgroupings within the network. The individual-level measure of *betweenness centrality* is used to examine a participant's centrality in a network. Individuals who have higher betweenness centrality scores are located in potential brokerage positions and therefore more likely to act as gatekeepers, controllers, or synthesizers of information. They interact with a greater number of people and/or their interactions result in the dissemination of information to additional people.

During the first PINEMAP annual meeting in May 2011, baseline data were collected through a paper survey distributed to the 51 original team members, assessing the extent to which participants had worked together in a professional context in the past. In April 2013, an online survey asked respondents to describe their interactions with all other PINEMAP members over the first two years of the project.

Aim		# (n=124)	%
1	Silviculture and ecophysiology	52	42%
2	Modeling	19	15%
3	Genetics	16	13%
4	Economics and policy	14	11%
5	Education	9	7%
6	Extension	14	11%

Table 23.1. PINEMAP participants are grouped into six subteams (Aims) that serve as functional units to achieve project goals.

PINEMAP team members participate in a field tour at the Tier III throughfall reduction x fertilization site in Taliaferro County, Georgia. Photo by John Seiler.

Social Network Analysis (SNA) can be used to characterize ties among researchers, the types of collaborations they represent, and changes in the network of relationships that develop over time.

Results

In 2013, the PINEMAP network consisted of 124 participants from 12 institutions and 17 disciplines, indicating a growth of 73 participants since 2011. Although the baseline network shows that some participants are not connected to others (isolates), by 2013, the network shows a relative cohesiveness and that everyone is connected. Respondents identified the type of interaction they had with others in the team, and 22% of the interactions were the highest form of integration: communication, collaboration, and shared thinking.

Participants are grouped into six subteams known as "Aims" that serve as functional units to achieve specific project goals (Table 23.1, see previous page). Silviculture and ecophysiology researchers (Aim 1) occupy more space in the network than any other group and have several brokers (larger nodes) who are centrally located (Figure 23.1). In comparison, members of Aim 4 (economics and policy) have equally sized nodes and are peripherally located in the network. Findings show that education and Extension specialists (Aims 5 and 6) are spread throughout the network. In some cases, leaders (boxes) are centrally located within their Aim groups. In other cases, they appear to be more peripheral to their own Aim, suggesting that they may function more in bridging across disciplines.

Next Steps

Research findings are shared continuously with project participants to foster ongoing reflection and to elicit suggestions or actions for improving project implementation. During the next phase of this study, researchers will stratify participants into categories based on SNA betweenness centrality scores to facilitate sampling for interviews that examine perceptions about the circumstances that influence cross-disciplinary integration and collaboration. Furthermore, participation in specific "integration platforms" will be studied to identify barriers and opportunities for boundary crossing. More broadly, lessons learned in PINEMAP will inform the creation and management of future "team science" research and training programs.

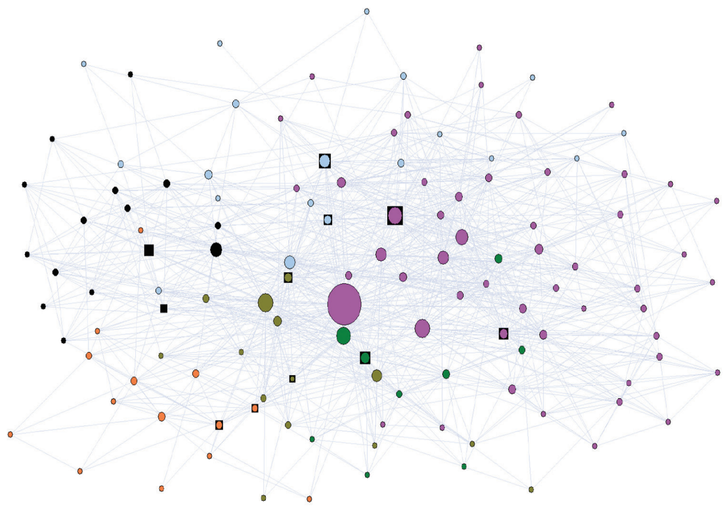

Figure 23.1. The 2013 PINEMAP network with nodes colored by Aim group (see Table 23.1). The size of the node indicates betweenness centrality, and leaders can be identified by boxes.

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Appendix A: PINEMAP Team Members

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- **Richard Plate,** School of Forest Resources and Conservation, University of Florida
- **Andres Susaeta,** School of Forest Resources and Conservation, University of Florida
- **Eric J. Ward,** Department of Forestry and Environmental Resources, North Carolina State University
- **Jared Westbrook,** School of Forest Resources and Conservation, University of Florida

GRADUATE STUDENTS

Name	University	Advisor(s) name(s)	Degree	Thesis / Dissertation Title / Topic
Benjamin Ahlswede	Virginia Polytechnic Institute and State University (Virginia Tech)	Quinn Thomas	M.S.	Biophysical Climate Effects of Sub-biomes within the Temperate Forest; Implications for Plantation Forestry and Urban Expansion in the Southeast United States
Hyunjin An	Texas A&M University	Jianbang Gan	Ph.D.	Impact of Climate Change Extremes and Adaptation on Southern Pine Beetle Infestation
Casey Ausmus	Oklahoma State University	Thomas Hennessey	M.S.	Partitioning and Quantifying Autotrophic and Heterotrophic Components of Soil Respiration in a Loblolly Pine Plantation Influenced by Nutrient and Water Availability
Bruce Barros	University of Georgia	Robert Teskey	M.S.	Estimating Transpiration in Loblolly Pine (*Pinus taeda*) Plantations Using the 3-PG Model
Stan Bartkowiak	Auburn University	Lisa Samuelson	Ph.D.	Impacts of Precipitation Reduction Combined with Varying Nutrient Availability on Water Use and Hydraulic Properties of Loblolly Pine (*Pinus taeda* L.)
Rajesh Bawa	Virginia Polytechnic Institute and State University (Virginia Tech)	Jason Holliday	Ph.D.	Association and Evolutionary Genetics of Loblolly Pine
Rachel Burnett	North Carolina State University	Mark Megalos	M.S.	Climate Predictors of Wildfire Size in North Carolina, 1979-2006: A Quantile Regression Approach
Joe Clark	Auburn University	Lisa Samuelson	M.S.	Physiology and Growth of a 6-year-old Loblolly Pine (*Pinus taeda* L.) Plantation in Response to Rainfall Exclusion and Fertilization Treatments
Zachary Clark	University of Georgia	Mike Kane	M.S.	Effects of Site, Planting Density, Cultural Intensity, and Site Preparation on the Growth and Development of Non-planted Vegetation in Loblolly Pine Plantations
Margaret Clifford	University of Florida	Martha Monroe	M.S.	Motivating Extension Agents with Reasonable Training and Opportunities
Yuan Fang	North Carolina State University	Jose Stape	Ph.D.	Modeling Carbon Dynamics of Two Loblolly Pine Plantations in the Piedmont Region
Alfredo Farjat	North Carolina State University	Ross Whetten and Fikret Isik	Ph.D.	Modeling Climate Change Effects on the Growth of Loblolly Pine; Prediction of Genetic Merit in a Clonal Population of Loblolly Pine
Anslei Foster	North Carolina A&T University	Joshua Idassi	M.S.	Growth of *Pleurotus ostreatus* Fungus on Degraded Canola Plant Material Substrate and the Rate of Measurement on the Release of Glucose
Ranjith Gopalakrishnan	Virginia Polytechnic Institute and State University (Virginia Tech)	Randolph Wynne and Valerie Thomas	Ph.D.	Effective Characterization of Fuel Load and its Impact on Future Fire Regimes in Managed Loblolly Pine Plantations of Southeast USA
Nabin Gyawali	Virginia Polytechnic Institute and State University (Virginia Tech)	Harold Burkhart	Ph.D	Modeling General Response to Silvicultural Treatments in Loblolly Pine Stands
Stephanie Hall	University of Florida	Martha Monroe	M.S.	Addressing Climate Change through Biology Concepts: Insights for Educators
Brett Heim	Virginia Polytechnic Institute and State University (Virginia Tech)	John Seiler and Brian Strahm	M.S.	Partitioning Soil Respiration in Response to Drought and Fertilization in Loblolly Pine: Laboratory and Field Approaches
Miles Ingwers	University of Georgia	Robert Teskey	Ph.D.	To be determined
Puskar Khanal	Mississippi State University	Donald Grebner	Ph.D.	Nonindustrial Private Forest Landowners Willingness to Sequester Forest Carbon in the Southern United States
John Kidd	Virginia Polytechnic Institute and State University (Virginia Tech)	John Seiler	Ph.D.	A Systematic Review of Existing Natural Resources Research Experiences for Undergraduates Programs and Evaluation of the PINEMAP Undergraduate Fellowship Program
Shelby Krantz	University of Florida	Martha Monroe	M.S.	Message Framing to Affect Forest Landowners' Intention to Adapt to Climate Change

Graduate Students continued ...

Name	University	Advisor(s) name(s)	Degree	Thesis / Dissertation Title / Topic
Melissa Kreye	University of Florida	Damian Adams	Ph.D.	Valuing Forest Conservation Programs to Protect Water Quality
Kristen Kunkle	University of Florida	Martha Monroe	M.S.	Integrating Climate Change Education in the Classroom: Applying a Motivated Reasoning Framework to Mitigate Cultural Conflict
Andy Laviner	Virginia Polytechnic Institute and State University (Virginia Tech)	Thomas Fox	Ph.D.	Water Use and Nitrogen Cycling in Loblolly Pine Plantations Under Reduced Water Availability
Jie (Christine) Li	University of Florida	Martha Monroe	Ph.D.	Effective Climate Change Education: Factors affecting Students' Learning and Teachers' Self-Efficacy
Wen Lin	North Carolina State University	Asko Noormets and J.-C. Domec	Ph.D.	Drought Sensitivity of Plant Carbon Exchange and Allocation in Loblolly Pine
Mengmeng Lu	Texas A&M University	Carol Loopstra and Konstantin Krutovsky	Ph.D.	Association of Exome Variation with Potential Adaptation to Climate Change in Loblolly Pine (*Pinus taeda* L.)
Cody Luedtke	University of Georgia	Robert Teskey	M.S.	Carbon Dioxide Fluxes and Nonstructural Carbohydrates in Seedlings as Influenced by Heat, Drought, and Low Light
Adam Maggard	Oklahoma State University	Rodney Will	Ph.D.	Implications of Potential Climate Change on Loblolly Pine (*Pinus taeda* L.) and the Interaction Between Fertilizer and Drought; Drought and Carbon Stress Mortality in Loblolly Pine (*Pinus taeda* L.)
Kristin McElligott	Virginia Polytechnic Institute and State University (Virginia Tech)	John Seiler and Brian Strahm	Ph.D.	Environmental Drivers of Soil and Forest Floor Respiration as Influenced by Age and Management in Loblolly Pine Stands
Teri Medsker	Oklahoma State University	Duncan Wilson	M.S.	The Effect of Soil Moisture on Nutrient Dynamics and Productivity of Loblolly Pine Plantations
April Meeks	North Carolina State University	Jose Stape	M.S.	Characterization and Assessment of Competing Vegetation in Mid-rotation Loblolly Pine Stands at Hofmann Forest, NC
Hilary Morris	North Carolina State University	Mark Megalos	M.S.	2013 Climate Change Attitudes of Southeast Forestry Professionals: Implications for Outreach
Charles Pell	Auburn University	Lisa Samuelson	M.S.	Long-term Interactive Effects of Throughfall Rain Exclusion and Fertilization on Physiology of Loblolly Pine (*Pinus taeda* L.)
Ji (Jill) Qi	University of Georgia	Daniel Markewitz	Ph.D.	Drying-Rewetting Cycles: Impacts on Deep Soil Carbon and Hydrology
Jay Raymond	Virginia Polytechnic Institute and State University (Virginia Tech)	Thomas Fox	Ph.D.	Use of ^{15}N Labeled Nitrogen Fertilizer to Evaluate Uptake Efficiency and Environmental Fate of Urea and Enhanced Efficiency Fertilizers in Forest Plantations
Tracey Ritchie	University of Florida	Martha Monroe	Ph.D.	Assessing Strategies for Teaching Systems Thinking in Secondary Science
C. Wade Ross	University of Florida	Sabine Grunwald	Ph.D.	Simulating Terrestrial Ecosystem Dynamics Across the Southeastern U.S.
Jose Soto	University of Florida	Damian Adams	Ph.D.	Estimating the Supply of Forest Carbon Offsets: A Comparison of Best-Worst and Discrete Choice Valuation Methods
Santosh Subedi	Virginia Polytechnic Institute and State University (Virginia Tech)	Thomas Fox	Ph.D.	Fertility Rating Assessment in the 3-PG Model
Ram Thapa	Virginia Polytechnic Institute and State University (Virginia Tech)	Harold Burkhart	Ph.D.	Modeling Mortality of Loblolly Pine (*Pinus taeda* L.) Plantations
Laura Townsend	North Carolina State University	Ross Whetten	M.S.	Identifying Genetic Variation in Site Adaptability in Loblolly Pine (*Pinus taeda* L.)
Mohamad Traboulsi	University of Florida	Damian Adams	M.S.	Assessing the Economic Value of Forest Water Yield in Florida: A Production Function Approach
Aaron Vuola	North Carolina State University	Mark Megalos	M.S.	North Carolina Cooperative Extension Perceptions and the Six Americas of Climate Change
Ying (Maggie) Wang	Univeristy of Georgia	Robert Teskey	Ph.D.	Predicting Loblolly Pine Growth Under the Climate Change Conditions in the Southeastern Region with a Set of Validated Physiological Parameters
Maxwell Wightman	University of Florida	Timothy Martin	M.S.	Loblolly Pine (*Pinus taeda*) Water Relations in Response to Fertilization and Throughfall Exclusion
Elizabeth Wilson	Texas A&M University	Jason West and Jason Vogel	M.S.	The Effects of Water Stress on Variability in Mesophyll Conductance of Loblolly Pine (*Pinus taeda* L.) Leaves
Jinyan Yang	University of Georgia	Robert Teskey	Ph.D.	Effects of Throughfall Exclusion and Fertilization on Soil CO_2 Efflux and its Components in a Loblolly Pine (*Pinus taeda*) Plantation
Lu Zhai	Texas A&M University	Jason Vogel	M.S.	Interactions among Silvicultural Intensity, Genotype, and Environment and Their Effects on the Growth and Mortality of Loblolly Pine and Slash Pine Families
Jianxing Zhang	University of Florida	Gary Peter	Ph.D.	Integrating Climate and Genetic Effects of Loblolly Pine by Universal Response Functions
Yang Zhang	Texas A&M University	Jason West and Jason Vogel	Ph.D.	Effect of Climate Change and Forest Management on Carbon and Nitrogen Dynamics of Woody Debris in Southern U.S. Loblolly Pine Forests

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